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ORIGINAL ARTICLE

Health Risks of Mobile Phone Addiction Among College Students in China

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Abstract

Mobile phone addiction (MPA) is a widespread problem in China, and college students face an especially high risk of its associated consequences. This study aimed to examine the interactions between level of mobile phone addiction and duration of mobile phone use and their impacts on psychological health, physical health, and sleep status of Chinese college students. Our study was a cross-sectional questionnaire-based survey which applied stratified random sampling method to recruit 946 participants. The level of mobile phone addiction was measured by Mobile Phone Addiction Index Scale. Sleep status was assessed by Pittsburg Sleep Quality Index. Designed questions were asked to evaluate the psychological and physical health status of the previous month of participants. The prevalence of MPA among Chinese undergraduates was estimated to be 36.6%. Severe MPA was significantly associated with psychological problems (anxiety symptoms, depressive symptoms, loneliness, social anxiety, impaired concentration, and sad or hopeless), physical problems (palpitation, nausea, and asphyxia), and sleep problems (sleep quality, sleep latency, sleep disturbances, sleep duration, and sleep dysfunctions). Interaction analysis indicated that college students with severe MPA who used their phones for more than 4 hours everyday were more likely to develop above problems. The findings reveal that relieving the MPA and controlling duration of phone use can ameliorate the psychological, physical, and sleep-related issues.

Keywords Mobile phone addiction · Health risk · Physical state · Psychological state · Sleep state

Smartphones are advanced electronic media devices which are capable of processing more information than other phones. Smartphones include many features such as games, videos,

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Internet browser, social media applications, messaging, multimedia system, and navigation, in addition to their use for communication (Lo Coco et al., 2020). Furthermore, with the development of phone applications and technologies, it is easier for phones to satisfy people's requirements for daily communication and entertainment (Fallahi-Khoshknab & Yahyazadeh, 2016). Globally, 90% of the population own mobile phones, of which 59% are smartphones (Pew Research Center, 2018). According to the 47th China statistical report on Internet development, by the end of December 2020, there were 986 million mobile phone users in China, which accounted for 99.7% of the total Chinese Internet users (China Internet Network Information Center).

A major proportion of Chinese mobile phone users consist of the young adults. Some studies indicated that young adults, especially college students, were more dependent on mobile phone in daily life (Carbonell et al., 2018). However, the overdependence on mobile phone raised the problems of excessive and problematic use of mobile phone and, more serious, addiction on mobile phone (Ewa et al., 2016). One study reported that 48.0% of undergraduate university students were identified as smartphone addicted (Aljomaa et al., 2016). A meta-analysis revealed that the prevalence of mobile phone addiction (MPA) among Chinese college students was 23.0% (Tao et al., 2018). Another study reported that the prevalence of MPA among Chinese undergraduates was 21.3% (Long et al., 2016).

Mobile phone addiction (MPA) as a new concept aroused a wide range of interests (Elhai et al., 2017; Elhai, Levine, et al., 2019; Elhai, Yang, et al., 2019). Mobile phone addiction refers to a state of obsession that the individual behavior is out of control results from the overuse of mobile phone, leading to the significant impairment physical state, psychological state, and social function (Kim et al., 2018). It is a relatively new concept which has not been included in DSM-5 or ICD-11, therefore, the accuracy of the term "mobile phone addiction" is being questioned at present. The terminologies like mobile phone addiction, problematic use, excessive use, and overuse of mobile phones have been interchangeably used across studies in current research as there are no said criteria till date for addictive use. While various limitations exist, the growing body of empirical research generally supports the concept of MPA as a genuine addictive disorder (Billieux et al., 2015). We therefore adopt the term mobile phone addiction (MPA) in our research. At the same time, we argue that research should focus on the negative consequences of MPA rather than determine whether it should be considered as a behavioral addiction.

Increasing evidences indicated that MPA among adolescents and young adults had become a matter of concern due to its high occurrence rate (Ka Chun et al., 2020; Lopez-Fernandez, 2017) and serious adverse impacts on their physical, psychological and sleep quality (Yen et al., 2009). MPA has been considered as an important inducement for a variety of psychological problems (Yang et al., 2019). MPA has been linked to anxiety, depression (Elhai, Levine, et al., 2019; Elhai, Yang, et al., 2019), social anxiety (Di Matteo et al., 2021), attention (Tsai, 2020), and loneliness (Darcin et al., 2015). Soni et al. demonstrated that adolescents with MPA also developed various sleeping problems (Soni et al., 2017). It is reported that MPA was associated with at least one sleep outcome, such as insomnia, excessive daytime sleepiness, poor sleep quality, and short sleep duration (Kang et al., 2020). Therefore, adolescents who are addicted to mobile phones may have more psychological distress due to poor sleep quality and high levels of procrastination induced by excessive or uncontrolled use of mobile phones. In addition, uncontrolled mobile phone use could also cause physical related issues, such as neck, shoulder, and hand pain (Vally & Hichami). However, few studies have found the influence of MPA on autonomic symptoms, such as palpitation, nausea, and being chill or hot. Therefore, presence of autonomic symptoms would be included in the scope of this study.

MPA is associated with the duration of mobile phone use (Lee et al., 2017). According to a study conducted in 4,434 adolescents in 2019, the failure to control usage time accounted for the highest percentage of the prevalence of MPA (National Information Society Agency, 2019). Rozgonjuk reported that smartphone usage duration was closely related to MPA (Rozgonjuk et al., 2018). In addition, increased duration of smartphone usage in adolescents was related to physical and psychological health problems, such as the development of depressive symptoms (Riehm et al., 2019), decreased general happiness, physical symptoms, and poor sleep quality (Buxton et al., 2015). However, there were few studies that focused on the interaction effect between MPA and duration of mobile phone use on health outcomes.

