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Original Article

ORIGINAL ARTICLE

The associations of long-time mobile phone use with sleep disturbances and mental distress in technical college students: a prospective cohort study

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Abstract

Study Objectives: To determine the longitudinal associations of long-time mobile phone use (LTMPU) with sleep disturbances and mental distress in a prospective cohort of technical college students.

Methods: A total of 4333 (response rate: 91.5%) and 3396 (response rate: 78.4%) participants were recruited at baseline and 8-month follow-up, respectively. Data were collected by a set of questionnaires including socio-demographics, lifestyle practice, duration of mobile phone use per day, sleep patterns on weekdays and weekends, as well as Insomnia Severity Index, Epworth Sleepiness Scale, reduced Morningness-Eveningness Questionnaire, Beck Depression Inventory, and Zung Self-Rating Anxiety Scale. LTMPU was defined as using mobile phone ≥4 hours/day.

Results: At baseline, 23.5% (n = 1020) of the participants reported using mobile phone ≥ 4 hours/day. LTMPU at baseline was positively associated with the new incidences (range, adjusted odds ratio 1.31–1.53) of a series of the sleep disturbances and mental distress at follow-up. The discontinuation of LTMPU was associated with an amelioration of the risks of most of these problems. Cross-lagged analyses revealed bidirectional associations of the duration of mobile phone use with poor sleep and mental health outcomes.

Conclusions: LTMPU predicts the new incidences of most sleep disturbances and mental distress, while discontinuation of LTMPU is associated with amelioration of these problems. Moreover, there are bidirectional associations between the duration of mobile phone use and various sleep and mental outcomes. These findings highlight the critical role of prevention and early recognition of excessive mobile phone use and their accompanied mental and sleep problems.

Statement of Significance

The ubiquitous excessive use of mobile phone has raised concerns about their potential impacts on sleep and mental health in youth, as evidenced by a handful of cross-sectional and prospective studies. The current study, by using a school-based cohort in China, comprehensively examined the longitudinal and bidirectional associations of excessive mobile phone use with sleep disturbances and mental distress. This study demonstrated that long-time mobile phone use predicted the new incidences of most sleep and mental health outcomes. Moreover, the bidirectional relationship between excessive mobile phone use and various outcomes reflects a vicious circle between them. These findings highlight the critical role of prevention and early recognition of both excessive mobile phone use and their accompanied mental and sleep problems.

Key words: technical college students; mobile phone; sleep disturbance; mental distress; China

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Introduction

Electronic media, such as televisions, computers, tablets, and game consoles, have become increasingly common. However, the overuse of electronic media has raised concerns about their potential impacts on sleep and mental health, especially in youth [1–4]. Excessive use of electronic media (e.g. TVs, computers, tablets, video games, and/or Internet) or use before bedtime has been found to be associated with negative effects on sleep duration, sleep quality, sleep efficiency [5, 6], and tiredness [7], as well as depressive symptoms [8, 9] and anxiety symptoms [10, 11]. A list of Chinese studies also reported that high screen time (e.g. using a computer, playing video games, and watching TV/video programs) was positively associated with depression [12–14], anxiety [12, 13], and poor sleep quality [14].

Particularly, mobile phone has become the most prevalent electronic media in our daily life. By the end of 2016, there were a total of 7.51 billion mobile phone subscribers in the world [15], among which 1.36 billion were from China [16], especially among young population [17, 18]. There is also a parallel dramatic increase in the time spent on mobile phone in young generation [19]. A recent study reported that 18.6% of high school students regularly used mobile phone for over 4 hours per day [19], while another study reported an average of 4.4 hours per day spent on mobile phone among college students [20]. Despite the convenience and practicability, the excessive use of mobile phone has also raised a myriad of sleep and mental health problems [21]. In particular, apart from having more problematic mobile phone use when compared with older groups [22, 23], adolescence and early adulthood are also vulnerable periods to develop various sleep disturbances and mental problems [24–29]. Thus, it is not unexpected that the overuse of mobile phone is associated with various sleep disturbances, such as insomnia [19, 30–32], excessive daytime sleepiness [30, 33, 34], short sleep duration [19, 30, 34, 35], eveningness chronotype [32], poor sleep quality [30, 34, 36, 37], and mental distress, especially depression and anxiety [9, 37–40].

However, only very few studies have used prospective design to explore the long-term impacts of mobile phone use on sleep and mental health [9, 33, 38, 39]. In general, these studies have found that the overuse of mobile phone is longitudinally associated with poor sleep and mental health outcomes, including tiredness [33], sleep disturbances [38], and depressive symptoms [9, 38, 39]. Nonetheless, the relatively small sample size [9] and/or high drop-out rate [38] limited the generalizability of the findings, and most of these studies only examined one or two aspects of these outcomes. On the other hand, it is reported that the penetration rate of mobile phone in Chinese has dramatically increased from 6.7% to 96.9% since the beginning of the 21st century [16], especially in young generation [17, 18], together with an amazingly increasing time spent on mobile phone [19, 20]. To our knowledge, there is no prospective study examining the long-term impact of mobile phone use in Chinese youth. Finally, several researchers have suggested that the longitudinal associations of overuse of mobile phone with sleep and mental health outcomes may be bidirectional [21, 22, 30], while only one study has directly examined the bidirectionality between mobile phone use and depression in youth [39].

