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FULL-LENGTH REPORT



A longitudinal study of the effects of problematic smartphone use on social functioning among people with schizophrenia: Mediating roles for sleep quality and self-stigma

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ABSTRACT

Background and aims: Individuals with schizophrenia may often experience poor sleep, self-stigma, impaired social functions, and problematic smartphone use. However, the temporal relationships between these factors have not been investigated. The present study used a longitudinal design to examine potential mediating roles of poor sleep and self-stigma in associations between problematic smartphone



use and impaired social functions among individuals with schizophrenia. *Methods:* From April 2019 to August 2021, 193 individuals with schizophrenia (mean [SD] age = 41.34 [9.01] years; 88 [45.6%] males) were recruited and asked to complete three psychometric scales: the Smartphone Application-Based Addiction Scale to assess problematic smartphone use; the Pittsburgh Sleep Quality Index to assess sleep quality; and the Self-Stigma Scale-Short Scale to assess self-stigma. Social functioning was evaluated by a psychiatrist using the Personal and Social Performance Scale. All measures were assessed five times (one baseline and four follow-ups) at three-month intervals between assessments. *Results:* General estimating equations found that problematic smartphone use (coefficient = -0.096 , $SE = 0.021$; $P < 0.001$), sleep quality (coefficient = -0.134 , $SE = 0.038$; $P < 0.001$), and self-stigma (coefficient = -0.612 , $SE = 0.192$; $P = 0.001$) were significant statistical predictors for social functioning. Moreover, sleep quality and self-stigma mediated associations between problematic smartphone use and social functioning. *Conclusion:* Problematic smartphone use appears to impact social functioning longitudinally among individuals with schizophrenia via poor sleep and self-stigma concerns. Interventions aimed at reducing problematic smartphone use, improving sleep, and addressing self-stigma may help improve social functioning among individuals with schizophrenia.

KEYWORDS

schizophrenia, sleep, smartphone use, social function, stigma, internet addiction, addictive behaviors

INTRODUCTION

Access to the internet has become easily available via multiple devices (e.g., smartphones, tablets, laptops, and computers) and have become readily affordable (O’Dea, 2020). Therefore, different populations, including individuals with schizophrenia, often use the internet to engage in various activities for different purposes and reasons. With the use of smartphones, individuals can surf the internet and use applications (‘apps’) almost anytime and anywhere. Although smartphones provide powerful functions conveniently for many individuals, excessive use of smartphone (or problematic smartphone use) may generate negative consequences for individuals’ health, including psychiatric symptoms or psychological distress (Chen, Pakpour, et al., 2020a; Oluwole, Obadeji, & Dada, 2021; Wong et al., 2020). Individuals with schizophrenia may have a particularly high likelihood of developing problematic smartphone use because they may use apps or access the internet via smartphones to cope with their symptoms and/or to modify their emotions or feelings (e.g., reduce anxiety and stress) (Aliyari et al., 2018; von der Heiden, Braun, Müller, & Egloff, 2019). Therefore, understanding problematic smartphone use among individuals with schizophrenia is important as this may guide mental health professionals to know how problematic smartphone use impacts the health of individuals with schizophrenia.

Longitudinal relationships between problematic smartphone use and social functioning, as well as considering

sleep quality and self-stigma, were the focus of the present study for the following reasons. Individuals with schizophrenia often experience impaired social functions, which may further result in difficulties in daily living, such as unemployment and poor maintenance of their households (Cheng et al., 2019; Lysaker, Davis, Warman, Strasburger, & Beattie, 2007; Mersh, Jones, & Oliver, 2015). Problematic smartphone use has been associated with poor cognitive-social skills (Sarti et al., 2019), cognitive-emotional regulation, and communication skills (Wacks & Weinstein, 2021). Therefore, if individuals with schizophrenia use their smartphones as a coping strategy to deal with their symptoms or emotional problems, they may be more likely to enter vicious cycles in which poor social functioning leads to increased smartphone use which further worsens social functioning.

