

AKADÉMIAI KIADÓ

Temporal associations between physical activity and three types of problematic use of the internet: A six-month longitudinal study











Journal of Behavioral Addictions

11 (2022) 4, 1055–1067

DOI:

10.1556/2006.2022.00084

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Received: June 9, 2022 • Revised manuscript received: October 14, 2022 • Accepted: November 5, 2022

Published online: November 25, 2022

FULL-LENGTH REPORT



ABSTRACT

Background and aims: Internet use has become an important part of daily living. However, for a minority it may become problematic. Moreover, problematic use of the Internet/smartphone (PUIS) has been associated with low physical activity. The present study investigated the temporal associations between three types of PUIS (i.e., problematic smartphone use [PSPU], problematic social media use [PSMU] and problematic gaming [PG]) and physical activity among Taiwanese university students. **Methods:** A six-month longitudinal survey study comprising three time points for assessments was conducted. From the original 974 participants, a total of 452 completed all three waves of an online survey comprising the International Physical Activity Questionnaire Short Form (IPAQ-SF) assessing physical activity level, Smartphone Application-Based Addiction Scale (SABAS) assessing PSPU, Bergen Social Media Addiction Scale (BSMAS) assessing PSMU, and Internet Gaming Disorder Short Form (IGDS9-SF) assessing PG. **Results:** The linear mixed effects model found positive temporal associations of PSMU and PG with physical activity level (PSMU: $B = 85.88$, $SE = 26.24$; $P = 0.001$; PG: $B = 36.81$, $SE = 15.17$; $P = 0.02$). PSPU was not associated with physical activity level ($B = 40.54$, $SE = 22.99$;

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$P = 0.08$). Additionally, the prevalence rates were 44.4% for at-risk/PSPU, 24.6% for at-risk/PSMU, and 12.3% for at-risk/PG. *Discussion and Conclusions:* PSMU and PG unexpectedly demonstrated correlations with higher physical activity level. The nature of these relationships warrants additional investigation into the underlying mechanisms in order to promote healthy lifestyles among university students.

KEYWORDS

problematic Internet use, problematic smartphone use, problematic social media use, problematic gaming, physical activity, behavioral addictions, video games, Internet addiction

INTRODUCTION

Internet use has various pros and cons for individuals of all ages (Sinkkonen, Puhakka, & Merilainen, 2014). With its feature characteristics, the Internet may provide convenience, entertainment, and information access. Unfortunately, unfavorable issues such as privacy violation, addiction, or disinformation and misinformation can impact Internet use (González-Pérez, 2020; Lopez-Fernandez, Freixa-Blanchart, & Honrubia-Serrano, 2013; Weinberg, Milne, Andonova, & Hajjat, 2015). Among these issues, addictive use of the Internet has become an area of increasing research interest. There is no consensus on the diagnostic criteria for Internet addiction and many scholars prefer to call it problematic use of the Internet (PUI, where excessive use of the Internet causes impairments of important daily activities), and a minority of individuals using the Internet may experience PUI (Spada, 2014). Several types of PUI have been described (Davis, 2001; Duke & Montag, 2017; Kamolthip et al., 2022) but many in the field make distinctions between generalized and specific PUI (Montag et al., 2015a, 2015b; Müller et al., 2022; Saffari, Chen, Chang et al., 2022; Tung et al., 2022). For the present paper, the term ‘problematic use of the Internet/smartphone (PUIS)’ is used as an umbrella term to include both generalized and specific PUI. Generalized PUIS includes problematic smartphone use [PSPU] (excessive interactions with smartphones resulting in physical, psychological or social harms [Csibi, Griffiths, Cook, Demetrovics, & Szabo, 2018; Montag, Wegmann, Sariyska, Demetrovics, & Brand, 2021]) and specific PUIS includes problematic social media use [PSMU] (excessive communication behavior via social networking that impairs other important aspects of daily living [Andreassen, Pallesen, & Griffiths, 2017; Montag et al., 2021]); and problematic gaming [PG], (excessive engagement in playing videogames resulting in consequential harms [Pontes & Griffiths, 2015]).