We hypothesized that the overuse of mobile phone was associated with various sleep and mental health problems in young population. In this study, we aimed to determine the long-term impacts of the overuse of mobile phone in terms of sleep disturbances and mental distress in a school-based cohort. In particular, we also examined the potential bidirectional associations of the overuse of mobile phone with these outcomes.

Methods

Participants

This study was part of a school-based cohort study, which aimed to investigate the longitudinal course of sleep disturbances and mental distress as well as their risk factors. The baseline and follow-up of this study were conducted in November 2014 and in July 2015, respectively. At baseline, a total of 4733 students aged 14 to 24 years (98.0% aged 15–21 years) in a technical college in Baiyun District, Guangzhou, China were recruited in this study. Among them, 4333 (91.5%) responded at baseline with valid data. At 8-month follow-up, 3396 (78.4%) out of 4333 had a valid response (Figure 1). Questionnaires were distributed to the students during class period at both baseline and follow-up. This study was approved by the institutional research ethics committee.

Measures

Socio-demographics and lifestyle practice (baseline)

A general questionnaire was designed to collect information on socio-demographics, lifestyle practice and health conditions. Specifically, socio-demographics, such as living in a rural area or suburban area, only child (yes or no), parental education level (tertiary or not), parents being migrant workers (yes or no), and family income (≤15 000 yuan/month or >15 000 yuan/month) were collected by dichotomic or ordinal questions at baseline. Life styles and health conditions included habitual afternoon napping (≥3 days/week, yes or no), habitual snoring (≥3 days/week, yes or no), boarding in school during school days (yes or no), time spending on TV or Internet (>3 hours/day or ≤3 hours/day), smoking (yes or no), drinking (often or not often), chronic medical conditions (yes or no), perceived study stress (high or

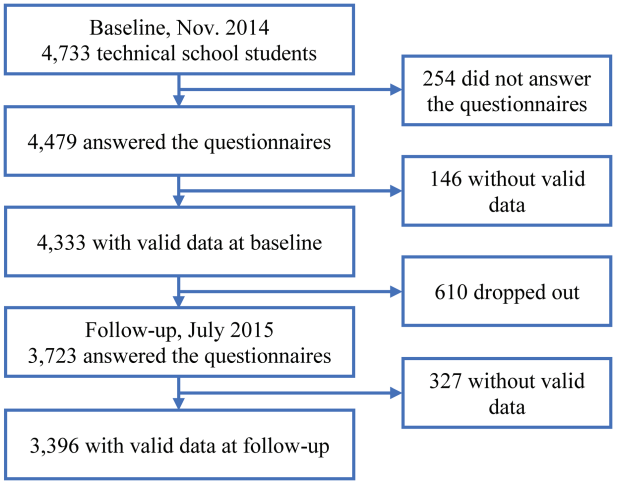

Figure 1. Flowchart in the recruitment of participants.

low), perceived study interest (high or low), and living expenses (≤2000 yuan/month or >2000 yuan/month). In addition, body mass index (BMI) was calculated by self-reported weight in kilograms divided by height in meters squared (kg/m^2). A BMI ≥ 25 was defined as overweight.

Duration of mobile phone use (both waves)
The duration of mobile phone use per day was obtained by the following question: How long do you usually spend on using mobile phone per day? The response categories for this question were: less than 2 hours, 2 to 4 hours, 4 to 6 hours, and more than 6 hours. In the current study, long-time mobile phone use (LTMPU) was defined as using mobile phone ≥4 hours per day in consideration of the recent findings [19, 20].

Sleep duration and weekend sleep compensation (both waves)
The sleep patterns were assessed using the following questions: During the past month, when do you usually fall asleep at night? When do you usually wake up in the morning? And these questions were asked on weekdays and weekends respectively. Sleep duration was calculated as the time interval between falling asleep and wake-up on weekdays and weekends, respectively. The duration less than 7 hours was considered as short sleep duration according to the recommendations of National Sleep Foundation [41]. In addition, weekend sleep compensation was defined as the difference between sleep duration on weekdays and weekends. The compensation more than 2 hours were regarded as long weekend sleep compensation.

Insomnia symptoms (Insomnia Severity Index ≥ 9, both waves)
Insomnia symptoms were assessed by the Insomnia Severity Index (ISI), a seven-item questionnaire evaluating the subtype, severity, and impacts of sleep difficulties in the past 2 weeks. Each item is rated by a 5-point Likert scale (e.g. 0 = not at all, 4 = very severe) with a total score ranging from 0 to 28. A total score of ≥9 was recognized as having insomnia symptoms among Chinese adolescents [25, 42].