In relation to sleep quality, individuals with schizophrenia have been reported to suffer from poor sleep (Kiwan et al., 2020; Manoach & Stickgold, 2019), which may subsequently impact on their daily functioning (Pakpour, Griffiths, Ohayon, Broström, & Lin, 2020). Poor sleep may lead to disadvantageous decision-making and poor social functioning (Kent, Uchino, Cribbet, Bowen, & Smith, 2015; Salfi et al., 2020). Problematic smartphone use has been associated with poor sleep (Huang et al., 2020; Kwok, Leung, Poon, & Fung, 2021; Wong et al., 2020). Therefore, engaging in smartphone activities as a coping strategy to deal with symptoms and/or emotional problems may generate sleep problems for individuals with schizophrenia. Moreover, poor sleep among individuals with schizophrenia may lead to more severe problems in their social functioning (Kent et al., 2015; Salfi et al., 2020).

In relation to self-stigma, a diagnosis of schizophrenia may lead individuals to feel devalued and experience discrimination related to misunderstandings about the disorder (Dickerson, Sommerville, Origoni, Ringel, & Parente, 2002). Here, individuals with schizophrenia may experience self-stigma because of their awareness of stereotypes about them (Chang, Wu, Chen, Wang, & Lin, 2014; Huang, Chen, Pakpour, & Lin, 2018; Lin, Chang, Wu, & Wang, 2016). Self-stigma has been associated with poor social functioning and may prevent individuals with schizophrenia from receiving appropriate treatment (Cheng et al., 2019; Fung, Tsang, & Corrigan, 2008; Yanos, Roe, & Lysaker, 2010). Individuals with schizophrenia may be exposed to a particularly high level of stereotyping toward schizophrenia via smartphone activities. Associations between problematic smartphone use and self-stigma have previously been reported (e.g., Chang, Chang, Hou, Lin, & Griffiths, 2020; Fung et al., 2021). Therefore, individuals with schizophrenia may experience greater self-stigma if they engage in problematic smartphone activities.

Although the relationships between problematic smartphone use, social functions, sleep quality, and self-stigma have been reported, most data are cross-sectional (Alimoradi et al., 2019). Therefore, there are insufficient data concerning how problematic smartphone use may lead to impaired social functioning among individuals with schizophrenia.



Consequently, the present study tested the hypothesis that sleep quality and self-stigma would mediate associations between problematic smartphone use and social functioning among individuals with schizophrenia. The mediated effects are proposed because problematic smartphone use has been associated with social functioning (Sarti et al., 2019; Wacks & Weinstein, 2021), sleep quality (Wong et al., 2020), and self-stigma (Chang et al., 2020; Fung et al., 2021). Moreover, sleep quality and self-stigma have been associated with social functioning (Cheng et al., 2019; Kent et al., 2015). These cross-sectional relationships provide a theoretical rationale supporting these mediated relationships that can be formally tested utilizing longitudinal designs. In addition, Lane, Chang, Huang, and Chang (2021) reported that young adults with higher scores on the novelty seeking personality trait (indicating a more activated dopamine system), showed poor sleep quality. For the patients with schizophrenia, there is a hypothesized theory that the more positive symptoms the patients have suffered, the more activated dopamine system they may show, in which the patients with schizophrenia have poorer sleep quality and worse social functioning (Monti et al., 2013; Yates, 2016). For the mediation models, the present study tested the possible mechanism among these variables, dopamine-related to problematic smartphone use.

Based on the aforementioned literature, the present study tested two mediation models among individuals with schizophrenia. The first model tested whether sleep quality mediated associations between problematic smartphone use and social functioning (Fig. 1). The second model tested whether self-stigma mediated associations between problematic smartphone use and social functioning (Fig. 1).