There is no denying that mobile phone provides significant benefits for our daily life in countless ways. Nonetheless, increased accessibility and easy availability of mobile phones among college students have shown negative impacts on mental well-being, sleep quality, and physical health outcomes (Khalil et al., 2016). Research on MPA has notably increased in recent years (Aljomaa et al., 2016; Darcin et al., 2016). However, there are also few researches on the interaction effects between MPA and duration of phone use on physical, psychological health and sleep quality of college students. Therefore, the present research sought to explore the interaction effects between MPA and duration of phone use on physical and psychological health. This study assists in establishing professional measures to prevent negative health consequences caused by MPA.

Methods

Participants and Produce

The study was a cross-sectional research that recruited undergraduate students from a university in Changchun, China. We have randomly selected 5 departments which included the School of Health, Faculty of Arts and Sciences, Faculty of Engineering, Faculty of Economics, and Administrative Sciences; 200 students were randomly selected from each department. According to Kendall's principle of sample size calculation, the sample size is 5–10 times the number of questionnaire items (Chow et al., 2017). In this study, there is a total of 104 questionnaire items. The estimated sample size should fall in the range between 520 and 1040. Eventually, a total of 1141 questionnaires were distributed, and 1073 students responded to the survey. Students with missing information on the variables assessing MPA were removed from the sample (117 students). To ensure the quality of the data, students also were removed if they did not report their gender (10 students). After removing the invalid questionnaires, a total of 946 sets of data were included in the analysis, with a valid response rate of 88.2%.

The study was approved by Institutional Review Board of the university , and research procedures followed the protocol of the Declaration of Helsinki. The students were informed about the subject and objective of the study, and verbal consents of the students were taken.

Measures

Demographics and Lifestyle Behaviors

The sociodemographic characteristics were collected in the study including gender, age, and grades.

Lifestyle behaviors were measured by cigarette smoking, alcohol drinking, and physical exercise. These variables were collected by the participants' self-reported responses to the questionnaire's questions, such as "During the past 30 days, have you ever smoked cigarettes?", "During past 30 days, did you have at least one glass of alcohol or drink containing alcohol?", and "How often have you exercised frequently?". The participants who answered "always (yes)" were segmented within the "smoker group" or "drinker group" or "exercise frequently," and remaining participants were classified into "no tobacco users" or "no alcohol users" or " no exercise frequently."

Mobile Phone Addiction

The mobile phone addiction index scale (MPAI) was used to measure the severity of MPA of participants (Leung et al., 2008), which proven to have good reliability and validity among Chinese college student population (Cronbach's α: 0.86). The MPAI, revised by Leung et al., is a survey regarding mobile phone use with a total of 17 questions. Each question was answered on a five-point scale . Higher score indicates more severe MPA among all questions. Items 3, 4, 5, 6, 8, 9, 14, and 15 were designed to be MPA screening questions. If participants responded to five or more questions with a three or above score, they were considered to be mobile phone addicts. The others were classified as non-phone addicts. The categories of mobile phone addiction were created by interquartile range of the total score of MPAS. Scores from lowest to Q25 were defined as "no addiction", scores from Q25 to median were defined as "mild addiction", scores from median to Q75 were defined as "moderate addiction", and scores from Q75 to highest were defined as "severe addiction".

Mobile Phone Use Patterns

Mobile phone use patterns were regarded as key factors to MPA (George et al., 2018). Mobile phone use patterns were measured by mobile phone use duration and habits. The question regarding the duration of mobile phone use was "During the weekdays of the last 30 days, for how many hours on average did you use a smartphone in one day?". The mobile phone use time was measured as less than 4 hours and greater than 4 hours (China Internet Network Information Center, 2017). Questions regarding mobile phone use habits were "In the last 30 days, have you usually used a smartphone before going sleep (or after waking up)?" and "In the last 30 days, have you usually used a smartphone in class?".

Sleep Quality

Pittsburg Sleep Quality Index (PSQI) was compiled by Buysse et al. in 1989 (Buysse et al., 1989), which consisted of 24 questions (19 self-report items and 5 others-report items) to assess the sleep quality of subjects in the past month. It was divided into seven different dimensions, such as daytime dysfunctions, subjective sleep quality, sleep duration, use of sleep medication, sleep latency, sleep disturbances, and habitual sleep efficiency. Each dimension ranges from 0 to 3. The total score of PSQI ranges from 0 to 21, with a higher score indicating poorer sleep quality. Participants with 5 or higher total PSQI score were identified with poor sleep quality. The internal consistency of the questionnaire presented a Cronbach's α of 0.83 with a test–retest reliability of 0.85 a month later (Buysse et al., 1989). The Cronbach's α of the PSQI questionnaire in this study was 0.72.

Psychological Status

We listed six items to estimate psychological status which included anxiety symptoms, depressive symptoms, loneliness, social anxiety, sad or hopeless, and impaired concentration. (1) "During the past one month, did you ever feel so sad or hopeless?" (2) "During the past one month, did you ever feel anxious?" (3) "During the past one month, did you ever feel depressed?" (4) "During the past one month, did you ever feel lonely?" (5) "During the past one month, did you ever feel impaired concentration?" (6) "During the past one month, did you ever feel social anxiety?" Participants could choose between the following responses: "yes" or "no."

Physical Status

The physical status was collected with six items to assess whether the participant has the autonomic symptoms in the past month, such as "Have you ever had palpitation (nausea, dry mouth, being chill or hot, numbness, or asphyxia) in the past one month?". Participants could choose between the following responses: "yes" or "no."

Data Analysis

IBM SPSS Statistics 22.0 was applied to perform all the statistical analysis. Quantitative and qualitative measurements were summarized as mean ± standard deviation and n (%), respectively. The total MPAS score was compared between participants with and without variables of psychological, physical, and sleep problems by using independent sample t-test. Binary logistic regression models were used to examine the relationship between mobile phone addiction and psychological, physical, and sleep-related status and to evaluate the interaction of level of mobile phone addiction and mobile phone use time. Adjustment was made for confounding factors such as gender, grade, drinking, smoking, physical exercise, playing mobile phone before sleep, playing mobile phone after waking up, and playing mobile phone in class. $P < 0.05$ was considered statistically significant.