Excessive daytime sleepiness (Epworth Sleepiness Scale ≥ 14, both waves)
Excessive daytime sleepiness (EDS) was assessed by the Epworth Sleepiness Scale (ESS), which consists of eight questions inquiring the likelihood of falling asleep or dozing off across various situations in daily life. A 4-point Likert scale is employed to evaluate each item (e.g. 0 = no chance of dozing, 3 = high chance of dozing), yielding a total score ranging from 0 to 24. EDS was defined as having a total score of 14 or greater in the Chinese population [43, 44].

Eveningness chronotype (reduced Morningness-Eveningness Questionnaire ≤ 11, both waves)
Eveningness chronotype was assessed by the reduced version of Morningness-Eveningness Questionnaire (MEQ), which consists of the five most representative questions on circadian preference extracted from MEQ [44, 45]. The total score of reduced MEQ (rMEQ) ranges from 4 (extreme eveningness) to 25 (extreme morningness), and a total score of ≤ 11 was considered to be eveningness chronotype. This tool has been validated locally with adequate psychometric properties [45].

Depressive symptoms (Beck Depression Inventory ≥ 10, both waves)
Depressive symptoms were measured by the Beck Depression Inventory (BDI), which has been widely used to evaluate the intensity of depression. This 21-item questionnaire inquiries specific symptoms or mood changes during the past week by a 4-point scale with a total score ranging from 0 to 63. A total score of at least 10 was regarded as suffering depressive symptoms among Chinese [46].

Anxiety symptoms (Zung Self-Rating Anxiety Scale ≥ 50, both waves)
Anxiety symptoms were measured by the Zung Self-Rating Anxiety Scale (SAS), which was comprised of 20 items evaluating various symptoms of anxiety in the past week. A 4-point Likert scale is used to rate each item (e.g. 1 = never or a little of the time, 4 = most of the time). The total score, ranging from 25 to 100, is obtained by multiplying the total raw score by 1.25. A total score of ≥50 was considered to experience anxiety symptoms in the Chinese population [47].

Statistical analysis

Descriptive statistics were reported as means (*SD*) for continuous variables and as percentages for discrete variables between groups where appropriate (Table 1 and Supplementary Table S1). In the cross-sectional (Table 2) and follow-up studies (Tables 3 and 4), chi-square test was conducted to determine the associations between LTMPU and the outcomes of sleep disturbances or mental distress (prevalence, incidence, and persistence). Those without a certain kind of sleep or mental health problems at baseline were further classified into groups with new incidence or persistently free from this problem (Table 3). Those with a certain kind of problem at baseline were further classified into groups with persistence or remission (Table 4). Then, additional analyses were performed according to whether reported LTMPU at baseline and follow-up (Supplementary Tables S2 and S3). The strengths of these relationships were further explored by multivariate logistic regression model, in which age, sex, and other socio-demographics with significant associations with LTMPU at baseline were controlled by using enter method, while lifestyle practice and health conditions with significant associations with LTMPU at baseline were controlled by using forward likelihood method.

Furthermore, cross-lagged analyses were conducted to determine the longitudinal bidirectional relationships between the duration of mobile phone use per day (less than 2 hours, 2 to 4 hours, 4 to 6 hours, and more than 6 hours) and the total score of ISI, ESS, rMEQ, BDI, SAS, as well as sleep duration on weekdays or weekends, and sleep compensation on weekends, respectively. The cross-lagged model is able to determine whether longer time of mobile phone use at baseline predicted the severity of a specific problem (such as ISI total score) at follow-up and meanwhile whether the severity of this problem (such as ISI total score) at baseline predicted longer time of mobile phone use at follow-up after adjusting for age, sex, and all the socio-demographics, lifestyle practice and health conditions that were significantly associated with LTMPU at baseline.

A p value < 0.05 was regarded as statistically significant. All statistical tests were conducted by using SPSS 22.0 for Windows

Table 1. Comparisons in sample characteristics between participants with and without LTMPU at baseline

