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# Sleep quality as a mediator of problematic smartphone use and clinical health symptoms

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*Background and aims:* Although smartphone use brings many benefits for adolescents, it is also associated with many serious health problems. This study examined the relationship between problematic smartphone use (PSU) and clinical health symptoms (e.g., body dysfunction) and the mediating effects of sleep quality on this relationship in adolescents. *Methods:* Participants in this cross-sectional survey were 686 middle- and high-school students (girls = 55.7%, $M_{age} = 12.98 \pm 1.38$ years). Participants completed self-report measures of PSU, sleep quality, and physical symptoms. Correlation analyses and structural equation modeling between adolescents' PSU and the variables of interest were conducted. *Results:* This study indicated that there was a significant positive correlation between PSU and health symptoms. Furthermore, sleep quality mediated the relationship between PSU and health symptoms. *Discussion and conclusions:* Findings suggest that to promote health and wellness in adolescents, individuals should be encouraged to place boundaries on smartphone use, especially at bedtime. Reducing adolescents' exposure to smartphone use in this way may hold promise for improving the efficacy of PSU prevention efforts for adolescents.

**Keywords:** problematic smartphone use, sleep quality, clinical health symptoms, adolescents

## INTRODUCTION

A recent survey revealed that an estimated 200 million adolescents in China are smartphone users (China Internet and Information Center, 2015). Smartphones have already become a necessity in the lives of adolescents and create a new and complex virtual context in which youth interact and socialize. Smartphones readily facilitate activities such as online social networking and online gaming. However, problematic smartphone use (PSU) may contribute to the development of health problems, such as depression (Choi, Lee, & Ha, 2012) and daytime fatigue (Kim, Ahn, Jeon, & Lee, 2012), and also negatively impact upon academic performance (Liu, Kirschner, & Karpinski, 2017). As a critical period encompassed by alterations in physical and psychological development (Schulenberg, Maggs, & Hurrelmann, 1997), adolescence may increase the likelihood of experiencing health hazards. Relatively immature levels of self-regulation make adolescence a time of vulnerability and may lead to a higher likelihood of smartphone addiction and the development of other disorders among adolescents (Bianchi & Phillips, 2005).

Despite the prevalence of problems associated with smartphone use, relatively few studies have examined the adverse health effects of smartphone use specifically on adolescents (Strasburger, 2009). Moreover, little attention has been given to the potential mechanisms through which smartphone use affects adolescent health, as prior studies have only focused on the direct relationship between smartphone use and adolescent health issues (Demirci, Akgönül, & Akpinar, 2015). Drawing on recent studies (Li, Lepp, & Barkley, 2015; Wang, Wang, Gaskin, Wang, 2015) and recurring public concerns, we seek to explore whether PSU may be related to physical and mental health symptoms among Chinese adolescents.

### *The relationship between PSU and physical health symptoms*

PSU may directly lead to various health symptoms. For example, it has been found that smartphone screens are much more harmful than computer and television screens to eyes and can lead to dry eye syndrome for school children (Moon, Lee, & Moon, 2014). Ko, Kim, and Woo (2013) found that texting on a smartphone may increase the risk of fatigue in the upper trapezius muscles and cause cumulative

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trauma disorders. PSU may be characteristic of a sedentary lifestyle, and thus adolescents with PSU may be more likely to suffer from physical symptoms, such as lack of physical energy, physiological dysfunction, and weakened immunity (Cao, Sun, Wan, Hao, & Tao, 2011). Based on previous studies, we hypothesized that PSU would positively correlate with physical health symptoms (H1).