METHODS

Participants and data collection

Data were collected at five timepoints at three-month intervals between April 30, 2019 and August 6, 2021 in the Jianan Psychiatric Center (JPC). The JPC is the largest psychiatric center in Tainan (i.e., a city in southern Taiwan) and provides psychiatric treatment (including inpatient treatment, outpatient treatment, and daycare services) to individuals in southern Taiwan. The JPC currently delivers outpatient treatment for more than 5,000 patients with severe mental illness monthly (Chang et al., 2020). The present

study's participants were recruited from the daycare and outpatient units from the JPC with the following inclusion criteria. First, the participants were diagnosed as having schizophrenia according to the DSM-5 criteria (American Psychiatric Association, 2013). Second, participants used a smartphone to access the internet during the study period. Third, participants were in a stable condition as evidenced by regular follow-ups in daycare or during outpatient treatment. Fourth, participants were aged 20 years or older. Finally, participants understood the study purpose and provided handwritten informed consent for participation. Participants were excluded if they had a history of moderate to severe substance use disorder (with the exclusion of tobacco use disorder) or a history of head injury.

Measures

Personal and Social Performance Scale (PSPS). The PSPS is a psychiatrist-administered scale that evaluates the social functioning of an individual with mental illness (Morosini, Magliano, Brambilla, Ugolini, & Pioli, 2000). The PSPS contains four items (socially useful activities [including work and study], personal and social relationships, self-care, and disturbing/aggressive behaviors) rated on six-point Likert-like scales (scores ranging from 1 *absent* to 6 *very severe*). With the use of the four item scores, a single overall score ranged between 1 and 100 is calculated to provide an individual's level of social functioning, with higher scores reflecting better social functioning. More specifically, there is a conversion guideline for a psychiatrist to transform the findings from the four items to the 1-100 scale. For example, a psychiatric may score a patient between 21 and 30 when the individual has one of the following conditions: (i) two severe difficulties (i.e., score 5) from the first three items (i.e., socially useful activities, personal and social relationships, and self-care); (ii) severe difficulty from the last item (i.e., disturbing and aggressive behaviors) regardless the scores for the first three items. Detailed information regarding the conversion guideline can be found elsewhere (see Morosini et al., 2000). The psychometric properties of the Chinese PSPS have been supported by satisfactory test-retest reliability (Cronbach's $\alpha = 0.91$) and internal consistency ($\alpha = 0.73$) (Wu et al., 2013).

Smartphone Application-Based Addiction Scale (SABAS). The SABAS is a participant-administered scale that evaluates the

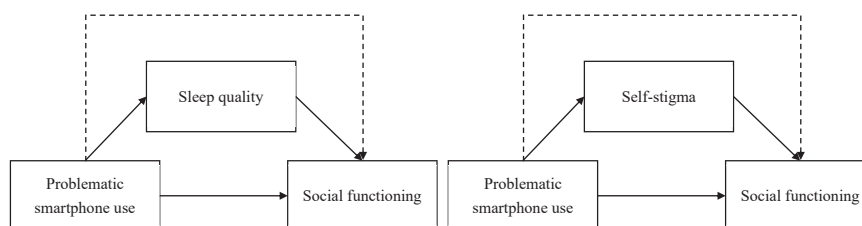


Fig. 1. Hypothesized mediation models investigating potential effects of sleep quality and self-stigma on associations between problematic smartphone use and social functioning. Solid lines indicate direct effects; dashed lines indicate mediated (indirect) effects

risk of problematic smartphone use (Csibi, Griffiths, Cook, Demetrovics, & Szabo, 2018). The SABAS contains six items rated on six-point Likert-like scales (score ranging from 1 *strongly disagree* to 6 *strongly agree*). With the use of the six item scores, summed overall scores ranging between 6 and 36 are calculated to provide an individual's risk of problematic smartphone use, with higher scores reflecting more severe problematic smartphone use (Chen, Chen, et al., 2021a, b). The psychometric properties of the Chinese SABAS have been supported by satisfactory internal consistency ($\alpha = 0.78$) and construct validity (comparative fit index = 0.980–1.000) (Chen, Strong, et al., 2020; Leung et al., 2020; Yam et al., 2019).