	Total sample $n = 4333$	Mobile phone use < 4 hours/day $n = 3313$	Mobile phone use ≥ 4 hours/day $n = 1020$	p value
Socio-demographics				
Age, year, mean (SD)	18.3 (1.7)	18.4 (1.7)	17.9 (1.6)	<0.001***
Sex, female, *n* (%)	827 (19.1)	505 (15.2)	322 (31.6)	<0.001***
Rural area, *n* (%)	3005 (69.4)	2339 (70.6)	666 (65.3)	0.001**
Only child, *n* (%)	768 (17.7)	579 (17.5)	189 (18.5)	0.44
Paternal education level (tertiary), *n* (%)	383 (8.8)	277 (8.4)	106 (10.4)	0.046*
Maternal education level (tertiary), *n* (%)	246 (5.7)	188 (5.7)	58 (5.7)	0.99
Paternal migrant workers, *n* (%)	2254 (52.0)	1734 (52.3)	520 (51.0)	0.45
Maternal migrant workers, *n* (%)	1531 (35.3)	1196 (36.1)	335 (32.8)	0.06
Family income (>15 000 yuan[a]/month), *n* (%)	520 (12.0)	334 (10.1)	186 (18.2)	<0.001***
Lifestyle practice and health conditions				
Overweight, *n* (%)	314 (7.2)	221 (6.7)	93 (9.1)	0.008**
Habitual napping, *n* (%)	2866 (66.1)	2258 (68.2)	608 (59.6)	<0.001***
Habitual snoring, *n* (%)	147 (3.4)	105 (3.2)	42 (4.1)	0.14
Boarding in school, *n* (%)	4161 (96.0)	3186 (96.2)	975 (95.6)	0.41
TV/Internet (>3 hours/day), *n* (%)	1813 (41.8)	1214 (36.6)	599 (58.7)	<0.001***
Smoking, *n* (%)	809 (18.7)	604 (18.2)	205 (20.1)	0.18
Drinking, *n* (%)	112 (2.6)	80 (2.4)	32 (3.1)	0.20
Chronic medical conditions, *n* (%)	85 (2.0)	52 (1.6)	33 (3.2)	<0.001***
High perceived study stress, *n* (%)	2473 (57.1)	1853 (55.9)	620 (60.8)	0.006**
Low perceived study interest, *n* (%)	3074 (70.9)	2257 (68.1)	817 (80.1)	<0.001***
Living expenses (>2000 yuan[a]/month), *n* (%)	286 (6.6)	165 (5.0)	121 (11.9)	<0.001***

[a]One yuan equals 0.15 US dollar.
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Table 2. Associations of LTMPU with sleep disturbances and mental distress at baseline

		Prevalence of sleep disturbances and mental distress at baseline			
	Total sample $n = 4333$	Mobile phone use < 4 hours/day $n = 3313$	Mobile phone use ≥ 4 hours/day $n = 1020$	Crude OR (95% CI)	Adjusted OR (95% CI)[a]
Insomnia symptoms, *n* (%)	1060 (24.5)	716 (21.6)	344 (33.7)	1.85 (1.58–2.15)***	1.49 (1.26–1.76)***
Excessive daytime sleepiness, *n* (%)	239 (5.5)	153 (4.6)	86 (8.4)	1.90 (1.45–2.50)***	1.35 (1.00–1.82)*
Short weekday sleep duration (<7 hours), *n* (%)	604 (13.9)	388 (11.7)	216 (21.2)	2.03 (1.69–2.43)***	1.62 (1.33–1.97)***
Short weekend sleep duration (<7 hours), *n* (%)	86 (2.0)	60 (1.8)	26 (2.5)	1.42 (0.89–2.26)	1.40 (0.86–2.26)
Long weekend sleep compensation (>2 hours), *n* (%)	1360 (31.4)	935 (28.2)	425 (41.7)	1.82 (1.57–2.10)***	1.31 (1.11–1.53)***
Eveningness chronotype, *n* (%)	467 (10.8)	278 (8.4)	189 (18.5)	2.48 (2.03–3.03)***	1.97 (1.58–2.45)***
Depressive symptoms, *n* (%)	1662 (38.4)	1133 (34.2)	529 (51.9)	2.07 (1.80–2.39)***	1.58 (1.35–1.85)***
Anxiety symptoms, *n* (%)	749 (17.3)	500 (15.1)	249 (24.4)	1.82 (1.53–2.16)***	1.35 (1.12–1.63)**

[a]Logistic regression model controlled for age, sex and other socio-demographics significantly correlated with LTMPU at baseline (enter method), as well as lifestyle practice and health conditions with statistical significance at baseline (forward likelihood method). Insomnia symptoms: Insomnia Severity Index ≥ 9; Excessive daytime sleepiness: Epworth Sleepiness Scale ≥ 14; Eveningness chronotype: reduced Morningness-Eveningness Questionnaire ≤ 11; Depressive symptoms: Beck Depression Inventory ≥ 10; Anxiety symptoms: Zung Self-Rating Anxiety Scale ≥ 50.
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

(IBM SPSS Statistics., Chicago, IL), except for the cross-lagged analyses, which were performed by AMOS 22.0 (IBM SPSS Statistics).

Results

Cross-sectional analyses

At baseline, 1020 out of 4333 participants (23.5%) reported using mobile phone ≥4 hours per day (LTMPU). The average time of falling asleep and waking up were 23:20 and 06:56 on weekdays and 23:53 and 09:08 on weekends, respectively, yielding average sleep duration of 7.60 hours on weekdays and 9.25 hours on weekends, as well as weekend sleep compensation of 1.65 hours. In addition, the percentage of participants with short sleep duration (<7 hours) was 13.9% ($n = 604$) on weekdays and 2.0% ($n = 86$) on weekends, along with 31.4% ($n = 1360$) reported long weekend sleep compensation (>2 hours).

