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Bidirectional association between problematic smartphone use and aggressive behavior: A cross-lagged longitudinal study

FAJUAN RONG, JUNHAN CHENG, JIE HU, YAN WANG, ZIXUAN XU, MEIQI GUAN, NAN ZHANG and YIZHEN YU*

Department of Maternal, Child and Adolescent Health, School of Public Health, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China

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FULL-LENGTH REPORT

ABSTRACT

Background and aims: Problematic smartphone use are prevalent worldwide, particularly among adolescents, and it is strongly linked with aggressive behavior. However, the understanding of how PSU may contribute to the emergence of aggressive behavior remains incomplete. *Methods:* The purpose of this study was to examine the bidirectional links between aggressive behavior and PSU among adolescents, utilizing data from a two-wave longitudinal study (the time interval is 15 months) conducted among 2,650 students in middle and high school. *Results:* The cross-lagged models revealed that: (1) PSU at Time 1 (December 12) positively predicted aggressive behavior at Time 2 (March 2023, 15 months apart) among older adolescents (15–19 years), but this was not the case for younger adolescents (11–14 years); (2) aggressive behavior at Time 1 positively predicted PSU at Time 2 for both younger and older adolescents. Our findings have identified PSU as a risk factor for aggressive behavior among older adolescents, with those perceiving higher PSU may be particularly vulnerable to developing aggressive behavior over time. *Discussion and Conclusions:* These results not only enhance our understanding of the links between PSU and aggressive behavior but also provide significant theoretical perspectives for developing future prevention strategies and intervention measures to tackle aggressive behavior among adolescents.

KEYWORDS

problematic smartphone use, aggressive behavior, younger and older adolescents, cross-lagged analysis

INTRODUCTION

With the widespread use of smartphones, the potential problems associated with their use have become a significant research focus. Problematic smartphone use (PSU) is a concept that emphasizes the uncontrolled excessive use of smartphones, resulting in psychological, physical problems as well as impaired interpersonal and social functioning (Busch & McCarthy, 2021; Horwood & Anglim, 2018; Lai et al., 2022). PSU has been linked to a range of consequences, including anxiety and depressive symptoms, sleep disturbances, headaches, gastrointestinal and musculoskeletal problems (Paterna et al., 2024; Yang, Fu, Liao, & Li, 2020). Furthermore, PSU increases the risk of traffic and pedestrian accidents (Rosenthal, Li, Wensley, Perez, & Gately, 2022), decreases academic and job achievement (Paterna et al., 2024), and can result in addiction-related distress, and functional impairment. It also manifests in non-addiction symptoms, such as escapism-driven aggression or aggressive behavior (Deng, Li, & Xiang, 2024; Fekih-Romdhane, Malaeb, Sarray El Dine, Obeid, & Hallit, 2022; Panova & Carbonell, 2018; Zou et al., 2017).

Although PSU is sometimes conflated with smartphone addiction (SA) in literature, these concepts are distinct, SA refers to excessive and psychosocially dysfunctional smartphone use

*Corresponding author.
E-mail: yuyizhen650@163.com

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and is considered a behavioral addiction, yet it has not been included in the DSM-5 and ICD-11, such as internet gaming disorder (Montag, Wegmann, Sariyska, Demetrovics, & Brand, 2021). The classification of PSU as a behavioral addiction remains controversial due to insufficient evidence for defining addiction characteristics, such as loss of control, tolerance symptoms, and withdrawal behaviors (Billieux, Maurage, Lopez-Fernandez, Kuss, & Griffiths, 2015; Panova & Carbonell, 2018). Additionally, compared to established behavioral addictions, there is a notable lack of etiological research into the neurobiological and psychological mechanisms underlying PSU (Billieux et al., 2015).

PSU is a growing behavioral issue worldwide, particularly among adolescents, with prevalence rate ranging from 14.0% to 31.2% (Olson et al., 2022; Sohn, Rees, Wildridge, Kalk, & Carter, 2019). Adolescence, a phase characterized by substantial social, physical, and psychological changes, is also a critical period for addiction vulnerability (Chambers, Taylor, & Potenza, 2003; Kim et al., 2019). Studies indicate that younger individuals exhibit more pronounced association with PSU symptom severity compared with older age groups (Nahas, Hlais, Saberian, & Antoun, 2018). Especially for adolescents aged 14–20, who tend to spend the most time on smartphones, may be more susceptible to the effects of PSU (Beranuy, Oberst, Carbonell, & Chamarro, 2009). Moreover, PSU can lead to a series of psychological or health problems in adolescents, as well as maladaptive behaviors, such as aggressive behavior (Rozgonjuk et al., 2023; Sohn et al., 2019).