Pittsburgh Sleep Quality Index (PSQI). The PSQI is a participant-administered scale (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). The PSQI contains 19 items rated on different forms and then converted into seven component scores using four-point Likert-like scales (scores ranging from 0 to 3). With the use of the seven component scores, a summated overall score ranging between 0 and 21 is calculated to provide an individual's level of sleep quality. Higher scores reflect poorer sleep quality. The psychometric properties of the Chinese PSQI have been supported by satisfactory test-retest reliability ($\alpha = 0.85$) and internal consistency ($\alpha = 0.83$) (Tsai et al., 2005).

Self-Stigma Scale-Short Scale (SSS-S). The SSS-S is a participant-administered scale evaluating self-stigma among minority group members (e.g., individuals with mental illness) (Mak & Cheung, 2010). The SSS-S contains nine items rated on four-point Likert-like scales (scores ranging from 1 *strongly disagree* to 4 *strongly agree*). With the use of the nine item scores, average overall scores ranging between 1 and 4 are calculated to assess an individual's level of self-stigma. Higher scores reflect higher levels of self-stigma. The psychometric properties of the SSS-S have been supported by satisfactory internal consistency ($\alpha = 0.95$) and construct validity (comparative fit index = 0.980–0.990) (Chang, Lin, Gronholm, & Wu, 2018; Wu, Chang, Chen, Wang, & Lin, 2015).

Covariate information. Participants' demographic data were collected using a background information sheet and then used as covariates in the statistical analysis. More specifically, the data collected included participants' age, gender (male or female), years of education, employment status (yes or no), physical disease (yes or no), and living condition (alone or with others).

Data analysis

Descriptive statistics were first applied to understand participants' characteristics at baseline, including with respect to age, gender, years of education, employment status, physical disease, living condition, social functioning, sleep quality, self-stigma, and problematic smartphone use. Because longitudinal study designs typically encounter some loss to follow-up, Little's Missing Completely At Random (MCAR) test was applied to examine whether participants

loss to follow-up followed a pattern (Little, 1988). The participants' demographic features and their scores on social functioning, sleep quality, self-stigma, and problematic smartphone use were used for the Little's MCAR test.

A general estimating equation (GEE) with a random effect on time was then performed to examine possible effects of problematic smartphone use, sleep quality, and self-stigma on participants' social functioning. Another two GEEs were performed to examine possible effects of problematic smartphone use on sleep quality and self-stigma separately. In order to examine the temporal associations between the studied variables (i.e., problematic smartphone use as the independent variable; sleep quality and self-stigma as mediators; and social functioning as the dependent variable), the three GEEs were constructed utilizing the following strategies. In the first GEE (i.e., the one examining possible effects of problematic smartphone use, sleep quality, and self-stigma on participants' social functioning), social functioning assessed at the first and second waves were not included in the GEE to be the outcome variable. Problematic smartphone use assessed at the first wave was included in the GEE to be the predictor; sleep quality and self-stigma assessed at the second wave were also included in the GEE. Moreover, social functioning assessed in the first wave was controlled for in the GEE. Therefore, the associations between problematic smartphone use (predictor) and social functioning (outcome) calculated using the GEE model represent the temporal associations. Similarly, the associations between sleep quality/self-stigma (mediator) and social functioning (outcome) represent temporal associations. In the following two GEEs (i.e., those examining possible effects of problematic smartphone use on sleep quality and self-stigma separately), sleep quality and self-stigma assessed in the first wave were not included in the GEEs to be the outcome variables. Again, problematic smartphone use assessed in the first wave was included in the GEE to be the predictor; sleep quality and self-stigma assessed in the first wave were controlled for in the GEE. Therefore, the associations between problematic smartphone use (predictor) and sleep quality/self-stigma (mediator) calculated using the GEEs represent the temporal associations.