### *The relationship between poor sleep quality and physical health symptoms*

Sleep is essential not only for work but also for living (Duran, Matter, Bravo, Moreno, & Reyes, 2014; Galambos, Vargas Lascano, Howard, & Maggs, 2013; Magnavita & Garbarino, 2017). Studies have revealed that poor sleep quality is associated with both poor mental and physical health. In terms of mental health, previous studies provide evidence that poor sleep quality is correlated with depressive symptoms (Park et al., 2010) and poor connection with school (Bao et al., 2018). Park et al. (2010) found that adolescents with poor sleep quality reported high levels of alcohol-use disorder and obsessive–compulsive disorder. Besides mental health aspects, individuals lacking good or sufficient sleep often experience negative feelings about physical fitness. Increasingly, studies are finding that poor quality of sleep is associated with impaired daytime functioning (e.g., Cain & Gradisar, 2010; Léger et al., 2010), weaker immune system (increased susceptibility to colds, fever, and other illnesses, e.g., Graham & Streitel, 2010; Lashley, 2003; Prather, Puterman, Eple, & Dhabhar, 2014), body fatigue (e.g., Dinges et al., 1997; Nagane, Suge, & Watanabe, 2016), and eye syndromes (e.g., Waller, Bendel, & Kaplan, 2008). For example, students with poor sleep often feel whole-body fatigue, lack motivation, and desire to rest (Nagane et al., 2016). Furthermore, sleep habits in adolescents are highly likely to be erratic, with a pronounced shift of bedtimes to later in the evening, resulting in sleep deprivation during the school week (Crowley, Acebo, & Carskadon, 2007; Perkinson-Gloor, Lemola, & Grob, 2013). Therefore, we hypothesized that reduced sleep quality would positively correlate with physical health symptoms (H2).

### *The relationship between PSU, poor sleep quality, and physical health symptoms*

There has been a particularly pronounced increase in the use of smartphones in adolescents. The availability of smartphones and the potential to use these in late evening and at bedtime may profoundly change adolescents' sleep patterns. All communication channels are available through a single smartphone now. Calling and texting are available through smarthphones, instant messaging, and social network site. With access to Wi-Fi, smartphones allow peers to communicate through multiple channels after school, regardless of location in the home and including the bedroom. Furthermore, smartphones are comfortable to use while lying in bed to surf the Internet, to play games, or to watch online videos as they are lighter than iPads or other tablets. Thus, smartphones are particularly practical to use when lying in bed or at rest. However, prolonged use of a smartphone can compete with and disturb sleep, resulting in a trend toward insufficient sleep and a downgrade in sleep quality (Lanaj, Johnson, & Barnes, 2014). Recent evidence suggests that smartphone use during adolescence is related to later bedtimes, shorter sleep duration, and increased sleep disturbance (Lemola, Perkinson-Gloor, Brand, Dewald-Kaufmann, & Grob, 2015). In addition to the direct displacement of sleep, presleep smartphone use may also increase cognitive, emotional, and physiological arousal, thereby increasing sleep onset latency and reducing total sleep time (Ivarsson, Anderson, Åkerstedt, & Lindblad, 2009). Finally, smartphone backlights may have a disruptive effect on circadian rhythms with associated sleep consequences, such as sleeping later than intended and thus reducing overall sleep time (Li et al., 2007). Thus, we predicted that poor sleep quality would mediate the relationship between adolescents' addictive smartphone use and health outcomes. In other words, we hypothesized that the more the adolescents were addicted to a smartphone, the weaker their sleep quality, which in turn, would further increase their daytime fatigue, body dysfunction, and eye problems, and simultaneously lower their immunity to fight diseases. Hence, we predicted that poor sleep quality would mediate the relation between PSU and physical health symptoms (H3).

### *The present study*

Despite the prevalence of smartphone use and the negative impact on well-being associated with smartphone addiction, few studies to date have investigated the link between PSU and physical health problems (Berolo, Wells, & Amick, 2011). This study aimed to examine PSU and its associations with sleep quality, body dysfunction, eye symptoms, and fatigue. We used structural equation modeling to determine whether sleep quality mediated the relationship between PSU and health symptoms in a Chinese adolescent population.