This present study aims to explore the direction of associations between adolescent PSU and aggressive behavior. Aggressive behavior is defined as a series of behaviors aimed at causing direct harm to others (Anderson & Bushman, 2002). Research indicates that aggressive behavior tends to decrease upon entering adolescence, but notably, children exhibiting high aggression continue to experience an increase in their aggressive tendencies in adolescence (Cleverley, Szatmari, Vaillancourt, Boyle, & Lipman, 2012; Ehrenreich, Beron, Brinkley, & Underwood, 2014; Xie, Drabick, & Chen, 2011), and that more severe aggressive behavior tends to occur during adolescence (Liu, Lewis, & Evans, 2013). Aggressive behavior severely impedes the development of adolescents, causing serious clinical and social issues like school violence and criminal conduct (Fekih-Romdhane et al., 2022; Juvonen & Graham, 2014). In addition, it can adversely affect interpersonal relationships and trigger mental health issues, including depression, anxiety, and even suicide (Joseph, Mela, & Pei, 2022).

Empirical studies have provided evidence of a strong correlation between PSU and aggressive behavior. For instance, PSU has been correlated with the increased risk of aggressive behavior and is linked with multiple aspects of aggression, including heightened physical and verbal aggression, anger, and hostility (Fekih-Romdhane et al., 2022; Lee et al., 2018). A study involving Korean middle school students suggested that PSU was associated with aggression and worse psychosocial outcomes (Lee et al., 2018). Similarly, among young Swiss, PSU was also significantly linked with aggression and hostility (Dey et al., 2019). Studies indicate a higher tendency towards aggressive behavior in individuals with PSU (Zarei, 2021). The theoretical basis of the association between PSU and aggression is based on models suggesting that experiences of PSU can influence aggressive behavior via cognitions and emotions related to aggression (Anderson & Bushman, 2002; Denson, DeWall, & Finkel, 2012). One of the primary theories is the general aggression model (GAM), which suggests that certain input variables (like individual traits and environment factors) can influence an individual's present internal state (such as cognition, emotion, and arousal), thereby affecting their decision-making process and behavioral outcomes (Allen, Anderson, & Bushman, 2018; Anderson & Bushman, 2002). GAM proposes that PSU, as an environmental factor, could stimulate aggressive thoughts and beliefs, thereby increasing the likelihood of aggressive behavior (Gentile, Coyne, & Walsh, 2011). For example, PSU could lead to stress and frustration, which in turn could trigger aggressive behavior. However, owing to the cross-sectional nature of previous studies, it's unable to establish the direction between PSU and aggressive behavior. Furthermore, most studies have not been able to exclude the possibility that adolescents exhibiting higher levels of aggression might prefer to use their smartphones more often. Due to the mood management properties, the negative experience of aggressive behavior may lead adolescents to excessive smartphone use, while frequent avoidance may ultimately lead to problematic use (Li et al., 2019). One exception is that Karaoglan and colleagues provide evidence that aggressive behavior could have an influence on PSU tendency (Karaoglan Yilmaz, Avci, & Yilmaz, 2022). Hence, it's essential to investigate this relationship with repeated independent samples for the benefit of public health interventions.

In addition, males and females are likely to exhibit significant differences in PSU and aggressive behavior (Augner & Hacker, 2012; Björkqvist, 2018; Mok et al., 2014). Previous research has shown that females tend to use their smartphone more for social and interactive purposes, while males are more inclined towards voice conversations and gaming applications (De-Sola Gutiérrez, Rodríguez de Fonseca, & Rubio, 2016). Moreover, there are sex disparities in PSU. Studies propose that females are inclined to spend more time on smartphone, thereby exhibiting a higher likelihood of PSU (Augner & Hacker, 2012; Lee, Chang, Lin, & Cheng, 2014; Mok et al., 2014). Sex differences in aggressive behavior appear consistently, with males engaging in more physical aggression, while females engage in much more verbal and indirect aggression (Björkqvist, 2018; Hyde, 2014). Thus, it is crucial to determine if the association between PSU and aggressive behavior is consistent across both sexes.

Previous studies indicate a significant but complex link between PSU and aggressive behavior. There is still much to learn about how their relationship changes over time, considering the bidirectional dynamics. The present study aims to explore the direction of relationships between PSU

and aggressive behavior in a sample of Chinese adolescents. Based on the empirical evidence and the GAM, we propose hypotheses as follows:

H1: PSU positively predicts subsequent aggressive behavior.

H2: Patterns of associations between PSU and aggressive behavior differ across sexes, with a prediction of stronger association for females.

METHODS

Participants

Participants were recruited from middle and high schools in Hubei, China, using cluster sampling. First, two regions (Ezhou and Xiaogan) were randomly selected. In each region, two junior and two senior schools were randomly selected. Then, we randomly select 4 to 6 classes from 7 grade (junior high schools) and 10 grade (senior high schools). All students in randomly selected classes were invited to participate in the study (3,419 students in total). Prior to participation, informed consent was obtained from the parents or legal guardians of each student.