All GEEs controlled for participants' age, gender, years of education, employment status, physical disease, and living condition. The GEEs were used because they could directly impute the missing data in the longitudinal data collection. The GEE coefficients and standard errors were then used for testing whether sleep quality and self-stigma mediated associations between problematic smartphone use and social functioning via the Monte Carlo method (Bauer, Preacher, & Gil, 2006; Preacher & Selig, 2012). In the Monte Carlo method, 20,000 repetitions were generated and a 95% confidence interval (CI) was used to examine the mediated effects. When the 95% CI does not include 0 (i.e., both upper limit and lower limit of the 95% CI were both negative values or both positive values), the mediated effect is supported (Preacher & Selig, 2012). Given that the GEEs took care of the temporal associations (i.e., the coefficients derived from



GEEs were temporal associations), the mediation models estimated using the Monte Carlo method also had the feature of temporal association. All the statistical analyses were performed using SPSS version 20 (IBM Corp., Armonk, NY), except for the Monte Carlo method which used the online source developed by Selig and Preacher (2008).

Ethics

The study protocol was approved by an Institute of Review Board from Institute of Review Board from Jianan Psychiatric Center, Ministry of Health and Welfare (IRB numbers: 18-039 & 19-034). Additionally, all the participants provided handwritten informed consent. All participants were assured of confidentiality anonymity, and freedom to withdraw their data at any time.

Table 1. Participant characteristics ($N = 193$)

	n (%) or $M \pm SD$
Age	41.34 \pm 9.01
Gender (Male)	88 (45.6)
Years of education	12.14 \pm 2.58
Employment (Yes)	71 (36.8)
Physical disease (Yes)	62 (32.1)
Living condition (Alone)	17 (8.8)
Social functioning	79.77 (5.12)
Sleep quality	9.13 (4.48)
Self-stigma	2.20 (0.84)
Problematic smartphone use	18.11 (6.83)

Social functioning was assessed using the Personal and Social Performance Scale.

Sleep quality was assessed using the Pittsburgh Sleep Quality Index. Self-stigma was assessed using the Self-Stigma Scale-Short.

Problematic smartphone use was assessed using the Smartphone Application-Based Addiction Scale.

RESULTS

Participants' characteristics ($N = 193$) are presented in Table 1. In brief, the mean age of the participants was 41.34 years ($SD = 9.01$) and slightly less than half of the participants were male ($n = 88$; 45.6%). On average, participants reported 12.14 years of education ($SD = 2.58$). Slightly over one-third of participants ($n = 71$; 36.8%) were employed, and slightly less than one-third reported a physical disease ($n = 62$; 32.1%). Less than one-tenth of participants ($n = 17$; 8.8%) reported living alone. Table 1 presents the mean scores relating to social functioning, sleep quality, self-stigma, and problematic smartphone use. The retained numbers of participants were 164 (first follow-up), 142 (second follow-up), 125 (third follow-up), and 103 (fourth follow-up). Little's MCAR test indicated that the loss to follow-up was at random ($\chi^2 = 151.75$, $df = 131$; $P = 0.104$).

GEE analysis indicated that problematic smartphone use (coefficient = -0.075 , $SE = 0.015$; $P < 0.001$), sleep quality (coefficient = -0.082 , $SE = 0.029$; $P = 0.004$), and self-stigma (coefficient = -0.545 , $SE = 0.136$; $P < 0.001$) were significant statistical predictors for social functioning among the participants after controlling for demographics. Over time, participants demonstrated poorer social functioning (coefficient = -0.635 , $SE = 0.099$; $P < 0.001$) and poorer sleep quality (coefficient = -0.175 , $SE = 0.083$; $P = 0.036$). Problematic smartphone use was a significant statistical predictor for sleep quality (coefficient = 0.055 , $SE = 0.021$; $P = 0.008$) and self-stigma (coefficient = 0.019 , $SE = 0.004$; $P < 0.001$) (Table 2).