Table 3. Long-term associations between LTMPU at baseline and the incidences of sleep disturbances and mental distress at follow-up

	Incidence of sleep disturbances and mental distress at follow-up			
	Mobile phone use < 4 hours/day	Mobile phone use ≥ 4 hours/day	Crude OR (95% CI)	Adjusted OR (95% CI)[a]
Incident insomnia symptoms (387/2595)	14.0%	18.3%	1.37 (1.07–1.76)*	1.28 (0.99–1.67)
Incident excessive daytime sleepiness (132/3215)	3.4%	6.5%	2.00 (1.39–2.88)***	1.39 (0.95–2.03)
Incident short weekday sleep duration (<7 hours) (226/2927)	6.9%	10.8%	1.65 (1.22–2.22)***	1.46 (1.08–1.96)*
Incident short weekend sleep duration (<7 hours) (38/3323)	1.1%	1.3%	1.19 (0.57–2.46)	1.12 (0.53–2.38)
Incident long weekend sleep compensation (>2 hours) (497/2346)	19.8%	26.9%	1.49 (1.18–1.88)***	1.31 (1.02–1.67)*
Incident eveningness chronotype (368/3050)	10.6%	17.4%	1.77 (1.39–2.25)***	1.53 (1.19–1.96)***
Incident depressive symptoms (405/2101)	17.9%	25.7%	1.59 (1.22–2.06)***	1.36 (1.04–1.79)*
Incident anxiety symptoms (350/2848)	11.3%	15.8%	1.47 (1.14–1.89)**	1.34 (1.04–1.74)*

[a]Logistic regression model controlled for age, sex, and other socio-demographics significantly correlated with LTMPU at baseline (enter method), as well as lifestyle practice and health conditions with statistical significance at baseline (forward likelihood method). Insomnia symptoms: Insomnia Severity Index ≥ 9; Excessive daytime sleepiness: Epworth Sleepiness Scale ≥ 14; Eveningness chronotype: reduced Morningness-Eveningness Questionnaire ≤ 11; Depressive symptoms: Beck Depression Inventory ≥ 10; Anxiety symptoms: Zung Self-Rating Anxiety Scale ≥ 50.
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Table 4. Long-term associations between LTMPU at baseline and the persistence of sleep disturbances and mental distress at follow-up

	Persistence of sleep disturbances and mental distress at follow-up			
	Mobile phone use < 4 hours/day	Mobile phone use ≥ 4 hours/day	Crude OR (95% CI)	Adjusted OR (95% CI)[a]
Persistent insomnia symptoms (451/801)	54.5%	60.2%	1.26 (0.93–1.70)	1.17 (0.86–1.60)
Persistent excessive daytime sleepiness (53/181)	25.4%	37.3%	1.75 (0.90–3.40)	1.47 (0.70–3.09)
Persistent short weekday sleep duration (<7 hours) (133/469)	26.6%	31.7%	1.28 (0.85–1.95)	1.26 (0.81–1.96)
Persistent short weekend sleep duration (<7 hours) (6/73)	8.0%	8.7%	1.10 (0.19–6.46)	1.51 (0.18–12.67)
Persistent long weekend sleep compensation (>2 hours) (534/1050)	47.6%	58.2%	1.53 (1.18–2.00)**	1.42 (1.08–1.87)**
Persistent eveningness chronotype (150/346)	39.0%	49.6%	1.54 (1.00–2.38)	1.48 (0.94–2.32)
Persistent depressive symptoms (754/1295)	56.8%	61.4%	1.21 (0.95–1.54)	1.13 (0.88–1.44)
Persistent anxiety symptoms (264/548)	47.4%	49.7%	1.10 (0.77–1.57)	0.98 (0.67–1.43)

[a]Logistic regression model controlled for age, sex and other socio-demographics significantly correlated with LTMPU at baseline (enter method), as well as lifestyle practice and health conditions with statistical significance at baseline (forward likelihood method). Insomnia symptoms: Insomnia Severity Index ≥ 9; Excessive daytime sleepiness: Epworth Sleepiness Scale ≥ 14; Eveningness chronotype: reduced Morningness-Eveningness Questionnaire ≤ 11; Depressive symptoms: Beck Depression Inventory ≥ 10; Anxiety symptoms: Zung Self-Rating Anxiety Scale ≥ 50.
**$p < 0.01$.

Table 1 delineates the sample characteristics and their differences between participants with and without LTMPU. Those participants reporting LTMPU were slightly younger (17.9 ± 1.6 years vs. 18.4 ± 1.7 years) and more likely to be girls, and had higher socioeconomic status (living in urban area, higher paternal education level, family income, and living expenses), more overweight and chronic medical conditions, a lower rate of habitual napping, longer time spending on TV or Internet, higher perceived study stress, and lower perceived study interest at baseline when compared to those without LTMPU. There were no significant differences among other socio-demographics or lifestyle practice between the participants with and without LTMPU.