A total of 3,329 and 2,713 anonymous questionnaires were collected at December 2021 (Time 1) and March 2023 (Time 2), with a follow-up -interval of 15 months. Among the 3,329 students who completed the questionnaire at Time 1, we excluded 53 students due to incomplete information on PSU and aggressive behavior. At Time 2, 2,713 students completed the follow-up study and 10 students were excluded due to the missing information about PSU and aggressive behavior. The response rate of students was 97.37% (3,329/3,419 = 97.37%) and the follow-up rate was 81.50% (2,713/3,329 = 81.50%). The primary reasons for dropouts included transfer to another school, be absent from school, and not interested in the research topic. Finally, we included 3,276 students (14.68 ± 1.57 years old; 54.2% were males, 45.8% were females) at Time 1 and 2,650 students (14.64 ± 1.53; 52.5% were females, 47.5% were males) at Time 2. Based on the aims of this study, PSU and aggression information was obtained at two-time points, and ultimately, 2,650 students were included in the final analysis.

Measures

Problematic smartphone use. The revised mobile phone addiction index scale (MPAI) by (Leung, 2008) was employed to measure PSU. The MPAI has 17 items (e.g., "time and energy expended on smartphone directly result in decreased productivity"). MPAI adopted a five-point Likert scale as follows: 1 = "never", 2 = "occasionally", 3 = "sometimes", 4 = "often", 5 = "always". Higher scores indicate greater problematic smartphone use. MPAI demonstrated reliability and validity among Chinese adolescents (Liu et al., 2017). The coefficient alpha of MPAI was 0.918 and 0.916 at Time 1 and Time 2, respectively.

Aggressive behavior. In this study, aggressive behavior in adolescents was assessed using the Chinese version of the Aggression Questionnaire by Buss and Warren (BWAQ) (Maxwell, 2008). The aggressive behavior level was assessed by the five-point Likert scale: 1 = "not at all like me", 2 = "somewhat like me", 3 = "to a certain extent, like me", 4 = "very much like me", 5 = "almost the same as me". The higher the BWAQ score, the more severe the aggressive behavior. The scale's Cronbach alpha values were 0.899 and 0.907 at Time 1 and Time 2, respectively.

Covariates. Sociodemographic variables, including age, sex (male or female), family type (nuclear family, single-parent family, blended family, skip-generation family, and other), only child (yes or no), father's and mother's education level (primary school and below, middle school, high school, university, and master and above), and family income (–8,000, 6,000–7,999, 4,000–5,999, 2,000–3,999, 1,000–1,999, and –999).

Procedures. The study's procedures, conducted in line with the 1964 Helsinki Declaration, received approval from the Ethic Committee of Huazhong University of Science and Technology, Tongji Medical College (2021-A216). Data for this study were collected through random cluster sampling. Participants were briefly informed by well-trained investigators on the aspects of anonymity and confidentiality, the option to participate willingly, and the freedom to withdraw at any moment. All students participated in this study voluntarily and did not receive any monetary or material compensation. This study received approval from the school and written informed consent from parents and students.

Analysis strategy. Statistical analyses were conducted using SPSS 26.0 and Mplus 8.3. This study aimed to investigate if there is a temporal pattern linking adolescent PSU with aggressive behavior and to determine if these associations are consistent across both sexes. Considering the wide age range of adolescents in this study (11–18 years old), they were divided into 11–14 years old (younger adolescents) and 15–18 years old (old adolescents) based on their age, which may enhance our understanding of the behavioral and psychological characteristics of adolescents across different age group. Descriptive statistics (mean ± SD) were performed to analyze the distribution of PSU and aggressive behaviors. We employed paired sample *t*-tests to investigate the score differences for PSU and aggressive behavior at Time 1 and Time 2. The relationship between PSU and aggressive behavior was evaluated using Pearson correlation coefficients. Structural equation modeling, performed with Mplus 8.3, was utilized to evaluate the link between PSU and aggressive behavior. A cross-lagged panel model (CLPM) was constructed to simultaneously examine the possible bidirectional effects between PSU and aggressive behavior. The model incorporated covariates such as family type, whether the child is an only child, education level of both parents and family income. The model's fit was assessed

using the root-mean-square error of approximation (RMSEA), comparative fit index (CFI), and Tucker-Lewis index (TLI). A model is deemed to fit well if the CFI and TLI exceed 0.95, and RMSEA is below 0.06 (RMSEA = 0 indicates a completed fit) (Hu & Bentler, 1999). To investigate sex differences in the relationship between PSU and aggressive behavior, we conducted a multi-group analysis by comparing cross-lagged models for each sex. Firstly, we performed unconstrained free estimation models for each group. Secondly, we constructed a structural weight equivalence model, assuming equal regression coefficients for each sex. The existence of sex differences was ascertained by comparing the statistics of these two models (Holmbeck, 1997). A path is deemed to be sex-invariant if it satisfies at least two of the following conditions: $\Delta\chi^2$ non-significant at $p < 0.05$, ΔCFI <0.01, and ΔRMSEA <0.015 (Cheung & Rensvold, 2002). Statistical significance was determined by a p-value less than 0.05 (two-tailed).