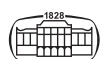
The mediating effects of sleep quality and self-stigma on temporal associations between problematic smartphone use and social functioning were supported by the Monte Carlo method. More specifically, the 95% CIs of the Monte Carlo

Table 2. Generalized estimating equations assessing relationships between variables and social functioning, sleep quality, and self-stigma among people with schizophrenia

	Social functioning	Coeff. (SE)/ P Sleep quality	Self-stigma
Age	0.017 (0.119)/0.16	0.046 (0.016)/0.003	0.006 (0.003)/0.08
Gender (Ref: male)	0.812 (0.195)/ <0.001	-0.035 (0.267)/0.90	-0.032 (0.059)/0.58
Years of education	0.046 (0.049)/0.34	-0.003 (0.052)/0.95	<0.001 (0.097)/0.99
Employed (Ref: yes)	-0.461 (0.195)/0.018	0.365 (0.277)/0.19	-0.050 (0.059)/0.39
Living (Ref: living alone)	0.470 (0.376)/0.21	-1.046 (0.432)/0.015	-0.048 (0.100)/0.63
Physical disease (Ref: yes)	0.109 (0.224)/0.63	-0.027 (0.310)/0.93	0.060 (0.064)/0.36
Problematic smartphone use	-0.075 (0.015)/ <0.001	0.055 (0.021)/0.008	0.019 (0.004)/ <0.001
Sleep quality	-0.082 (0.029)/0.004	–	–
Self-stigma	-0.545 (0.136)/ <0.001	–	–
Problematic smartphone use baseline	0.411 (0.021)/ <0.001	–	–
Sleep quality baseline	–	0.725 (0.032)/ <0.001	–
Self-stigma baseline	–	–	0.684 (0.036)/ <0.001
Time	-0.635 (0.099)/ <0.001	-0.175 (0.083)/0.036	-0.010 (0.017)/0.56

Coeff. = coefficient; SE = standard error.

Mediation effects were examined using the Monte Carlo method (<https://quantpsy.org/medmc/medmc.htm>); confidence intervals based on 20,000 repetitions.