Results

The characteristics and mobile phone using behaviors of participants were represented in Table 1. The average age of participants was 20.7 ± 1.6 years old. 84.4% of the participants played mobile phones before sleep, and 66.5% played after waking up. Around 37.6% of the participants used mobile phones for more than 4 hours a day. 36.6% of the participants were identified with MPA. Around 23.3% of the participants had mild mobile phone addiction, and 23.6% had severe mobile phone addiction.

Significant differences in total score of mobile phone addiction were found in psychological, physical, and sleep quality characteristics. Higher total MPAS score was found to be significantly associated with poor sleep quality ($T = 7.64$, $P < 0.001$), feeling anxious symptoms ($T = 5.03$, $P < 0.001$), feeling depressive symptoms ($T = 5.51$, $P < 0.001$), loneliness ($T = 5.46$, $P < 0.001$), social anxiety ($T = 4.80$, $P < 0.001$), impaired concentration ($T = 7.01$, $P < 0.001$), and sad or hopeless ($T = 7.69$, $P < 0.001$). Higher total MPAS score was also found to be significantly associated with palpitation ($T = 3.79$, $P < 0.001$),

Table 1 Characteristics and mobile phone using behavior of the study participants

Variables	M ± SD [*n* (%)]
Age	20.7 ± 1.6
Gender	
Male	448 (47.4)
Female	498 (52.6)
Grade	
One	129 (13.6)
Two	135 (14.3)
Three	343 (36.3)
Four	243 (25.7)
Five	96 (10.1)
Duration of mobile phone usage	
< 4 h	590 (62.4)
≥ 4 h	356 (37.6)
Playing mobile phone before sleep	
Yes	798 (84.4)
No	148 (15.6)
Playing mobile phone after waking up	
Yes	629 (66.5)
No	317 (33.5)
Playing mobile phone in class	
Yes	655 (69.2)
No	291 (30.8)
Level of mobile phone addiction	
Normal	256 (27.1)
Mild	220 (23.3)
Moderate	247 (26.1)
Severe	223 (23.6)
Mobile phone addiction	
Yes	346 (36.6)
No	600 (63.4)

nausea ($T = 5.05$, $P < 0.001$), dry mouth ($T = 4.03$, $P < 0.001$), being chill or hot ($T = 2.98$, $P = 0.003$), numbness ($T = 2.07$, $P = 0.039$), and asphyxia ($T = 3.04$, $P = 0.002$) (see Table 2).

To further analyze the relationships among all variables, we put them into logistics regression model. Binary logistic regression analysis revealed that the level of MPA was the influencing factor of anxiety symptoms, depressive symptoms, loneliness, social anxiety, impaired concentration, and sad or hopeless ($P < 0.05$), especially severe MPA. The effect of the duration of mobile phone use was found to be not significant with most psychological variables apart from sad or hopeless (OR = 1.39, $P = 0.042$). The interactive effect between DU and severe MPA had statistical significance in all psychological status ($P < 0.05$). All data are given in Table 3.

Binary logistic regression analysis revealed that level of mobile phone addiction was associated with a higher risk of developing palpitation, nausea, and asphyxia ($P<0.05$). The interaction effect between DU and severe mobile phone addiction had higher odds of

Table 2 Associations between total MPAS score and different participants variables ($N=946$)

Variables	*n* (%)	MPAS (M±SD)	Test statistic	*P* value
Poor sleep quality				
No	668 (66.8)	40.5 ± 11.6	7.64	< 0.001
Yes	314 (33.2)	46.8 ± 12.6		
Smoking				
No	904 (95.6)	42.7 ± 12.4	1.58	0.114
Yes	42 (4.4)	39.6 ± 11.1		
Drinking				
No	849 (89.7)	42.4 ± 12.2	1.45	0.148
Yes	97 (10.3)	44.3 ± 13.2		
Physical exercise				
Not frequently	560 (59.2)	43.2 ± 12.6	2.06	0.040
Frequently	386 (40.8)	41.6 ± 11.9		
Anxious symptoms				
No	451(47.7)	40.5 ± 11.9	5.03	< 0.001
Yes	495(52.3)	44.5 ± 12.4		
Depressive symptoms				
No	404 (42.7)	40.1 ± 11.8	5.51	< 0.001
Yes	542 (57.3)	44.5 ± 12.4		
Loneliness				
No	429 (45.3)	40.2 ± 12.2	5.46	< 0.001
Yes	517 (54.7)	44.5 ± 12.1		
Social anxiety				
No	633 (66.9)	41.2 ± 11.9	4.80	< 0.001
Yes	313 (33.1)	45.3 ± 12.8		
Impaired concentration				
No	481 (50.8)	39.8 ± 11.6	7.01	< 0.001
Yes	465 (49.2)	45.3 ± 12.5		
Sad or hopeless				
No	610 (64.5)	40.3 ± 12.1	7.69	< 0.001
Yes	336 (35.5)	46.6 ± 12.1		
Palpitation				
No	671 (70.9)	41.5 ± 11.8	3.79	< 0.001
Yes	275 (29.1)	45.5 ± 13.3		
Nausea				
No	724 (76.5)	41.5 ± 12.1	5.05	< 0.001
Yes	222 (23.5)	46.2 ± 12.4		
Dry mouth				
No	691 (73.0)	41.6 ± 12.2	4.03	< 0.001
Yes	255 (27.0)	45.2 ± 12.3		
Being chill or hot				
No	854(90.3)	42.2 ± 12.1	2.98	0.003
Yes	92(9.7)	46.2 ± 13.7		

Table 2 (continued)

Variables	*n* (%)	MPAS (M±SD)	Test statistic	*P* value
Numbness				
No	885 (93.6)	42.3 ± 12.3	2.07	0.039
Yes	61 (6.4)	45.7 ± 12.3		
Asphyxia				
No	831 (87.8)	42.1 ± 12.2	3.04	0.002
Yes	115 (12.2)	45.8 ± 12.7		

having palpitation (OR = 2.25, $P = 0.001$) and nausea (OR = 2.34, $P = 0.001$). All data are given in Table 4.