Ethics

The study procedures were carried out under the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration. We followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines. The study was approved by the Medical Ethics Committee of Tongji Medical College, Huazhong University of Science and Technology (No. 2021-A216).

RESULTS

Descriptive statistics and correlations

Table 1 separately presents the descriptive statistics for both males and females. For younger adolescents, females reported significantly higher aggressive behavior scores at both Time 1 and Time 2. For older adolescents, females reported significantly higher aggressive behavior scores at Time 1; however, there is no significant difference in aggressive behavior scores between males and females at Time 2. Females also reported higher PSU scores than males at Time 1 for younger adolescents. However, males and females did not differ in PSU scores at Time 2 for younger adolescents and Time 1 and Time 2 for older adolescents. Table 2 shows the Pearson correlation coefficients for the variables, separately for males and females. Aggressive behavior was significantly positively associated with PSU. Additionally, we used paired sample t-tests to examine the differences in scores for aggressive behavior and PSU in Time 1 and Time 2 for younger and older adolescents. The results show that for both younger and older adolescents, these differences are statistically significant ($ps < 0.001$) (Table 3).

Table 1. Descriptive statistics for study variables stratified by sex ($N = 2{,}650$)

	Males [mean (SD)]	Females [mean (SD)]	p-value
Younger			
Aggression (T1)	62.7 (18.0)	69.1 (18.0)	<0.001
Aggression (T2)	66.3 (19.5)	72.3 (18.4)	<0.001
PSU (T1)	29.9 (12.7)	32.3 (13.5)	0.003
PSU (T2)	32.6 (13.6)	32.5 (12.1)	0.925
Older			
Aggression (T1)	70.7 (17.2)	72.7 (17.2)	0.029
Aggression (T2)	70.0 (18.9)	71.6 (17.5)	0.088
PSU (T1)	49.9 (12.1)	41.1 (13.6)	0.076
PSU (T2)	36.1 (12.4)	37.1 (13.1)	0.157

Longitudinal models using CLPM

Figure 1 presents the CLPM results for the relationship between PSU and aggressive behavior among younger

Table 2. Paired sample t-tests stratified by sex in PSU and aggressive behavior between Time 1 and Time 2

	Males		Females	
	t	p	t	p
Younger adolescents				
Aggression (T1)				
Aggression (T2)	−5.095	<0.001	−4.333	<0.001
PSU (T1)				
PSU (T2)	−5.016	<0.001	−0.435	<0.001
Older adolescents				
Aggression (T1)				
Aggression (T2)	1.120	<0.001	1.850	<0.001
PSU (T1)				
PSU (T2)	8.690	<0.001	9.362	<0.001

Table 3. Correlations between PSU and aggression stratified by sex

	1	2	3	4
Younger adolescents				
Males				
1. Aggression (T1)	1	0.58**	0.57**	0.44**
2. Aggression (T2)		1	0.35**	0.55**
3. PSU (T1)			1	0.48**
4. PSU (T2)				1
Females				
1. Aggression (T1)	1	0.57**	0.58**	0.37**
2. Aggression (T2)		1	0.57**	0.58**
3. PSU (T1)			1	0.46**
4. PSU (T2)				1
Older adolescents				
Males				
1. Aggression (T1)	1	0.56**	0.50**	0.38**
2. Aggression (T2)		1	0.34**	0.55**
3. PSU (T1)			1	0.51**
4. PSU (T2)				1
Females				
1. Aggression (T1)	1	0.62**	0.54**	0.39**
2. Aggression (T2)		1	0.42**	0.56**
3. PSU (T1)			1	0.61**
4. PSU (T2)				1

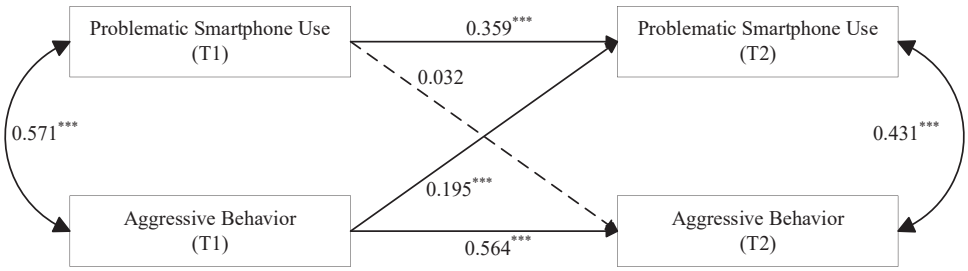

Fig. 1. Cross-lagged model of associations between problematic smartphone use and aggressive behavior among younger adolescents. The model was adjusted by family type, only child, father's and mother's education, and family income. *** $p < 0.001$

adolescents. The model fit demonstrated a fully saturated cross-lagged model (RMSEA = 0, CFI = 1, TLI = 1). The results revealed that PSU at Time 1 did not predict aggressive behavior at Time 2 ($\beta = 0.032$, $p > 0.05$), and aggressive behavior at Time 1 significantly predicted PSU at Time 2 ($\beta = 0.195$, $p < 0.001$). In addition, PSU at Time 1 significantly predicted PSU at Time 2 ($\beta = 0.359$, $p < 0.001$), and aggressive behavior at Time 1 significantly predicted aggressive behavior at Time 2 ($\beta = 0.564$, $p < 0.001$).