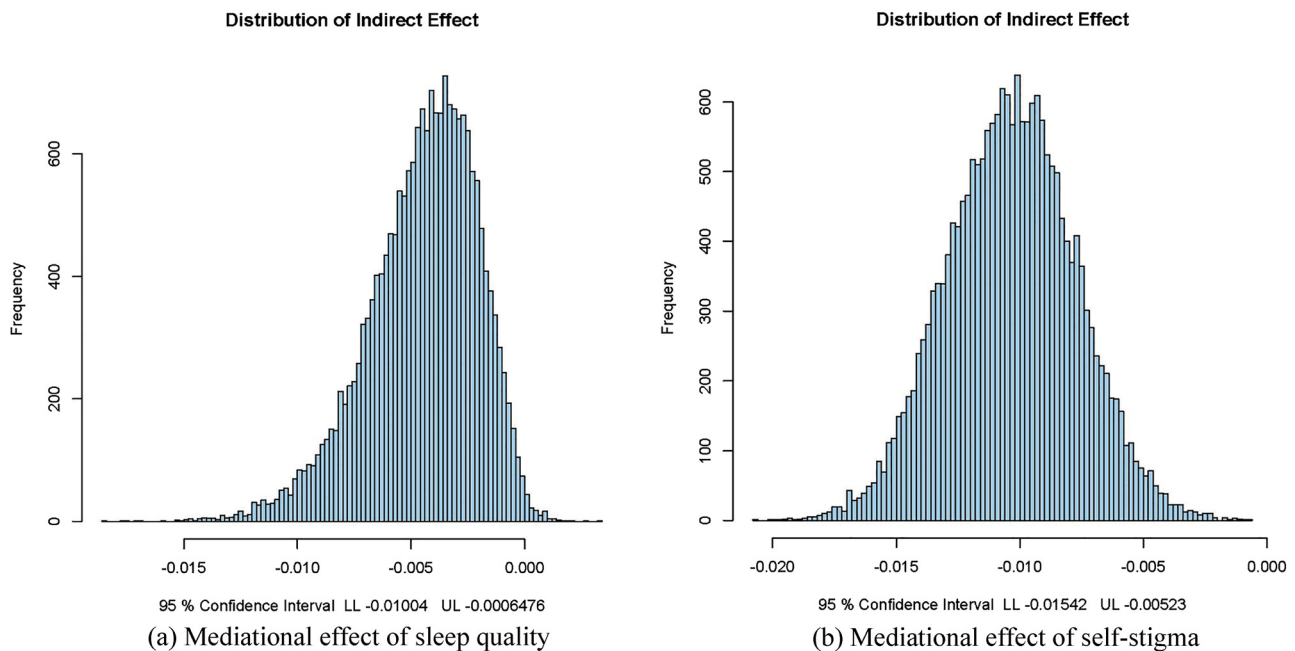


Fig. 2. Mediational effects of sleep quality and self-stigma on associations between problematic smartphone use and social functioning among people with schizophrenia. LL = lower limit; UL = upper limit

repetitions were between -0.01004 and -0.0006476 for sleep quality, and between -0.01542 and -0.00523 for self-stigma (Fig. 2).

DISCUSSION

The present study found that sleep quality and self-stigma mediated the temporal associations between problematic smartphone use and social functioning over time among individuals with schizophrenia. Moreover, problematic smartphone use was a significant statistical predictor directly relating to participants' poor sleep quality, high levels of self-stigma, and impaired social functioning. Models indicated that poor sleep quality and high levels of self-stigma also had a significant and direct effects on participants' impaired social functioning. The temporal associations between the studied variables were supported because social functioning was assessed in later waves (i.e., Waves 3–5), sleep quality and self-stigma assessed in Wave 2, and problematic smartphone use assessed in Wave 1. Moreover, the longitudinal design demonstrated a decline in social functioning and sleep quality over time among individuals with schizophrenia. However, the level of self-stigma did not change significantly over time.

The findings that problematic smartphone use led to poor sleep, and that poor sleep led to poor social functioning echo the findings of previous studies (e.g., Huang et al., 2020; Kent et al., 2015; Kwok et al., 2021; Salfi et al., 2020; Wong et al., 2020). Sleep is important for individuals irrespective of age or psychiatric status in order to maintain effective cognitive and emotional processing (Pakpour et al., 2020). Therefore, individuals with schizophrenia may benefit

from a sufficient quantity and quality of sleep to optimize social functioning. However, the present findings showed that problematic smartphone use, a method that individuals with schizophrenia may possibly use as a coping strategy to deal with their illness symptoms or emotional distress, could lead to poor sleep. The previously reported relationship between problematic smartphone use and poor sleep may exist for several reasons (Huang et al., 2020; Kwok et al., 2021; Wong et al., 2020). First, before sleep, smartphone use may increase arousal and interfere with sleep onset (Wong et al., 2020). Second, the blue light emitted from smartphones may also disrupt sleep quality (Heo et al., 2017). Third, problematic smartphone use has been found to be associated with psychological distress (Chen, Chen, et al., 2021c, d), a factor contributing to poor sleep. As such, poor sleep may arise from problematic smartphone use and lead to poorer social functioning.

The findings that problematic smartphone use may increase self-stigma, and that self-stigma may lead to poorer social functioning also confirm the findings of previous studies (e.g., Cheng et al., 2019; Chang et al., 2020; Fung et al., 2008; Yanos et al., 2010). Self-stigma and its negative effects have been studied among individuals with schizophrenia (Dubreucq, Plasse, & Franck, 2021). Moreover, impacts on social functioning have been reported (e.g., Cheng et al., 2019; Fung et al., 2008; Yanos et al., 2010). Moreover, problematic smartphone use among individuals with schizophrenia may expose them to biased or unfriendly online communications, thereby potentially increasing self-stigma (Chang et al., 2020). Therefore, self-stigma may mediate associations between problematic smartphone use and poorer social functioning among individuals with schizophrenia.