Generalized and specific forms of PUIS have been associated with poor psychosocial and physical health (Ko, Yen, Yen, Lin, & Yang, 2007; Lepp, Barkley, Sanders, Rebold, & Gates, 2013; Matusitz & McCormick, 2012; Park, 2014; Shapira, Goldsmith, Keck, Khosla, & McElroy, 2000; Tsitsika et al., 2016; Vandelanotte, Sugiyama, Gardiner, & Owen,

2009; Yang, Chen, Huang, Lin, & Chang, 2017; Yen, Ko, Yen, Wu, & Yang, 2007). Psychological comorbidities including depression (Park, 2014; Yen et al., 2007), social anxiety (Ko et al., 2007), bipolar disorder (Shapira et al., 2000) and others have been reported for individuals with PUIS, both with generalized and specific forms. Additionally, poor physical health including obesity (Matusitz & McCormick, 2012; Tsitsika et al., 2016; Vandelanotte et al., 2009), musculoskeletal problems (Yang et al., 2017), and reduced physical fitness levels (Lepp et al., 2013) have been associated with PUIS. Subsequently, these concerns may lead to additional health challenges (e.g., diabetes, myocardial infarction, chronic back pain, etc.) (Matusitz & McCormick, 2012). Apart from the psychological comorbidities and physiological impairments, PUIS may result in individuals engaging in more sedentary lifestyles or behaviors (Vandelanotte et al., 2009; Tsitsika et al., 2016), an important factor also contributing to psychosocial and physical health problems (Griffiths, 2010; Lepp et al., 2013; Matusitz & McCormick, 2012).

Sedentary behaviors may reflect insufficient physical activity (Matusitz & McCormick, 2012), which has been associated with PUIS (Islam et al., 2020; Lepp et al., 2013; Matusitz & McCormick, 2012; Park, 2014; Saffari, Chen, Wu et al., 2022). Physical activity can improve health psychologically (e.g., reduce depression and anxiety) and physically (e.g., improve cardiovascular function and physical fitness) (Yohannes, Doherty, Bundy, & Yalfani, 2010). However, individuals with PUIS have demonstrated less physical activity (Matusitz & McCormick, 2012), and this unhealthy lifestyle has also been associated with health concerns including impaired glucose or lipid metabolism (Hamilton, Hamilton, & Zderic, 2014; Reutrakul & Van Cauter, 2014), obesity (Matusitz & McCormick, 2012), and increased mortality (Lepp et al., 2013). In other words, PUIS may promote sedentary lifestyle and diminished physical activity (Matusitz & McCormick, 2012), promoting obesity or cardiovascular disease (Griffiths, 2010; Hamilton et al., 2014; Lepp et al., 2013; Matusitz & McCormick, 2012; Reutrakul & Van Cauter, 2014). Therefore, strategies aiming to increase physical activity in individuals with PUIS have been proposed (Park, 2014; Tsitsika et al., 2016).

The use of the Internet for important activities is widespread. For example, the Internet has been frequently used in university education (Cheung & Huang, 2005), especially during the COVID-19 pandemic (Heiman-Patterson et al., 2021; Novikov, 2020). Online activity such as remote learning (Clary, Dick, Akbulut, & Van Slyke, 2022) or web-based homework (Wimmer, Powell, Kilgus, & Force, 2017) may result in university students having more sedentary lifestyles (Buckworth & Nigg, 2004). For example, university students need not move from classroom to classroom on campus, and they may simply sit in front of their screen for learning. Indeed, a study analyzed the nationally representative data reported that 81.4% of university students were “physically inactive” and 37% reported having a sedentary lifestyle (Pechtl, Kim, & Jacobsen, 2022). In addition, time spent on the Internet (Gao, Gan, Whittal, & Lippke, 2020;



Mottram & Fleming, 2009), loneliness, and boredom (Skues, Williams, Oldmeadow, & Wise, 2016) have been associated with PUIS among university students. Therefore, university students may constitute an at-risk population for PUIS because they may often maintain more sedentary lifestyles and have relatively more time to use the Internet.