## METHODS

### *Participants and procedure*

This cross-sectional survey was conducted in Shanghai in December 2015 among 11- to 17-year-old middle- and high-school adolescents. Students from one middle school ($N = 326$, $M_{age} = 12.98$ years, $SD = 0.89$) and one high school ($N = 562$, $M_{age} = 15.67$ years, $SD = 0.64$) were recruited. A total of 686 participants (77% smartphone users, $M_{age} = 14.76$ years, $SD = 1.38$, females = 55.7%) reported carrying and regularly using a smartphone and participated into this study.

Data collection took place in classrooms. Trained researchers supported the participants in taking part in the survey. After signing the consent form, adolescents were invited to fill in the pencil-and-paper questionnaires. All the participants were thanked and debriefed at the end.

### *Measures*

*Problematic smartphone use.* Problematic use of smartphone was assessed by a 33-item Chinese inventory, which was adapted from the Smartphone Addiction Inventory (Lin et al., 2014) and the Mobile Phone Addiction Inventory

(Huang, Wang, Qian, Zhong, & Tao, 2007). Four subdimensions of PSU were identified by confirmatory factor analysis: overuse (14 items), withdrawal (9 items), compulsive behavior (7 items), and disturbances (3 items). An example question is "I feel distressed or down once I cease using a smartphone for a certain period of time." The respondents were asked to report how often they experienced obsession, dysfunction, or problems such as phantom vibrations and ringing related to the use of smartphone, on a 4-point Likert scale (1 = *never* to 4 = *always*). This inventory had good structural validity, $\chi^2(489) = 1403.47$, $p < .001$, comparative fit index (CFI) = 0.97, Tucker–Lewis index (TLI) = 0.97, root mean square error of approximation (RMSEA) [90% CI] = 0.05 [0.05, 0.06]. Nearly all item loadings were above 0.60. All four dimensions had satisfactory reliability, $\alpha = .86$, .88, .81, and .77.

*Sleep quality.* Sleep quality was measured by eight items adapted from the Pittsburgh Sleep Quality Index (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). It consists of six items relating to several domains of sleep patterns in the preceding 1-month period. The components refer to domains, such as subjective sleep quality, sleep duration, sleep latency, and sleep disturbances. Respondents were asked to report how often they experienced sleep problems, such as "difficult to sleep within 30 minutes" on a 4-point Likert scale (1 = *not during the past month* to 4 = *frequently*). The scale has high reliability, $\alpha = .80$.

*Physical Symptom Inventory.* Physical symptoms items were selected from Cornell Medical Index (Brodman, Erdmann, & Wolff, 1949) and the Multidimensional Sub-Health Questionnaire of Adolescents (Tao, Hu, Sun, & Hao, 2008). The measure is a multidimensional inventory that consists of 26 items in total. Four symptoms were included: eye syndromes (three items, e.g., "dry eyes," $\alpha = .76$), body fatigue (six items, e.g., "sleepy in class," $\alpha = .82$), physiological dysfunction (eight items, e.g., "waist, shoulders, and neck pain," $\alpha = .87$), and weakened immunity (four items, e.g., "sore throat and colds," $\alpha = .81$). Participants rated all items on a 4-point Likert scale (1 = *not during the past month* to 4 = *frequently*).

### *Data analysis*

Descriptive analyses were conducted using means and standard deviations. Correlation analyses and structural equation modeling were conducted to examine unadjusted relationships between the outcome variable (i.e., adolescent PSU) and variables of interest, such as demographics and smartphone usage of adolescents. Data were analyzed using IBM SPSS Statistics (version 23, Chicago, IL, USA) software. To test the mediation effect of sleep quality, we used Mplus 7.0 (Muthén & Muthén, 1998–2012).

### *Ethics*

Institute ethics approval was granted by the university's institutional review board. After the permissions were obtained from schools, students who were eligible to participate were invited to complete the questionnaire. This questionnaire was accompanied by a letter explaining the objectives of the project and instructions for completing the questionnaire.