The finding in the present study suggests that individuals with schizophrenia may need help in navigating their smartphone use and using apps or the internet in a way that limits negative impacts. In particular, they may benefit from educational efforts on how to prevent problematic use of smartphones or apps or the internet more generally (COST Action CA16207, 2021). Other leisure activities not involving use of digital technologies may be incorporated into the daily repertoires of individuals with schizophrenia in order to promote social functioning. Moreover, individuals with schizophrenia may benefit from psycho-educational efforts regarding how problematic smartphone use may be harmful to their sleep, psychological health and/or social functioning. Second, mental health professionals could provide psychoeducation and other interventions to help improve sleep quality among individuals with schizophrenia. For example, the effectiveness of cognitive behavioral therapy for insomnia has been documented (Rajabi et al., 2020) and such techniques may have the potential to improve sleep quality. Third, mental health professionals could help individuals with schizophrenia address self-stigma. Programs aimed at reducing self-stigma among individuals with schizophrenia have documented efficacy (Yanos, Lucksted, Drapalski, & Roe, 2015). Therefore, mental health professionals may encourage individuals with schizophrenia to participate in such programs.

There are limitations to the present study. First, the present sample was collected in one treatment center in Taiwan. Therefore, the representativeness of the present sample may not generalize to other populations. Second, only individuals with schizophrenia who received daycare or outpatient services participated. Therefore, the present findings may not necessarily generalize to individuals with schizophrenia receiving inpatient treatment or in the community. Third, problematic smartphone use, sleep quality, and self-stigma were assessed by participant self-report. Therefore, they are subject to multiple biases including single-rater bias, recall bias, and social desirability bias. Fourth, nearly half of the participants (90 out of 193; 46.6%) did not complete all follow-up measures. Therefore, loss to follow-up may have impacted the findings. However, this impact appears mitigated because Little's MCAR tests suggested no significant patterns in losses to follow-ups and the GEE models addressed some concerns related to missing values. Fifth, multiple measures (e.g., medication adherence, adverse and therapeutic effects of antipsychotic drugs, behavioral treatments) were not collected, therefore potential confounding effects were not considered. Sixth, measures of illness severity (e.g., positive and negative symptoms) and co-occurring symptomatology (e.g., depression) were not collected and this could also have impacted the findings. Accordingly, the present study findings cannot provide any information regarding how problematic smartphone use links to positive symptoms (e.g., delusion, hallucination), disorganization of thoughts, and negative symptoms (e.g., social withdrawal). The causal relationship between these psychotic symptoms and problematic smartphone use cannot be concluded. Future studies

using an exploratory method are therefore needed to clarify this. Seventh, problematic smartphone use may include different specific online activities (e.g., online shopping, online gaming, online pornography viewing, and social networking), and the present study did not collect information on each specific online activity. Future studies should therefore examine the potential effects of each specific online activity.

CONCLUSION

In summary, the present study used a longitudinal design to assess how problematic smartphone use may impact social functioning among individuals with schizophrenia. The models suggested that poor sleep quality and self-stigma mediated the associations between problematic smartphone use and social functioning longitudinally. Therefore, in order to optimize social functioning among individuals with schizophrenia, it appears important to consider problematic smartphone use, sleep quality, and self-stigma and their interactions. Future research (e.g., randomized controlled trials) is needed to investigate whether interventions to reduce problematic smartphone use, sleep problems, and self-stigma may improve social functioning among individuals with schizophrenia.

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Authors' contribution: K-CC, Y-HC, C-FY, P-JC, and C-YL created and organized the study and collected the data. J-SC, AHP, and C-YL analyzed the data. AHP provided the directions of data analysis. Y-HC, C-FY, P-JC, MNP, and MDG interpreted the data results. K-CC, Y-HC, P-JC, and C-YL wrote the first draft. C-YL supervised the entire study. MNP and MDG were responsible for all final editing. All the authors critically reviewed the manuscript and provided constructive comments.

Conflict of interest: The authors declare no conflict of interest.

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participated in surveys, mailings or telephone consultations related to drug addiction, impulse control disorders or other health topics; has contributed to a patent application for gambling and gaming disorder treatment; and has consulted for law offices and gambling entities on issues related to impulse control or addictive disorders.

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