To the best of the present authors' knowledge, few previous studies have separately and simultaneously examined associations between different types of PUIS and physical activity. Previous studies have investigated the association of generalized PUIS with physical activity (e.g., Gao et al., 2020; Islam et al., 2020; Park, 2014; Tsitsika et al., 2016) or specific PUIS with physical activity (e.g., Brailovskaia, Ozimek, & Bierhoff, 2021; Brailovskaia, Teismann, & Margraf, 2018; Lepp et al., 2013; Precht, Stirnberg, Margraf, & Brailovskaia, 2022; Saffari, Chen, Wu et al., 2022; Xu et al., 2022). As far as the present authors are aware, no previous studies have simultaneously compared different types of PUIS and levels of physical activity or investigated the longitudinal influences of PUIS on physical activity. In addition, the 'pickle jar theory' (Wright, 2002) of time management considers time as a finite entity that has limits. Therefore, the priorities of less important activities may jeopardize the completion of more important activities. In the present study, it was hypothesized that time devoted to PUIS may displace time that could be used for physical activities. Therefore, the present study longitudinally examined associations between PSPU, PSMU and PG and physical activity among Taiwanese university students. Based on the pickle jar time management theory and the prior studies examining the associations between PUIS and physical activity (Lepp et al., 2013; Park, 2014; Saffari, Chen, Wu et al., 2022; Vandelanotte et al., 2009; Wright, 2002; Xu et al., 2022), the present study hypothesized that specific PUIS comprising (i) PSPU, (ii) PSMU, and (iii) PG at baseline would be negatively associated with physical activity level assessed six months later among Taiwan university students. The findings were anticipated to provide evidence regarding the longitudinal effects of general and specific PUIS and how it affects physical activity levels.

METHODS

Participants and recruitment procedure

Participants fulfilled the following inclusion criteria: (i) being a university student (either undergraduate or post-graduate) at the onset of the study; (ii) understanding written Chinese in traditional Chinese characters; and (iii) providing informed consent to participate in the present study. Exclusion criteria were (i) being aged below 20 years because the Civil Law in Taiwan defines adults as being aged 20 years or above (i.e., when a participant is aged below 20 years, a guardian's consent is needed) and (ii) having a chronic disease or condition that might affect participants' physical activity (chronic disease was self-reported by the participants in the online survey).

With assistance from the university's faculty and students, a link to the online survey (hosted on *Google Forms*) was distributed using a snowballing sampling method. Therefore, the response rate was unable to be calculated given the nature of snowballing sampling method in online surveys (i.e., the present authors were unable to trace where the link was distributed). When a potential participant logged in to take the survey, the first page described the eligibility of a participant and the study purpose. After participants read the descriptions, they were asked to provide informed consent by clicking the 'agree' button. The survey questions were then presented for the participant to complete. If a participant clicked the 'disagree' button after reading the first page descriptions, there was no access to the online survey. For those who participated in the baseline online survey (between August and September 2021), they were asked to provide their email addresses and mobile phone numbers. Three months later, research assistants sent out the Time 2 online survey (between November and December 2021) to the participants via the email addresses and mobile phone numbers. A reminder was sent again one week later, and two attempts of reminders were sent for the Time 2 follow-up. A similar procedure was used for the Time 3 survey (between February and April 2022). The data collection periods for the three times of assessments overlapped with the COVID-19 pandemic, including with a relatively minor outbreak in Taiwan.

Participants' data were linked using their email addresses and mobile phone numbers. Moreover, each participant received 100 New Taiwan Dollar (about \$3.3 US) for each participation (i.e., a participant could obtain 300 New Taiwan Dollars if the participant completed baseline, Time 2, and Time 3 surveys).