The results of a regression analysis examining the interactions effect of DU and level of MPA on sleep quality was shown in Table 5. There was a interactive effect between DU and level of MPA on sleep quality, sleep latency, sleep disturbances, sleep duration, and sleep dysfunctions ($P < 0.001$); college students with severe MPA who used mobile phone for more than 4 h per day were more likely to be with sleep problems.

Discussion

There was a large number of young people with MAP (36.6%) in this study sample, and the prevalence was higher than the number reported by other similar studies conducted in China (Long et al., 2016; Tao et al., 2018). Previous studies conducted on university students in Asia have used various measuring instruments, with prevalence of MAP or excessive smartphone use ranging from 19.1% to 36.5% (Chen et al., 2017; Kim et al., 2017). The prevalence of our study is higher than previous studies. These discrepancies could be explained by the use of different measure instruments, classification method used, and the difference in the timing of the study. Moreover, the inconsistencies might be due to the differences among participants in different studies. Regardless, all findings have come to the conclusion; that is, MPA is a widespread problem in the young population. The wide range of prevalence rate identified in various studies indicated that MPA was a potential health concern and requires more attentions.

Our study found that students with severe MPA were more likely to feel anxiety symptoms, depressive symptoms, loneliness, social anxiety, impaired concentration, and sad or hopeless. This phenomenon is consistent with previous research results (Darcin et al., 2015; Di Matteo et al., 2021; Elhai, Levine, et al., 2019; Elhai, Yang, et al., 2019; Hyun & Hwa, 2017; Tsai, 2020). Our study also revealed that more severe MPA and longer duration of smartphone use led to poorer psychological health status. College students spend plenty of time on their mobile phones, which occupies their effective time and reduces their time to participate in other social activities (Cho & Lee, 2017). Furthermore, the wireless feature on mobile phone allows students to engage in internet surfing anywhere at any time, which further drives them away from reality and drown in virtual world (Mehroof & Griffiths, 2010). These circumstances alienate students from face-to-face interaction in the real world and weaken their social skills and enlarge the gap between people (Zhang , 2016). When one's degree of satisfaction of his social intercourse is lower than his expectation, the feeling of loneliness arises (Liu et al., 2016). Slowly, the psychological emptiness could lead to disappointment and depression, which aggravates social anxiety (Li et al., 2017).

Table 3 Logistic regression model for interaction between DU and level of mobile phone addiction on psychological status

Variables	Anxious symptoms			Depressive symptoms			Loneliness			Social anxiety			Impaired concentration			Sad or hopeless		
	β	OR	*P*	β	OR	*P*	β	OR	*P*	β	OR	*P*	β	OR	*P*	β	OR	*P*
Level of mobile phone addiction																		
Normal		1.00	< 0.001		1.00	< 0.001		1.00	0.001		1.00	0.001		1.00	< 0.001		1.00	< 0.001
Mild	0.61	1.85	0.002	0.33	1.39	0.088	0.33	1.40	0.082	0.40	1.49	0.066	0.57	1.76	0.004	0.59	1.81	0.006
Moderate	0.74	2.11	< 0.001	0.60	1.81	0.002	0.57	1.76	0.003	0.38	1.47	0.076	0.61	1.85	0.002	0.60	1.81	0.006
Severe	0.79	2.20	< 0.001	0.69	2.00	< 0.001	0.59	1.80	< 0.001	0.78	2.17	< 0.001	0.97	2.63	< 0.001	0.85	2.34	< 0.001
Duration of phone use	0.15	1.17	0.321	− 0.23	0.14	0.144	− 0.01	0.97	0.974	0.14	1.15	0.397	0.18	1.19	0.251	0.33	1.39	0.042
Normal * DU		1.00	< 0.001		1.00	< 0.001		1.00	0.006		1.00	< 0.001		1.00	< 0.001		1.00	< 0.001
Mild * DU	0.03	1.03	0.900	− 0.18	0.83	0.467	0.16	1.17	0.538	0.10	1.10	0.720	0.27	1.31	0.289	0.16	1.18	0.548
Moderate * DU	0.42	1.52	0.027	0.23	1.26	0.220	0.24	1.27	0.210	0.14	1.15	0.483	0.38	1.46	0.045	0.67	1.96	0.001
Severe * DU	1.15	3.14	< 0.001	1.17	3.24	< 0.001	0.84	2.28	< 0.001	0.92	2.50	< 0.001	1.17	3.23	< 0.001	0.99	2.68	< 0.001
Cox & Snell R^2	0.05			0.04			0.02			0.03			0.05			0.05		
Nagelkerke R^2	0.07			0.05			0.03			0.04			0.07			0.07		
Model χ^2	52.33			34.09			21.74			29.69			47.84			46.62		

DU= duration of phone use; *interaction Adjusted for gender, grade, drinking, smoking, physical exercise, playing mobile phone before sleep, playing mobile phone after waking up, and playing mobile phone in class.

Table 4 Logistic regression model for interaction between DU and level of mobile phone addiction on physical status