Figure 2 illustrates the cross-lagged analysis results between PSU and aggressive behavior among older adolescents. The model fit demonstrated a fully saturated cross-lagged model (RMSEA = 0, CFI = 1, TLI = 1). The results revealed that PSU at Time 1 significantly predicted aggressive behavior at Time 2 ($\beta = 0.099$, $p < 0.001$), and aggressive behavior at Time 1 significantly predicted PSU at Time 2 ($\beta = 0.133$, $p < 0.001$). In addition, PSU at Time 1 significantly predicted PSU at Time 2 ($\beta = 0.489$, $p < 0.001$), and aggressive behavior at Time 1 significantly predicted aggressive behavior at Time 2 ($\beta = 0.542$, $p < 0.001$).

Longitudinal models using multigroup CLPM

Multiple group analyses by sex were performed to investigate sex differences in CLPM. First, a freely estimated model that allowed for free estimation of all paths in both the male and female groups was constructed. Second, a path equivalence model, which assumed equal regression coefficients between sex groups as equivalent was constructed. Finally, the two models were compared. The findings revealed that in the cross-lagged models of PSU and aggressive behavior, there were no significant differences between younger and older adolescents based on sex (younger adolescents: $\Delta\chi^2 = 4.382$, $\Delta df = 4$, $p > 0.05$; older adolescents: $\Delta\chi^2 = 5.356$, $\Delta df = 4$, $p > 0.05$).

The model shown in Fig. 1 is relevant to younger male and female adolescents. The details of cross-lagged analysis between PSU and aggressive behavior for both sexes among younger adolescents are displayed in Fig. 3. For males, PSU at Time 1 did not predict aggressive behavior at Time 2 ($\beta = 0.030$, $p > 0.05$), aggressive behavior at Time 1 significant predicted PSU at Time 2 ($\beta = 0.247$, $p < 0.001$). PSU at Time 1 significantly predicted PSU at Time 2 ($\beta = 0.332$, $p < 0.001$), and aggressive behavior at Time 1 significantly predicted aggressive behavior at Time 2 ($\beta = 0.555$, $p < 0.001$). For females, PSU at Time 1 did not predict aggressive behavior at Time 2 ($\beta = 0.037$, $p > 0.05$), aggressive behavior at Time 1 significantly predicted PSU at Time 2 ($\beta = 0.146$, $p < 0.001$). PSU at Time 1 significantly predicted PSU at Time 2 ($\beta = 0.391$, $p < 0.001$), and aggressive behavior at Time 1 significantly predicted aggressive behavior at Time 2 ($\beta = 0.545$, $p < 0.001$).

The model shown in Fig. 2 applies to older male and female adolescents. The details of cross-lagged analysis between PSU and aggressive behavior for both sexes among older adolescents are displayed in Fig. 4. For males, PSU at Time 1 significantly predicted aggressive behavior at Time 2 ($\beta = 0.081$, $p < 0.05$), aggressive behavior at Time 1 significant predicted PSU at Time 2 ($\beta = 0.181$, $p < 0.001$). In addition, PSU at Time 1 significantly predicted PSU at Time 2 ($\beta = 0.416$, $p < 0.001$), and aggressive behavior at Time 1 significantly predicted aggressive behavior at Time 2 ($\beta = 0.524$, $p < 0.001$). For females, PSU at Time 1 significantly predicted aggressive behavior at Time 2 ($\beta = 0.117$, $p < 0.01$), and aggressive behavior at Time 1 significantly predicted PSU at Time 2 ($\beta = 0.081$, $p < 0.05$). In addition, PSU at Time 1 significantly

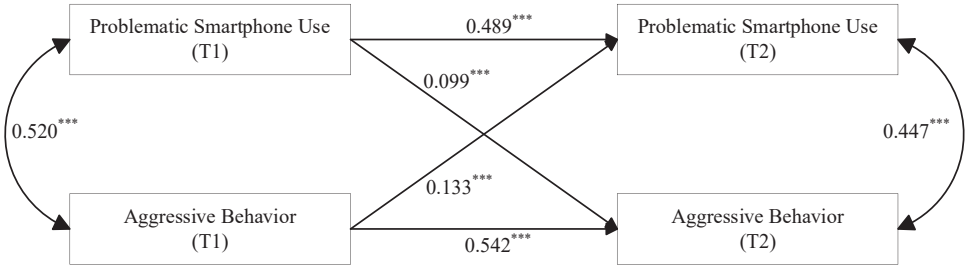

Fig. 2. Cross-lagged model of associations between problematic smartphone use and aggressive behavior among older adolescents. The model was adjusted by family type, only child, father's and mother's education, and family income. *** $p < 0.001$