## RESULTS

### *Descriptive statistics*

The results showed that adolescents spent $1.24 \pm 1.68$ hr per day using smartphones. In the analyses examining associations between PSU and physical symptoms, the four dimensions of PSU predicted higher levels of daytime fatigue, eye syndromes, body dysfunctions, and lower immunity and sleep quality. Here, the average score of the four dimensions was used. The results also showed significant associations between smartphone use (time) and health symptoms, but the strength of the links was notably lower (Table 1).

### *Mediation analyses*

A focal question in this study was whether PSU influenced students' health by adversely affecting their sleep. This hypothesis was modeled and tested by setting direct paths from PSU to sleep quality, and health symptoms, as well as a mediation pathway through sleep quality to the health symptoms (Figure 1). It should be noted that latent variables were created for the four dimensions of PSU (withdrawal, overuse, compulsive behavior, and disturbances) to filter out measurement errors, while physical health symptoms and sleep quality were considered as manifest variables and the mean scores were used. To better account for the categorical, ordinal nature of the PSU indicators, we used weighted least squares with adjusted mean and variance estimation within Mplus 7.0 (Li, 2015). Standardized estimates of the model path were reported in Figure 1. The data fitted the final model very well, $\chi^2(652) = 1{,}604.68$, $p < .05$, CFI = 0.97, TLI = 0.96, RMSEA [90% CI] = 0.05 [0.04–0.05].

A bias-corrected bootstrap confidence interval for the indirect effect is presented in Table 2. The results indicated significant indirect paths, such that participants with higher PSU scores experienced poorer sleep, which in turn predicted stronger symptoms of weakened immune systems, daytime fatigue, body dysfunction, and eye discomfort. It is important to note that sleep quality fully mediated the association between PSU and immune symptoms. The indirect model explained 43.90%, 34.62%, 33.96%, and all variance of the total effect of PSU on eye symptoms, body dysfunction, daytime fatigue, and immunity symptoms, respectively.

## DISCUSSION

### *Practical and theoretical implications*

The results demonstrated that there were strong relations between smartphone overuse and physical health problems. Physical symptoms in adolescence might be important signs of physical illnesses, and these should be taken seriously by parents and school health staff. Teenagers tend to use smartphones as a medium for socializing, but overuse can result in spending increasing amounts of time on online activities, leading to eye difficulties, spinal disorders, wrist pain, poor sleep quality, lack of physical energy, attentional

*Table 1*. Mean, standard deviation, and zero-order correlations of variables ($N = 686$)

| | *M* | *SD* | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Eye symptoms | 1.95 | 0.76 | 1.00 | | | | | | | | | | | |
| 2. Daytime fatigue | 1.82 | 0.60 | 0.67** | 1.00 | | | | | | | | | | |
| 3. Body dysfunction | 1.90 | 0.62 | 0.65** | 0.77** | 1.00 | | | | | | | | | |
| 4. Sleep quality | 1.64 | 0.56 | 0.50** | 0.55** | 0.55** | 1.00 | | | | | | | | |
| 5. Immune problems | 1.92 | 0.70 | 0.49** | 0.54** | 0.60** | 0.46** | 1.00 | | | | | | | |
| 6. Age | 14.76 | 1.38 | 0.17** | 0.19** | 0.15** | 0.10* | 0.01 | 1.00 | | | | | | |
| 7. Gender | 1.56 | 0.50 | 0.09* | 0.18** | 0.13** | −0.04 | 0.06 | −0.01 | 1.00 | | | | | |
| 8. Use time | 1.68 | 2.34 | 0.08* | 0.10* | 0.10** | 0.13** | 0.04 | 0.01 | −0.03 | 1.00 | | | | |
| 9. Overuse | 1.85 | 0.53 | 0.34** | 0.46** | 0.44** | 0.23** | 0.24** | 0.13** | 0.07 | 0.17** | 1.00 | | | |
| 10. Withdraw | 1.66 | 0.55 | 0.36** | 0.46** | 0.44** | 0.31** | 0.23** | 0.09* | 0.05 | 0.18** | 0.71** | 1.00 | | |
| 11. Compulsive | 1.64 | 0.54 | 0.29** | 0.36** | 0.41** | 0.32** | 0.23** | 0.07 | 0.00 | 0.21** | 0.62** | 0.73** | 1.00 | |
| 12. Disturbance | 1.28 | 0.43 | 0.19** | 0.28** | 0.28** | 0.25** | 0.17** | 0.12** | 0.03 | 0.03 | 0.38** | 0.43** | 0.47** | 1.00 |