Variables	Palpitation			Nausea			Mouth dryness			Being chill or hot			Numbness			Asphyxia		
	β	OR	*P*	β	OR	*P*	β	OR	*P*	β	OR	*P*	β	OR	*P*	β	OR	*P*
Level of mobile phone addiction																		
Normal		1.00	0.003		1.00	0.004		1.00	0.064		1.00	0.748		1.00	0.206		1.00	0.010
Mild	0.37	1.45	0.091	0.12	1.13	0.619	0.05	1.05	0.251	0.03	1.03	0.943	0.57	1.76	0.262	0.90	2.45	0.008
Moderate	0.20	1.22	0.379	0.45	1.57	0.057	0.54	1.72	0.047	0.13	1.14	0.768	0.31	1.37	0.582	1.09	2.98	0.001
Severe	0.51	1.66	0.003	0.70	2.01	< 0.001	0.83	2.30	0.050	0.65	1.91	0.286	1.38	3.98	0.037	0.76	2.13	0.044
Duration of phone use	− 0.10	0.90	0.553	0.03	1.03	0.877	− 0.49	0.61	0.300	− 0.11	0.90	0.866	0.62	1.86	0.382	− 0.09	0.91	0.685
Normal * DU		1.00	0.003		1.00	0.002		1.00	0.676		1.00	0.310		1.00	0.454		1.00	0.003
Mild * DU	− 0.06	0.94	0.836	0.05	1.05	0.875	0.67	1.95	0.251	− 0.99	0.37	0.330	− 0.81	0.45	0.388	− 0.99	0.37	0.007
Moderate * DU	− 0.30	0.74	0.173	0.15	1.17	0.499	0.27	1.31	0.623	0.62	1.86	0.423	− 0.23	0.79	0.794	0.18	1.20	0.490
Severe * DU	0.81	2.25	0.001	0.85	2.34	0.001	0.39	1.47	0.540	0.04	1.04	0.967	− 1.28	0.28	0.169	0.51	1.67	0.061
Cox & Snell R^2	0.02			0.02			0.02			0.01			0.01			0.02		
Nagelkerke R^2	0.03			0.03			0.03			0.03			0.02			0.03		
Model χ^2	20.02			20.70			19.78			12.44			5.49			16.73		

DU =duration of phone use; *interaction

Adjusted for gender, grade, drinking, smoking, physical exercise, playing mobile phone before sleep, playing mobile phone after waking up, and playing mobile phone in class.

Table 5 Logistic regression model for interaction between DU and level of mobile phone addiction on sleep problems

Variables	Sleep quality			Sleep latency			Sleep efficiency			Sleep disturbances			Sleep duration			Daytime dysfunctions		
	β	OR	*P*	β	OR	*P*	β	OR	*P*	β	OR	*P*	β	OR	*P*	β	OR	*P*
Level of mobile phone addiction																		
Normal		1.00	< 0.001		1.00	0.015		1.00	0.872		1.00	0.018		1.00	0.025		1.00	0.008
Mild	0.24	1.28	0.420	0.23	1.26	0.468	0.21	1.23	0.756	0.72	2.07	0.086	0.26	1.30	0.362	0.40	1.50	0.106
Moderate	0.41	1.50	0.175	0.24	1.27	0.465	-0.34	0.71	0.610	1.23	3.41	0.002	0.32	1.38	0.290	0.61	1.83	0.021
Severe	0.49	1.63	0.021	0.66	1.94	0.004	0.19	1.21	0.671	0.53	1.70	0.046	1.31	3.70	0.002	0.79	2.20	< 0.001
Duration of phone use	0.49	1.63	0.032	-0.20	0.82	0.406	-0.53	0.59	0.615	-0.13	0.88	0.631	1.03	2.81	0.006	0.51	1.66	< 0.001
Normal * DU		1.00	0.015		1.00	0.011		1.00	0.977		1.00	0.028		1.00	0.028		1.00	< 0.001
Mild * DU	-0.79	0.46	0.102	-0.27	0.77	0.555	-0.09	0.92	0.944	-0.65	0.52	0.286	0.89	2.44	0.084	0.28	1.33	0.282
Moderate * DU	-0.15	0.86	0.590	-0.11	0.90	0.724	0.30	1.34	0.837	0.64	1.90	0.028	0.93	2.57	0.066	0.52	1.69	0.007
Severe * DU	1.35	3.87	< 0.001	0.95	2.59	0.005	0.24	1.28	0.837	1.07	2.93	0.013	1.67	5.29	0.003	1.27	3.55	0.002
Cox & Snell R^2	0.03			0.01			0.01			0.02			0.02			0.04		
Nagelkerke R^2	0.06			0.03			0.01			0.05			0.03			0.05		
Model χ^2	30.18			13.23			3.33			21.65			16.60			36.92		

DU =duration of phone use; *interaction

Adjusted for gender, grade, drinking, smoking, physical exercise, playing mobile phone before sleep, playing mobile phone after waking up, and playing mobile phone in class.

Coupled with competitive pressure and academic stress, students' psychological needs cannot be met. In order to seek emotional support and sustenance, students utilize mobile phone to resolve, which exacerbates the addiction on mobile phone (Xue-Yuan & Fan, 2016). Ultimately, it comes into being a vicious circle.

The research results showed that people with more severe MPA were more prone to develop palpitations, nausea, and asphyxia. It is possible that electromagnetic fields generated by mobile phones may have influences on the autonomic nervous system (ANS), which modulates the function of the circulatory system (Andrzejak et al., 2008). That results in numbness of palpitations, nausea, and asphyxia. Some studies found that the autonomic symptoms get worse with longer duration of daily phone use, which could be considered signs of dose response (Durusoy et al., 2017; Khan et al., 2008). Our study revealed that the interaction between severe mobile phone addiction and more than 4 h mobile use time was more likely to cause autonomic symptoms among college students. The reason for this result was that heart rate variability (HRV) was under the direct control of the central and autonomic nervous systems, and it was one of the most important indicators of adaptive processes in the human organism (Singh et al., 2018). Young people may lose control of time with prolonged use of Internet on mobile phones (Turel et al., 2018). The ability to accurately determine the duration of human-controlled events is important for human to have high HRV (Ogden et al., 2019). Otherwise, it will increase the possibility of developing autonomic symptoms (Krivonogova et al., 2021).