The cross-sectional associations of LTMPU with sleep and mental health problems at baseline were presented in Table 2. Univariate analyses revealed that LTMPU was a correlated factor for all kinds of sleep disturbances and mental distress studied at baseline (range, odds ratio [OR] 1.82–2.48), except for short sleep duration on weekends. These associations of LTMPU with various sleep and mental health problems at baseline remained statistically significant even after adjustment for socio-demographics, lifestyle practice, and

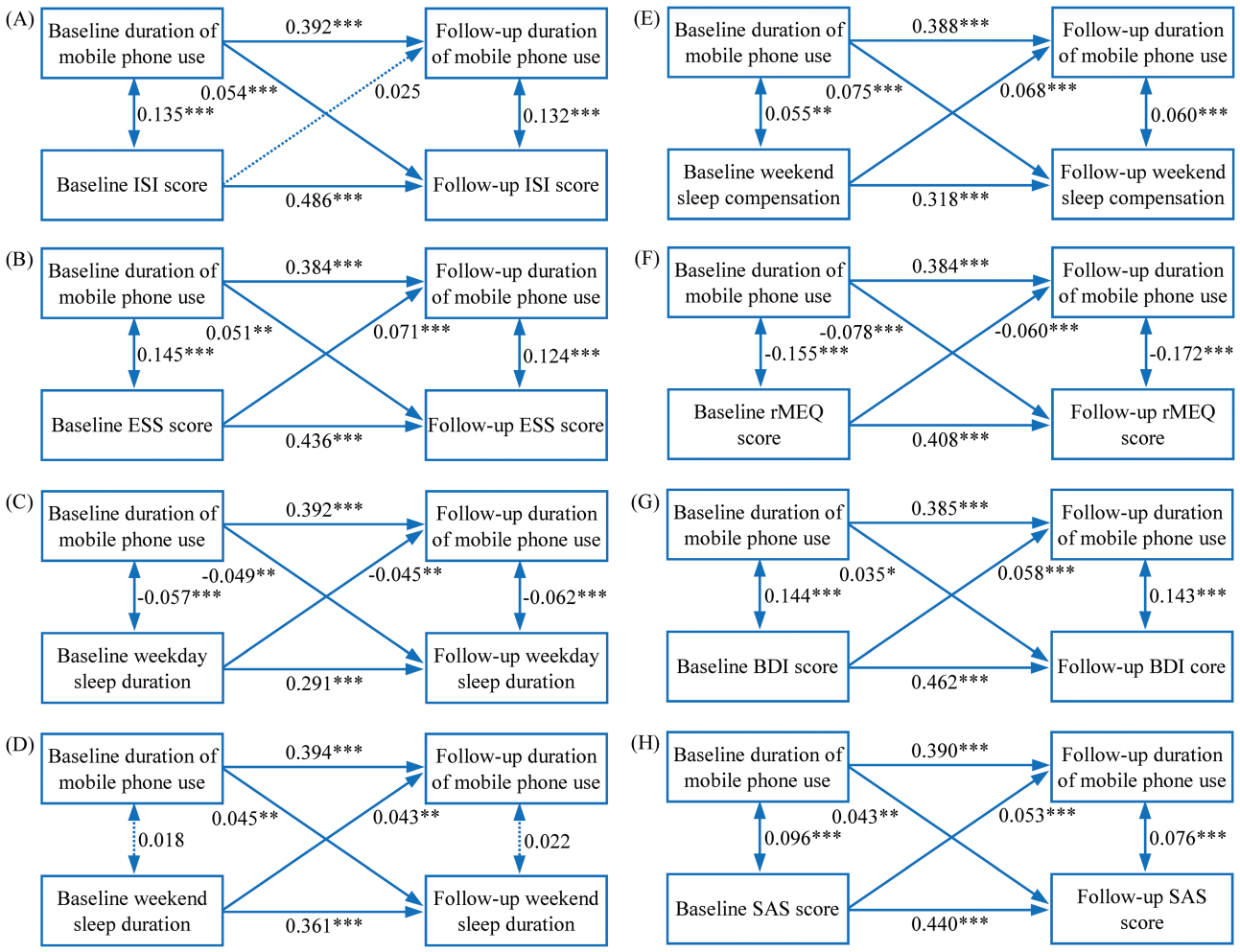

Figure 2. Cross-lagged associations of duration of mobile phone use with sleep disturbances and mental distress. (A) Cross-lagged association between duration of mobile phone use and ISI score. (B) Cross-lagged association between duration of mobile phone use and ESS score. (C) Cross-lagged association between duration of mobile phone use and weekday sleep duration. (D) Cross-lagged association between duration of mobile phone use and weekend sleep duration. (E) Cross-lagged association between duration of mobile phone use and weekend sleep compensation. (F) Cross-lagged association between duration of mobile phone use and rMEQ score. (G) Cross-lagged association between duration of mobile phone use and BDI score. (H) Cross-lagged association between duration of mobile phone use and SAS score. All models were adjusted for age, sex, and all the socio-demographics, lifestyle practice and health conditions that were significantly associated with LTMPU at baseline. Standardized β coefficients are stated in longitudinal associations at baseline and follow-up. $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$. Double-headed arrows denote correlations and single-headed arrows denote direct paths (variables pointed by arrows are dependent variables). Solid lines indicate statistically significant associations and dashed lines indicate insignificant associations.

health conditions in multivariate analyses (range, adjusted OR 1.31–1.97).