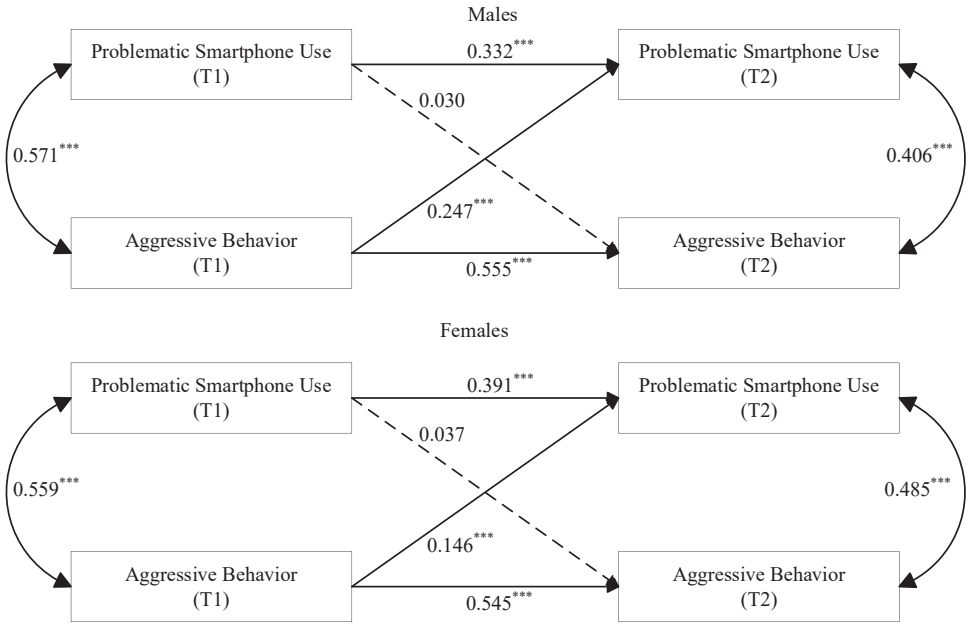

Fig. 3. Cross-lagged model of associations between problematic smartphone use and aggressive behavior for males and females among younger adolescents. Models were adjusted by family type, only child, father's and mother's education, and family income. $^{***}p < 0.001$

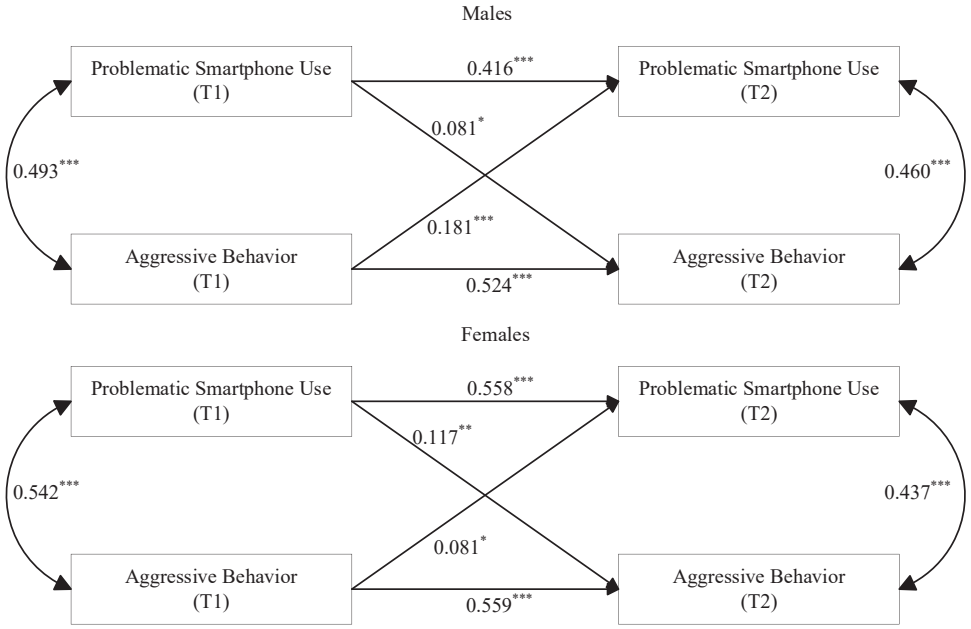

Fig. 4. Cross-lagged model of associations between problematic smartphone use and aggressive behavior for males and females. Models were adjusted by family type, only child, father's and mother's education, and family income. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

predicted PSU at Time 2 ($\beta = 0.558$, $p < 0.001$), and aggressive behavior at Time 1 significantly predicted aggressive behavior at Time 2 ($\beta = 0.559$, $p < 0.001$).