We found that nearly 33.2% of our sample of the Chinese college students reported poor sleep quality. It was higher than that of Chinese university students (25.7%) and the general population (15.0%) reported by two meta-analytic reviews (Cao et al., 2017; Li et al., 2018). Considering the many negative health effects associated with sleep problems and the very large number of Chinese college students, this 33.2% prevalence figure suggests that the sleep problems of college students deserve preventive and clinical attentions. Moreover, this study found strong and significant relationship between MPA and sleep problems. MPA would cause poor sleep quality, long sleep latency, sleep disturbances, short sleep duration, and daytime dysfunctions. This is consistent with the previous research results (Kumar et al., 2019; Lin et al., 2017). Further research found that the interaction between MPA and duration of phone use increased the risk of developing sleep problems among college students. When the duration of phone time was more than 4 h, there was a cumulative adverse effect of MPA on sleep problems. Long-time phone use may directly reduce the user's time on sleep, resulting in insufficient sleep. Second, exposured to the light of smartphone screens for a long time during bedtime could influence the onset time and secretion of melatonin, which in turn causes sleep–wake rhythm disorders (Liu et al., 2019).

In summary, education and dissemination of information about mobile phone use and healthy use time could greatly improve the psychological and physical health status of college students. College students with moderate MPA are at intermediate risk of becoming more severe MPA if they do not reduce its usage. Severe MPA and duration of mobile phone were associated with psychological and physical health of all students. These findings suggest that parents, school counselors, psychiatrists, and other mental health professionals should take steps toward preventing physical and psychological problems by considering mobile phone use patterns and severity of addiction when developing early detection tools and intervention programs in school or community settings.

There are several limitations to our study. First, we used a cross-sectional design, and causal relationships were not defined. Second, physical and psychological status was determined by the several designed questions. The results could be more reliable if they were

measured through clinical examinations. Third, we used self-reported data, and information bias might be inevitable.

Conclusions

There was a high prevalence of MPA among college students in China. The findings of study indicated that MPA and the interaction between MPA and duration of mobile phone use had strong influences on people's physical and psychological health status.

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References

National Information Society Agency. (2019). *2019 The survey on smartphone overdependence (NIA VIII-RSE-C-19067)*.

Aljomaa, S. S., Al Qudah, M. F., Albursan, I. S., Bakhiet, S. F., & Abduljabbar, A. S. (2016). Smartphone addiction among university students in the light of some variables. *Computers in Human Behavior, 61(C)*, 155-164. https://doi.org/10.1016/j.chb.2016.03.041

Andrzejak, R., Poreba, R., Poreba, M., Derkacz, A., Skalik, R., Gac, P., & Pilecki, W. (2008). The influence of the call with a mobile phone on heart rate variability parameters in healthy volunteers. *Industrial Health, 46*(4), 409–417. https://doi.org/10.2486/indhealth.46.409.

Billieux, J., Maurage, P., Lopez-Fernandez, O., Kuss, D. J., & Griffiths, M. D. (2015). Can disordered mobile phone use be considered a behavioral addiction? An update on current evidence and a comprehensive model for future research. *Current Addiction Reports, 2*(2), 156–162.

Buxton, O. M., Chang, A.-M., Spilsbury, J. C., Bos, T., Emsellem, H., & Knutson, K. L. (2015). Sleep in the modern family: Protective family routines for child and adolescent sleep. *Sleep Health, 1*(1), 15-27. https://doi.org/10.1016/j.sleh.2014.12.002

Buysse, D. J., Reynolds, C. F., Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989). The Pittsburgh Sleep Quality Index: A new instrument for psychiatric practice and research. *Psychiatry Research, 28*(2), 193–213. https://doi.org/10.1016/0165-1781(89)90047-4.

Cao, X. L., Wang, S. B., Zhong, B. L., Zhang, L., Ungvari, G. S., Ng, C. H., Lu, J. P. (2017) The prevalence of insomnia in the general population in China: A meta-analysis. *PLoS One*, *12*(2), e0170772. https://doi.org/10.1371/journal.pone.0170772

Carbonell, X., Chamarro, A., Oberst, U., Rodrigo, B., & Prades, M. (2018). Problematic use of the Internet and smartphones in university students: 2006–2017. *International Journal of Environmental Research and Public Health*, 15(3), 475. https://doi.org/10.3390/ijerph15030475

China Internet Network Information Center. http://www.cnnic.net.cn/hlwfzyj/hlwxzbg/hlwtjbg/202102/P020210203334633480104.pdf. Accessed data 2021-11-11.

China Internet Network Information Center. (2017). *China Statistical Report on Internet Develpment*. http://49.140.187.1/cache/8/03/cnnic.cn/5e3c9654a7d9a35535d47314210f46ce/P020170123364672657408.pdf. Accessed data 2021-06-06.

Pew Research Center. (2018). *Social media use continues to rise in developing countries but plateaus across developed ones*. http://www.pewinternet.org/2017/05/17/tech-adoption-climbs-among-older-adults. Accessed data 2021-10-26.

Chen, B., Liu, F., Ding, S., Ying, X., Wang, L., & Wen, Y. (2017). Gender differences in factors associated with smartphone addiction: A cross-sectional study among medical college students. *Bmc Psychiatry*, 17(1), 341. https://doi.org/10.1186/s12888-017-1503-z

Cho, K.-S., & Lee, J.-M. (2017). Influence of smartphone addiction proneness of young children on problematic behaviors and emotional intelligence: Mediating self-assessment effects of parents using smartphones. *Computers in Human Behavior, 66*, 303-311. https://doi.org/10.1016/j.chb.2016.09.063

Chow, S. C., Shao, J., Wang, H., & Lokhnygina, Y. (2017). *Sample Size Calculations in Clinical Research: Third Edition*. CRC Press.