*Note*. PSU refers to problematic smartphone use.
*$p < .05$. **$p < .01$ (two-tailed).

distraction, and immune disorders. The adverse effects of PSU are chronic and progressive, becoming apparent only after months or years, but eventually causing severe health problems. For example, looking down at a smartphone screen to play games, or update Facebook, leads to incrementally increased stresses on the cervical spine (Hansraj, 2014). Moreover, continually stressing the spine may lead to neck pain associated with spine difficulties. Another example is that late night use of a smartphone can cause sleep deprivation and daytime fatigue, which can adversely affect the immune system. Furthermore, smartphone use in darkness is particularly harmful to the eyes. The blue–violet light emitted by smartphones is extremely bright when other lights are off and could have a toxic effect behind the eyes, leading to macular degeneration and eye symptoms (Smick, 2014). As such, PSU may cause chronic problems for adolescents.

The SEM analysis substantiated the hypothesized mediating role of sleep. For adolescents, PSU negatively correlated with physical health, and sleep quality mediated this relation. Establishing healthy sleep routines and controlling smartphone use before and at bedtime are important to facilitate adequate quality sleep and a healthy life.

The present findings may have practical implications for professionals working with clients with PSU. Specifically, these new findings demonstrate that strengthening sleeping quality through reducing PSU before bed may foster physical health and increase immune power among this group of clients. Later bedtimes, shorter sleep duration, and more prolonged sleep latency caused by PSU may lead to chronic health problems in adolescents. Clinicians should be aware of PSU as one potential cause of poor sleep quality when they are designing interventions and care plans for this group. Promoting better sleep routines by minimizing sleep disturbances from PSU could improve body function and school vitality for adolescents.

### *Limitations and directions for future research*

First, all data collected were self-report, increasing the likelihood of self-report bias. Future studies may use clinical records and sleep diaries to enhance the study validity. Second, the study sample was relatively homogenous (mainly from Shanghai), which limits the generalizability of our findings. Third, most of the variables examined in this study (eye symptoms, body dysfunction, immunity, and fatigue) are physical outcomes and future research may explore the relationship between PSU and mental health symptoms in more depth. Finally, factors such as parental control may moderate the relationship between PSU, sleep quality, and health symptoms, and future research could examine this.

## CONCLUSIONS

In conclusion, although preliminary, our research suggests that PSU is harmful to both mental and physical health. It also emphasizes the importance of sleep quality in