Prospective analyses

The sample characteristics at baseline between responders and nonresponders are illustrated in Supplementary Table S1. In general, the responders had slightly lower socioeconomic status (lower family income and living expenses), lower rates of smoking behavior and chronic medical conditions, as well as higher rates of overweight and habitual napping at baseline, when compared with the nonresponders. None of the other socio-demographics or lifestyle practice showed significant difference between the participants with and without valid data at follow-up, including age, sex, and the duration of mobile phone use.

Table 3 presents the prospective associations of LTMPU at baseline with the incidences of various outcomes. LTMPU at baseline was a risk factor for most of the new incidences of these problems, including insomnia symptoms, EDS, short weekday sleep duration, long weekend sleep compensation, eveningness chronotype, depressive symptoms, and anxiety symptoms at follow-up in univariate analyses (range, OR 1.37–2.00). Furthermore, LTMPU at baseline was associated with new incidences of most of these outcomes (range, adjusted OR 1.31–1.53), except for insomnia and EDS, in the adjusted model.

Table 4 shows the long-term associations between LTMPU at baseline and the persistence of sleep and mental health outcomes. Among these outcomes, only the persistence of long weekend sleep compensation was predicted by LTMPU in both crude and adjusted model (adjusted OR = 1.42, 95% confidence interval [CI] 1.08–1.87).

Figure 2 delineates the results of cross-lagged analyses, which revealed the bidirectional longitudinal relationships between the duration of mobile phone use and various sleep and mental health problems in youth, except for the ISI total

score, which was predicted by the duration of mobile phone use but not vice versa. Interestingly, the duration of mobile phone use was negatively and bidirectionally associated with sleep duration during weekdays but positively and bidirectionally associated with sleep duration and sleep compensation during weekends.

Additional analyses

Supplementary Tables S2 and S3 present the longitudinal associations of LTMPU at different situations (persistently free, newly developed, discontinued, and persistent) with the incidences or persistence of various sleep and mental health outcomes, respectively. Those with newly developed or persistent LTMPU was significantly associated with increased incidences of most of these problems (insomnia symptoms, EDS, short weekday sleep duration, long weekend sleep compensation, eveningness chronotype, depressive symptoms, and anxiety symptoms) when compared with those persistently free from LTMPU (range, adjusted OR 1.44–2.61), but those with discontinuation of LTMPU exhibited no differences to those who were persistently free from LTMPU, except for eveningness chronotype (adjusted OR = 1.65, 95% CI 1.17–2.33). Likewise, the newly developed or persistent LTMPU was significantly associated with increased persistence of some problems (insomnia symptoms, eveningness chronotype, depressive symptoms, and anxiety symptoms, range, adjusted OR 1.53–2.31), while the discontinuation of LTMPU was not associated with the persistence of all these outcomes, except for long weekend sleep compensation (adjusted OR = 1.52, 95% CI 1.05–2.21).

Discussion

The current study found that LTMPU is quite prevalent among Chinese technical college students. They had relatively earlier bedtime and longer sleep duration when compared with the results of a recent meta-analysis in China [48], which may be partly due to a relatively younger mean age in the current study. This prospective study has confirmed that LTMPU was associated with the prevalence and incidence of most sleep disturbances and mental distress. Moreover, the newly developed or persistent LTMPU were significantly associated with increased risks of incidences in most outcomes and persistence in some outcomes, but the discontinuation of LTMPU was associated with lower risks in most of these problems at follow-up. Finally, the bidirectional longitudinal relationships reflected a vicious circle between the excessive use of mobile phone and sleep and/or mental health problems.

Bidirectional longitudinal relationships were found between the duration of mobile phone use and ESS score, rMEQ score, and sleep duration, which denotes that those who spend more time on mobile phone are more likely to have EDS, eveningness chronotype, and short weekday sleep duration, and vice versa. These findings are partially in line with previous studies using cross-sectional or prospective design [19, 30, 32–35]. On one hand, the excessive use of mobile phone leads to a number of consequences, including displacement of individual's sleep time, increased physiological and psychological arousal, and suppression of melatonin secretion by screen light [2, 4]. These changes will further contribute to various sleep problems, such as difficulty initiating sleep, delayed sleep phase, chronic sleep deprivation, and EDS. On the other hand, those youths with eveningness chronotype or short weekday sleep duration have more chances to use mobile phone till late at night [36], and those with EDS are also inclined to spend more time on mobile phone in order to maintain their alertness. Another interesting finding that should be noted was the associations of mobile phone use with decreased weekday sleep duration, increased weekend sleep duration and sleep compensation. These opposite impacts are related to sleep deprivation during weekdays in most students who are more likely to compensate the sleep during weekends [49].