Darcin, A. E., Kose, S., Noyan, C. O., Nurmedov, S., Yilmaz, O., & Dilbaz, N. (2016). Smartphone addiction and its relationship with social anxiety and loneliness. *Behaviour & Information Technology, 35*(7), 520-525. https://doi.org/10.1080/0144929X.2016.1158319

Darcin, A. E., Noyan, C., Nurmedov, S., Yilmaz, O., & Dilbaz, N. (2015). Smartphone addiction in relation with social anxiety and loneliness among university students in Turkey. *European Psychiatry*, 30(S1), 505. https://doi.org/10.1016/S0924-9338(15)30398-9

Di Matteo, D., Fotinos, K., Lokuge, S., Mason, G., Sternat, T., Katzman, M. A., & Rose, J. (2021). Automated screening for social anxiety, generalized anxiety, and depression from objective smartphone-collected data: Cross-sectional study. *Journal of Medical Internet research*, 23(8), e28918. https://doi.org/10.2196/28918

Durusoy, R., Hassoy, H., Ozkurt, A., & Karababa, A. O. (2017). Mobile phone use, school electromagnetic field levels and related symptoms: A cross-sectional survey among 2150 high school students in Izmir. *Environmental health : a global access science source*, 16(1), 51. https://doi.org/10.1186/s12940-017-0257-x

Elhai, J. D., Dvorak, R. D., Levine, J. C., & Hall, B. J. (2017). Problematic smartphone use: A conceptual overview and systematic review of relations with anxiety and depression psychopathology. *Journal of Affective Disorders, 207*, 251-259. https://doi.org/10.1016/j.jad.2016.08.030

Elhai, J. D., Levine, J. C., & Hall, B. J. (2019). The relationship between anxiety symptom severity and problematic smartphone use: A review of the literature and conceptual frameworks. *Journal of Anxiety Disorders, 62(1)*, 45-52. https://doi.org/10.1016/j.janxdis.2018.11.005

Elhai, J. D., Yang, H., & Montag, C. (2019). Cognitive- and emotion-related dysfunctional coping processes: Transdiagnostic mechanisms explaining depression and anxiety's relations with problematic smartphone use. *Current Addiction Reports, 6*(4), 410-417. https://doi.org/10.1007/s40429-019-00260-4

Ewa, D., Beata, P., Emilia, P. (2016). Coping strategies in individuals at risk and not at risk of mobile phone addiction. Current Problems of Psychiatry, 17(4), 250-260. https://doi.org/10.1515/cpp-2016-0024

Fallahi-Khoshknab, M., & Yahyazadeh, S. (2016). The prevalence of smart phone addiction among students in medical sciences universities in Tehran 2016. Advances in Nursing & Midwifery, 26(94), 1-10.

George, M. J., Russell, M. A., Piontak, J. R., & Odgers, C. L. (2018). Concurrent and subsequent associations between daily digital technology use and high-risk adolescents' mental health symptoms. *Child Development, 89*(1), 78-88. https://doi.org/10.1111/cdev.12819

Hyun, P. J., Hwa, P. J. (2017). The relationships among interpersonal relationship anxiety, college adjustment, self-control, and smartphone addiction in nursing students. Journal of the Korean Data and Information Science Society, 28(1), 185-194. https://doi.org/10.7465/jkdi.2017.28.1.185

Ka Chun, N., Wu, L. H., Lam, H. Y., Lam, L. K., Nip, P. Y., Cho Man, N., . . . Leung, S. F. (2020). The relationships between mobile phone use and depressive symptoms, bodily pain, and daytime sleepiness in Hong Kong secondary school students. *Addictive Behaviors*, 101, 105975. https://doi.org/10.1016/j.addbeh.2019.04.033

Kang, Y., Liu, S., Yang, L., Xu, B., Lin, L., Xie, L., . . . Zhang, B. (2020). Testing the bidirectional associations of mobile phone addiction behaviors with mental distress, sleep disturbances, and sleep patterns: A one-year prospective study among Chinese college students. *Frontiers in Psychiatry*, 11, 634. https://doi.org/10.3389/fpsyt.2020.00634

Khalil, A. I., Alharbi, N. B., Alhawasawi, H. Y., & Albander, A. B. (2016). Prevalence of Internet addiction among nursing students and the association with their academic performance and mental health. Athens Journal of Health, 3(4), 291-306. https://doi.org/10.30958/ajh.3-4-2

Khan, M. M. (2008). Adverse effects of excessive mobile phone use. International Journal of Occupational Medicine & Environmental Health, 21(4), 289-293. https://doi.org/10.2478/v10001-008-0028-6

Kim, H.-J., Min, J.-Y., Kim, H.-J., & Min, K.-B. (2017). Accident risk associated with smartphone addiction: A study on university students in Korea. *Journal of Behavioral Addictions, 6*(4), 699-707. https://doi.org/10.1556/2006.6.2017.070

Kim, Y.-J., Jang, H. M., Lee, Y., Lee, D., & Kim, D.-J. (2018). Effects of Internet and smartphone addictions on depression and anxiety based on propensity score matching analysis. *International Journal of Environmental Research and Public Health*, 15(5), 859. https://doi.org/10.3390/ijerph15050859

Krivonogova, O., Krivonogova, E., & Poskotinova, L. (2021). Heart rate variability, time estimation and Internet-dependent behaviour in 16–17-year-old adolescents: A study in Russian Arctic. *Life-Basel*, 11(6), 497. https://doi.org/10.3390/life11060497

Kumar, V. A., Chandrasekaran, V., & Brahadeeswari, H. (2019). Prevalence of smartphone addiction and its effects on sleep quality: A cross-sectional study among medical students. *Industrial Psychiatry Journal, 28*(1), 82-85. https://doi.org/10.4103/ipj.ipj_56_19

Lee, H., Kim, J. W., & Choi, T. Y. (2017). Risk factors for smartphone addiction in Korean adolescents: Smartphone use patterns. *Journal of Korean Medical Science, 32*(10), 1674-1679. https://doi.org/10.3346/jkms.2017.32.10.1674

Leung, L. (2008). Linking psychological attributes to addiction and improper use of the mobile phone among adolescents in Hong Kong. Journal of Children & Media, 2(2), 93-113. https://doi.org/10.1080/17482790802078565

Li, L., Wang, Y.-Y., Wang, S.-B., Zhang, L., Li, L., Xu, D.-D., . . . Xiang, Y. T. (2018). Prevalence of sleep disturbances in Chinese university students: A comprehensive meta-analysis. *Journal of Sleep Research*, 27(3), 1-13. https://doi.org/10.1111/jsr.12648

Li, M., Jiang, X., & Ren, Y. (2017). Mediator effects of positive emotions on social support and depression among adolescents suffering from mobile phone addiction. *Psychiatria Danubina, 29*(2), 207-213. https://doi.org/10.24869/psyd.2017.207

Lin, Y. H., Lin, Y. C., Lin, S. H., Lee, Y. H., Lin, P. H., Chiang, C. L., . . . Kuo, T. B. J. (2017). To use or not to use? Compulsive behavior and its role in smartphone addiction. Translational Psychiatry, 7(2), e1030. https://doi.org/10.1038/tp.2017.1

Liu, H. J., Yao, D. W. (2016). The relationship between mobile phone addiction and loneliness, self-harmony of university students. Studies of Psychology and Behavior, 14(3), 406-410.