Among 974 participants recruited at baseline, 452 participants completed all three waves of assessment, and their responses were used for data analysis. The participants were relatively young (mean age = 23.70 years; SD = 4.30) with fewer male (versus female) students (396 males; 40.7%). The reported percentages of having a chronic disease (5.0%), currently smoking tobacco (4.3%), and currently consuming alcohol (8.6%) were relatively low. The top two subjects studied were physics and engineering ($n = 301$; 30.9%) and management ($n = 262$; 26.9%).

Measures

Physical activity. Participants' levels of physical activity were assessed with the International Physical Activity Questionnaire Short Form (IPAQ-SF) (Liou, Jwo, Yao, Chiang, & Huang, 2008). The IPAQ-SF, including its Chinese version, is a robust instrument with strong psychometric properties; e.g., content validity = 0.99 for the Chinese IPAQ-SF (Cheng et al., 2019; Fung et al., 2019; Liou et al., 2008; Macfarlane, Lee, Ho, Chan, & Chan, 2007; Saffari, Chen, Wu et al., 2022; Xu et al., 2022). There are seven items asking how much time an individual has spent on different types of physical activity (e.g., resting/sitting, walking, moderate physical activity, and vigorous physical activity).



Then, a guideline on scoring was applied to convert the item scores into metabolic equivalent of task (MET) [minutes per week] scores (International Physical Activity Questionnaire Research Committee, 2022). A sample item from the IPAQ-SF is, “During the last 7 days, how much time did you spend sitting on a week day?”.

Problematic smartphone use (PSPU). Participants’ PSPU was assessed with the Smartphone Application-Based Addiction Scale (SABAS) (Csibi et al., 2018). The SABAS, including its Chinese version, has good psychometric properties; e.g., internal consistency = 0.79 for the Chinese SABAS (Chen, Strong et al., 2020; Csibi, Demetrovics, & Szabo, 2016; Csibi et al., 2018; Leung et al., 2020; C.-Y. Lin et al., 2019; Soraci, Ferrari, Urso, & Griffiths, 2021; Yam et al., 2019). There are six items rated on a six-point Likert-like scale ranging from 1 to 6 for the SABAS, generating a score range between 6 and 36, with higher scores reflecting more severe PSPU (Csibi et al., 2016, 2018). A total score higher than 21 indicates at-risk/PSPU (Mamun, Rayhan, Akter, & Griffiths, 2020). A sample item from the SABAS is “My smartphone use results in conflicts.” The internal consistency of the SABAS in the present longitudinal study was 0.83 (baseline), 0.89 (Time 2), and 0.88 (Time 3).

Problematic social media use (PSMU). Participants’ PSMU was assessed with the Bergen Social Media Addiction Scale (BSMAS) (Andreassen et al., 2017). The BSMAS, including its Chinese version, has good psychometric properties; e.g., internal consistency = 0.82 for the Chinese BSMAS (Andreassen et al., 2017; Banyai et al., 2017; Chen, Ahorsu et al., 2020; Dadiotis et al., 2021; Lin, Brostrom, Nilsen, Griffiths, & Pakpour, 2017; Leung et al., 2020; Monacis, de Palo, Griffiths, & Sinatra, 2017; Pontes, Andreassen, & Griffiths, 2016). There are six items rated on a five-point Likert-like scale ranging from 1 to 5 for the BSMAS, generating a score range between 6 and 30, with higher scores reflecting more severe PSMU (Andreassen et al., 2017; Banyai et al., 2017). A total score higher than 19 indicates at-risk/PSMU (Banyai et al., 2017). A sample item from the BSMAS is “You feel an urge to use social media more and more.” The internal consistency of the BSMAS in the present longitudinal study was 0.87 (baseline), 0.92 (Time 2), and 0.89 (Time 3).