However, we only found that the duration of mobile phone use positively predicts the severity of insomnia, but not vice versa. While previous studies have reported cross-sectional association between overuse of mobile phone and insomnia [19, 30–32], several authors have raised a question about whether insomnia is the consequence or the cause of mobile phone use [22, 30]. Nevertheless, this study suggested that insomnia is more likely a consequence rather than a cause of it.

In this study, we found the predictive effects of LTMPU on the new incidences of depression and anxiety, as well as the bidirectional longitudinal relationships between the duration of mobile phone use and the severity of depression and anxiety. Several studies have reported similar results in relation to mobile phone use and depression [9, 38, 39], but the longitudinal relationship between mobile phone use and anxiety has not been reported yet. Several mechanisms have been proposed to explain these associations. For one thing, youths with depression or anxiety may resort to social support through communicating with others in mobile phone due to its convenience and practicability, but paradoxically further leads to seclusion and reduction of face-to-face communications with peers and families [9, 50, 51]. For another, the myriad information received from mobile phone may also increase their cognitive or emotional burden and increase their vulnerability to depression and anxiety [51].

Clinical implications

The current study highlights the significance of prevention and early recognition of excessive mobile phone use. For example, appropriate limitation should be set for the use of mobile phone among youth. The American Academy of Pediatrics has recommended to limit the total media time of young people for entertainment to no more than 1 or 2 hours per day [52]. Text or voice reminders may be useful for those who have already used mobile phone for too long. Several active measures should also be taken to mitigate the deleterious influence of mobile phone use, especially on sleep, such as reading printed books before bedtime [5], reducing the brightness of mobile screen, or using a protective screen to reduce blue light exposure [53, 54]. Furthermore, schools and mass media should increase youth's awareness of the reciprocal relationship of excessive use of mobile phone with sleep disturbances and mental distress [3, 39]. In addition, youths may benefit from health education on sleep hygiene as well as face-to-face communications with others [3, 39, 55]. Early assessments and interventions should be carried out to detect and manage the potential mental health problems and break the vicious circle [3, 39].

Strengths and limitations

There are several strengths in the current study, including prospective study design, large sample size, and satisfactory response rate with minimal attrition bias. However, several limitations should be noted when interpreting our findings. First, all of the participants were recruited from one technical school and were dominated by male, which may limit the generalizability of the current study. Second, self-reported questionnaires were applied to data collection on both mobile phone use and sleep disturbances or emotional distress, which may lead to recall bias and social desirability bias [17, 32]. Nonetheless, previous authors have reported that self-reported sleep data were consistent with objective sleep measures, to some extent, especially over sleep duration [56–58]. Additionally, only a single self-reported question was employed in this study to document the duration of mobile phone use, and its reliability (e.g. test-retest reliability) and validity (compared with other measures or objective recording to mobile phone use) have not been well confirmed. Further studies using more comprehensive and objective measurement tools are warranted. Third, most of the participants were boarding in school, which may cause interactions among peers, to some degree. Fourth, the follow-up study (in July) was not conducted in the same month as at baseline (November). Differences in seasonality may have led to different responses in sleep patterns and mental distress [59]. Nonetheless, the lack of large variation in temperature and daytime light due to the low latitude (23°) of Guangzhou may minimize this potential source of variation in the study measures. In addition, both July and November are during the term of a semester; therefore, it is less likely to lead to holiday effects on both sleep and mental distress. Fifth, we only focused on different duration of mobile phone use per day without concerning the specific time period during the day or the differences between weekdays and weekends, which may have different impacts on sleep and mental health. Sixth, other kinds of electronic media, such as television, computers, tablets, and game consoles [5, 9, 22, 32, 35], were not taken into account in this study. As mentioned earlier, mobile phone is undoubtedly the most prevalent and representative electronic media in the current years [20, 36]. Nevertheless, further studies are warranted to investigate whether the use of alternative electronic media may reduce or eliminate the potential benefits of reduction in mobile phone use. Seventh, caution should be taken in the interpretation of the results in additional analyses, because the change of duration of mobile phone use in the current study was not experimentally manipulated. In this regard, the associations between the change of duration of mobile phone use and the incidence or persistence of sleep disturbances and mental distress may not necessarily be causal relationship. Finally, it should be noted that the cross-lagged analysis will not work well with highly inconsistent variables over time or a mismatch between the interval of reassessment and the latent interval of causality [60]. Nonetheless, it remains a valuable technique to make inferences about causality between variables in longitudinal, nonexperimental studies [61]. Besides, although there were significant cross-lagged relationships between various variables in the current study, the standardized β coefficients of these relationships were relatively small, which denotes that the strengths of associations were not very strong. However, this does not change the fact that there were significant relationships between them.

Conclusions

LTMPU predicts the new incidences of most of the sleep disturbances and mental distress, while discontinuation of LTMPU is associated with amelioration of these problems. Moreover, there are bidirectional associations between the duration of mobile phone use and various outcomes. These findings highlight the critical role of prevention and early recognition of both LTMPU and mental health and sleep problems.

Supplementary material

Supplementary material is available at *SLEEP* online.

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Conflict of interest statement. None declared.

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