DISCUSSION

This study examined the longitudinal relationship between PSU and aggressive behavior in Chinese adolescents. Although PSU was positively linked with aggressive behavior in both younger and older adolescents at Time 1 and Time 2, the longitudinal analysis only revealed that previous PSU triggered subsequent aggressive behavior among older adolescents (*vs.* younger adolescents). In addition, previous aggressive behavior triggered subsequent PSU among both younger and older adolescents. Notably, there are no differences in the relationship between PSU and aggressive behavior in males and females.

This study indicates a bidirectional relationship between a high level of PSU and highly aggressive behavior. contrary

to prior cross-sectional studies, this study established a cause-and-effect relationship between PSU and aggressive behavior. To the best of our knowledge, no studies have examined the longitudinal association between PSU and aggressive behavior. Only a recent study has explored the relationship between PSU and internalized/externalized aggression among younger adolescents (age: 12.29 ± 0.98) (Deng et al., 2024). Based on their half-longitudinal mediation model, the cross-lagged paths revealed that PSU at Time 1 did not predict internalized and externalized aggression at Time 2, which is consistent with our results among younger adolescents. while previous studies implied that PSU is a risk factor for aggressive behavior among adolescents (Fekih-Romdhane et al., 2022; Karaoglan Yilmaz et al., 2022), the present study found that PSU was unable to predict adolescents' aggressive behavior levels one year later among younger adolescents. This could be due to the possibility that the correlation is influenced by other variables, which complicate the relationship between them. For example, some studies have found that cognitive function serves as a mediator in the relationship between PSU and aggressive behavior (Fekih-Romdhane et al., 2022). Besides, aggressive behavior might be the result of multiple factors (Chen, Huang, Wang, & Chang, 2012; Denson et al., 2012; Kühn et al., 2019; Morris, Silk, Steinberg, Myers, & Robinson, 2007; Ritchie, Neufeld, Yoon, Li, & Mitchell, 2022), while PSU can potentially lead to aggressive behavior, individuals can still avoid such behavior if they receive adequate support and guidance in other areas such as family environment, personal traits, and stress-coping ability. Moreover, our study reveals that PSU at Time 1 significantly predicts aggressive behavior at Time 2 among older adolescents, which is different from the results in younger adolescents. This may be because younger adolescents are still in the process of cognitive and emotional development, and exhibit more fluid behaviors influenced by a multitude of factors, not solely PSU. In contrast, older adolescents with more established behavioral patterns are likely to have their actions influenced more significantly by persistent factors such as PSU. It is also possible that PSU in older adolescents could be a sign of underlying mental health issues like social anxiety, and depression, which could also contribute to aggressive. These issues may not be as evident in younger adolescents.

The longitudinal findings also revealed a positive association between aggressive behavior at Time 1 and PSU at the subsequent time for both younger and older adolescents. To date, evidence on the relationship between aggressive behavior and PSU is limited, and fewer studies have explored the causal relationship between them. Previous research has indicated that difficulties in emotional regulation could potentially manifest as aggressive behavior (Liu, Yu, Xu, & Che, 2023; Murray, Lavoie, Booth, Eisner, & Ribeaud, 2021). Some adolescents may excessively use smartphone use to escape facing or dealing with negative emotions (Kim, Seo, & David, 2015; Li, Li, Liu, & Wu, 2020), such as anger or frustration. However, this avoidance strategy could escalate into a dependency on smartphones, thereby resulting in PSU. Another potential explanation could be that aggressive behavior indirectly affects PSU through aggression-related transdiagnostic factors (e.g., social isolation) and an increase in smartphone use time (Elhai, Dvorak, Levine, & Hall, 2017). In other words, adolescents exhibiting aggressive behavior may develop a tendency to retreat from reality, leading to the increased time spent on smartphones and excessive smartphone use, and ultimately resulting in PSU. In addition, the prediction of aggressive behavior towards PSU may be explained with the failure model (Capaldi & Stoolmiller, 1999). Adolescents exhibiting aggressive behavior (e.g., physical or verbal aggression) are more prone to experience failure in interpersonal relationships as peers may be reluctant to interact with those who show high levels of aggressive behavior. Consequently, this heightens the likelihood of adolescents exhibiting more aggressive behavior to experience PSU (Capaldi & Stoolmiller, 1999; Zhang, Zhang, Zhuang, & Xu, 2023).