Liu, S., Wing, Y. K., Hao, Y., Li, W., Zhang, J., & Zhang, B. (2019). The associations of long-time mobile phone use with sleep disturbances and mental distress in technical college students: A prospective cohort study. *Sleep*, 42(2), 1-10. https://doi.org/10.1093/sleep/zsy213

Lo Coco, G., Salerno, L., Franchina, V., La Tona, A., Di Blasi, M., & Giordano, C. (2020). Examining bidirectionality between fear of missing out and problematic smartphone use. A two-wave panel study among adolescents. *Addictive Behaviors*, 106, 106360. https://doi.org/10.1016/j.addbeh.2020.106360

Long, J., Liu, T.-Q., Liao, Y.-H., Qi, C., He, H.-Y., Chen, S.-B., & Billieux, J. (2016). Prevalence and correlates of problematic smartphone use in a large random sample of Chinese undergraduates. *BMC Psychiatry*, 16(1), 408. https://doi.org/10.1186/s12888-016-1083-3

Lopez-Fernandez, O. (2017). Short version of the smartphone addiction scale adapted to Spanish and French: Towards a cross-cultural research in problematic mobile phone use. *Addictive Behaviors, 64*, 275-280. https://doi.org/10.1016/j.addbeh.2015.11.013

Mehroof, M., & Griffiths, M. D. (2010). Online gaming addiction: The role of sensation seeking, self-control, neuroticism, aggression, state anxiety, and trait anxiety. *Cyberpsychology Behavior and Social Networking, 13*(3), 313-316. https://doi.org/10.1089/cyber.2009.0229

Ogden, R. S., Henderson, J., McGlone, F., & Richter, M. (2019). Time distortion under threat: Sympathetic arousal predicts time distortion only in the context of negative, highly arousing stimuli. *PLoS One*, 14(5), e0216704. https://doi.org/10.1371/journal.pone.0216704

Riehm, K. E., Feder, K. A., Tormohlen, K. N., Crum, R. M., Young, A. S., Green, K. M., . . . Mojtabai, R. (2019). Associations between time spent using social media and internalizing and externalizing problems among US youth. *Jama Psychiatry*, 76(12), 1266-1273. https://doi.org/10.1001/jamapsychiatry.2019.2325

Rozgonjuk, D., Levine, J. C., Hall, B. J., & Elhai, J. D. (2018). The association between problematic smartphone use, depression and anxiety symptom severity, and objectively measured smartphone use over one week. *Computers in Human Behavior, 87*, 10-17. https://doi.org/10.1016/j.chb.2018.05.019

Singh, N., Moneghetti, K. J., Christle, J. W., Hadley, D., Plews, D., & Froelicher, V. (2018). Heart rate variability: An old metric with new meaning in the era of using nnHealth technologies for health and exercise training guidance. Part One: Physiology and Methods. *Arrhythmia & Electrophysiology Review, 7*(3), 193-198. https://doi.org/10.15420/aer.2018.27.2

Soni, R., Upadhyay, R., & Jain, M. (2017). Prevalence of smart phone addiction, sleep quality and associated behaviour problems in adolescents. International Journal of Research in Medical Sciences, *5*(2), 515-519. https://doi.org/10.18203/2320-6012.ijrms20170142

Tao, J., Luo, C., Huang, J., & Liang, L. (2018). Meta analysis of mobile phone dependence of Chinese college students. *Chinese Journal of School Health, 39*(6), 1391-1394. https://doi.org/10.16835/j.cnki.1000-9817.2018.09.032

Tsai, S.-J. (2020). The importance of measuring problematic smartphone use in children with attention deficit hyperactivity disorder. *Journal of the Chinese Medical Association, 83*(9), 803-804. https://doi.org/10.1097/JCMA.0000000000000372

Turel, O., Brevers, D., & Bechara, A. (2018). Time distortion when users at-risk for social media addiction engage in non-social media tasks. *Journal of Psychiatric Research, 97*, 84-88. https://doi.org/10.1016/j.jpsychires.2017.11.014

Vally, Z., & Hichami, F. E. (2019). An examination of problematic mobile phone use in the United Arab Emirates: Prevalence, correlates, and predictors in a college-aged sample of young adults. Addictive behaviors reports, 9, 100185. https://doi.org/10.1016/j.abrep.2019.100185

Xue-Yuan, L., & Fan, S. Q. (2016). Classification of college students' mobile phone addiction and its effects on interpersonal relationship and loneliness. Journal of Hubei University of Education, 33(7), 51-54.

Yang, X., Zhou, Z., Liu, Q., & Fan, C. (2019). Mobile phone addiction and adolescents' anxiety and depression: The moderating role of mindfulness. *Journal of Child and Family Studies, 28*(3), 822-830. https://doi.org/10.1007/s10826-018-01323-2

Yen, C. .F., Tang, T. .C., Yen, J. .Y., Lin, H. .C., Huang, C. .F., Liu, S. .C., & Ko, C. .H. (2009). Symptoms of problematic cellular phone use, functional impairment and its association with depression among adolescents in Southern Taiwan. *Journal of Adolescence, 32*(4), 863–873. https://doi.org/10.1016/j.adolescence.2008.10.006.

Zhang, W. P. (2016). Psychological causes and prevention countermeasures of mobile phone addiction of college students. Journal of Hubei Correspondence University, 15, 73-74.

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