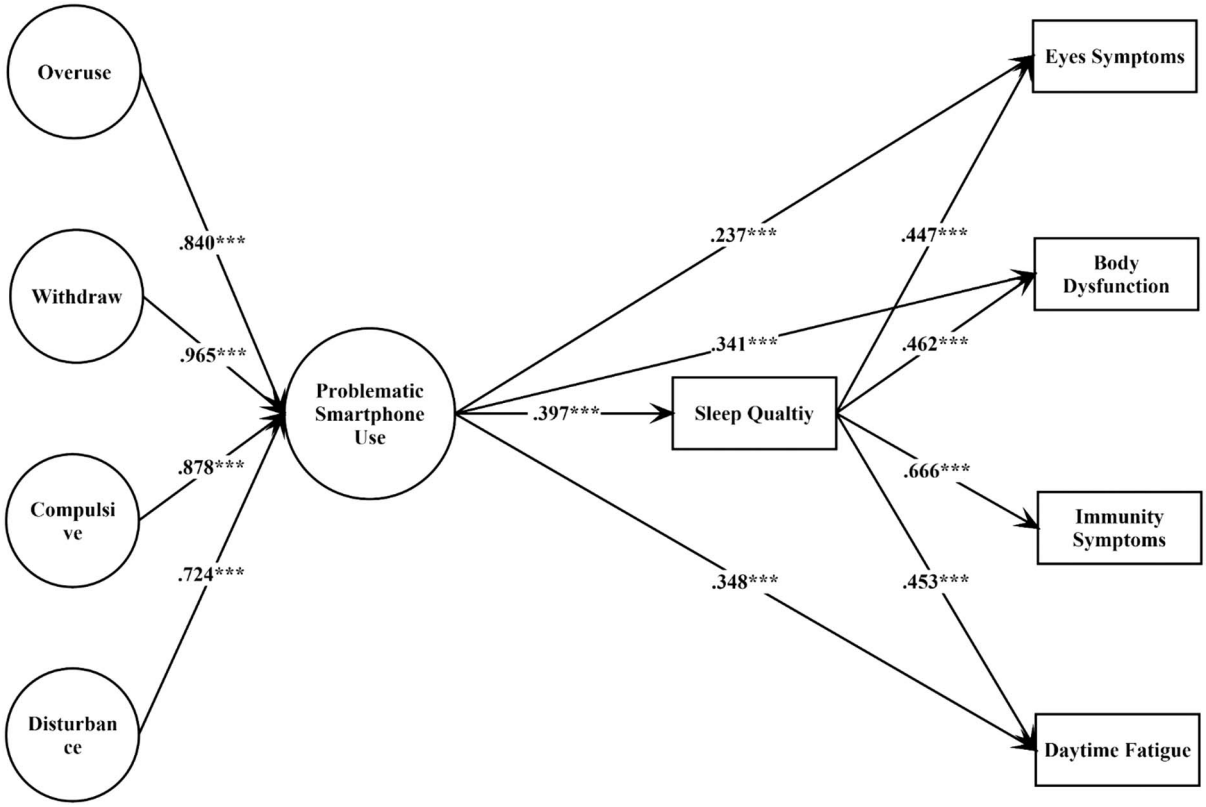


*Figure 1*. Sleep quality as a mediator between problematic smartphone use and health symptoms

*Table 2*. Indirect, direct, and total effects of PSU on clinical health symptoms

| Dependent variable | Indirect effect | Boot *SE* | Boot CI | Direct effect | Total effect | Total effect by indirect (%) |
|---|---|---|---|---|---|---|
| Eye symptoms | 0.18*** | 0.02 | 0.14–0.22 | 0.24*** | 0.41*** | 43.90 |
| Body dysfunction | 0.18*** | 0.03 | 0.12–0.24 | 0.34*** | 0.52*** | 34.62 |
| Immunity symptoms | 0.26*** | 0.04 | 0.18–0.34 | – | 0.26*** | 100 |
| Daytime fatigue | 0.18*** | 0.03 | 0.12–0.24 | 0.35*** | 0.53*** | 33.96 |

*Note*. Total effect by indirect refers to the proportion of indirect effect in total effect. *SE*: standardized error; CI: confidence interval. ***$p < .001$ (two-tailed).

mediating the effect of PSU on health symptoms in adolescents. This knowledge is vital for primary school healthcare staff, ophthalmologists, and psychiatrists, so that underlying physical and/or mental problems can be detected and prevented early.

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*Conflict of interest:* There is no conflict of interest and financial conflictions in this study.

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