Furthermore, our stratified analyses revealed no significant sex differences in the relationship between PSU and aggressive behavior, contradicting our initial hypothesis. However, sex remains a significant influence on the relationship between PSU and aggressive behavior because males and females do exhibit differences in their patterns of smartphone use (Chang & Ko, 2023). Indeed, individuals who use smartphone do not become addicted to the smartphone environment but to the behaviors they engage in when they are online (Sánchez-Fernández & Borda-Mas, 2023). Individuals who overuse smartphone are not addicted to the devices, but to their online behaviors. For instance, PSU in males is linked to media apps and games, while in females, it is related to communication and social networking apps (Chang & Ko, 2023). A meta-analysis revealed that males are more prone to online gaming disorder, however, females are more likely to be affected by social network addiction (Su, Han, Yu, Wu, & Potenza, 2020). Therefore, future research should continue to focus on sex differences, further understanding the relationship between PSU and aggressive behavior.

LIMITATIONS

A significant strength of this study is its ability to determine the direction of effects between PSU and aggressive behavior in adolescents. The division of younger and older adolescents helps to better understand the relationship between PSU and aggressive behavior in adolescents of different ages, which helps to develop more targeted prevention interventions.

This study has some limitations. First, the present study employed a self-reporting approach, which may lead to the occurrence of reporting bias due to social desirability when participants complete the survey. Secondly, participants were followed only two waves. In future research, it is necessary to utilize multiple survey data spanning longer durations, as longer studies and multiple waves may help to establish more comprehensive dynamic models on

relationships between PSU and aggressive behavior. Additionally, although MPAI has been shown to have good reliability and validity, it was developed in 2008 (Leung, 2008; Liu et al., 2017). Future research should consider using it alongside other scales for a more comprehensive evaluation. Third, the heterogeneity of symptoms associated with PSU is likely to have an impact on the results. For instance, aggressive behavior may have a stronger relation with some symptoms of PSU, such as fear of missing out and frequent smartphone checking (Abell, Buglass, & Betts, 2019). Moreover, previous studies have suggested that PSU may be driven by engaging in certain activities on smartphones, such as gaming or frequent social media use (Haberlin & Atkin, 2022; Rozgonjuk, Kattago, & Täht, 2018). Therefore, the specific activity, rather than the smartphone device itself, should be focused on understanding PSU. Furthermore, other psychosocial variables (e.g., parenting styles, depression) were not controlled, which may also influence the results. Fourth, this study only considered the longitudinal association between total aggression and PSU, however, the association between different types of aggressive behavior and PSU may vary. Finally, the participants in our study were limited to middle and high students, and hence the findings may not be applicable to other adolescent groups, such as non-students, or other cultures.

IMPLICATIONS

The present study may promote longitudinal, experimental, and theoretical studies involving PSU and aggressive behavior. Our findings provide some clues to help develop interventions and policies that promote the mental health of adolescents. In terms of practical implications, it may be particularly crucial to implement interventions aimed at reducing both PSU and aggressive behavior among adolescents. Research on PSU has indicated that overuse of smartphones can significantly impact mental health and overall well-being (Samaha & Hawi, 2016). Besides, adolescents with aggressive behavior are more likely to have peer conflicts and rejection, social exclusion, and emotional problems (Yue & Zhang, 2023), which is detrimental to adolescents' physical and mental health development.

According to the findings of this study, parents, educators, and psychological workers could consider dual approaches in prevention and intervention to decrease PSU and aggressive behavior. As a modifiable risk factor, PSU could serve as a significant target for intervention. For instance, employing mindfulness-based cognitive therapy could be an effective strategy to decrease both the duration of smartphone use and the severity of PSU symptoms (Lan et al., 2018). In addition, adolescents could strive to retrieve efficient emotion-regulation strategies, rather than resorting to excessive smartphone use (Estévez, Jáuregui, Sánchez-Marcos, López-González, & Griffiths, 2017). For example, encouraging and supporting adolescents in engaging in outdoor activities such as sports and travel, or taking up a new hobby as an alternative to smartphone use, could potentially alleviate aggressive behavior, reduce the time spent on smartphones, and prevent PSU (Fiorella, 2020). Increased social activities may make adolescents more aware of the real world, remove social isolation, and enhance social skills, thus reducing aggressive behavior (Elhai et al., 2017; Li et al., 2020). Furthermore, our study highlights that the longitudinal correlation between PSU and aggressive behavior is different among younger and older adolescents. Therefore, it is essential to develop prevention and intervention strategies for PSU and aggressive behavior among different adolescent age groups.

CONCLUSIONS

To conclude, this is the first study to provide longitudinal evidence, showing whether PSU will increase one's aggressive behavior. Our findings suggest that PSU predicted higher levels of aggressive behavior over time and aggressive predicted PSU among older adolescents. However, among younger adolescents, the bidirectional relationship between PSU and aggressive behavior does not exist. Our study complements existing literature and provides a theoretical guide for us to subsequent prevention strategies and interventions.

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Data availability: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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SUPPLEMENTARY MATERIAL

Supplementary data to this article can be found online at https://doi.org/10.1556/2006.2025.00015.

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