Problematic gaming (PG). Participants’ PG was assessed with the Internet Gaming Disorder Short Form (IGDS9-SF) (Pontes & Griffiths, 2015). The IGDS9-SF, including its Chinese version, has demonstrated very good psychometric properties; e.g., internal consistency = 0.94 for the Chinese IGDS9-SF (Chang et al., 2022; Chang, Chang, Hou, Lin, & Griffiths, 2020; Chen, Ahorsu et al., 2020; Chen, A. H. Pakpour et al., 2020; Leung et al., 2020; Poon et al., 2021; Wu et al., 2017). There are nine items rated on a five-point Likert-like scale ranging from 1 to 5 for the IGDS9-SF, generating a score range between 9 and 45, with higher scores reflecting more severe PG (Pontes & Griffiths, 2015). A total score higher than 32 indicates at-risk/PG (Qin et al., 2020).

A sample item from the IGDS9-SF is “Do you feel preoccupied with your gaming behavior?”. The internal consistency of the IGDS9-SF in the present longitudinal study was 0.95 (baseline), 0.96 (Time 2), and 0.96 (Time 3).

Demographics. Basic demographic information asked for in the survey included age (reported in years), gender (male or female), having a chronic disease (yes or no), currently smoking tobacco (yes or no), currently drinking alcohol (yes or no), and study major (medicine and biosciences; social sciences; literature; management; physics and engineering; and other).

Data analysis

The data were first examined to determine if they were missing completely at random (MCAR), missing at random (MAR), or missing not at random (MNAR). Little’s MCAR test was used to examine MCAR, and if MCAR was not satisfied, MAR was examined using independent *t*-tests or χ^2 tests to detect if significant differences were found in the studied variables at baseline between the participants who were retained in the study or lost to follow-up. According to Kristman, Manno, and Cote (2004), there is no important bias when the loss to follow-up is below 60% at MAR or MCAR.

After ensuring the data were MCAR or MAR with acceptable rates in loss to follow-up, descriptive statistics were used to summarize the participants’ demographic information at baseline and their levels of PSPU, PSMU, PG, and physical activity across the three assessment times. Pearson correlations were used to understand associations between PSPU, PSMU, PG, and level of physical activity across the three assessment times. Linear mixed-effect models with age and gender controlled for were then used to examine whether level of physical activity, PSPU, PSMU, and PG had changed across the three time points. Finally, linear mixed-effect models were constructed again to examine temporal relationships between each PUIS measure (i.e., PSPU, PSMU, and PG) and physical activity. All linear mixed-effect models shared the same dependent variable (i.e., physical activity) and controlled variables (i.e., age, gender, and time). The differences in these linear mixed effects models were the independent variable of PUIS and the interaction terms of each PUIS measure with time. The random effects were set at intercept and a first-order autoregressive algorithm (i.e., AR [1]) was used to serve as the variance covariance structure for all the linear mixed-effects models. All statistical analyses were performed using SAS 9.4 (SAS Institute Inc., Cary: NC).

Power analysis

Given that the main analysis in the present study involved linear mixed-effects models, the power and sample size estimations were conducted based on the guidelines of Snijders (2005) and Brysbaert and Stevens (2018). More specifically, the following assumptions were used to calculate the required sample size to achieve power of 0.9: a two-level design in the



multilevel analysis, number of clustered groups being 400 in the level-2 unit (i.e., having at least 400 participants to complete repeated measures), type I error being 0.05, and a small effect size (i.e., Cohen's d at 0.2). Consequently, a total sample size of 1,152 observations with each cluster having three observations was sufficient. In other words, the power is 0.9 when there are 384 participants with each participant completing the three timepoint assessments in the present study.

Ethics

Participation in the study was voluntary and informed consent was obtained. All the answers and personal information were treated confidentially. The study was approved by the Institutional Review Board in the Chi Mei Medical Center (IRB Serial No.: 11007-006) and the Human Research Ethics Committee in the National Cheng Kung University (Approval No.: NCKU HREC-E-109-551-2).

RESULTS

Among 974 participants recruited at the baseline, 452 participants completed all three waves of assessment (retention

rate: 46.4%). That is, the rate of loss to follow-up was 53.6% (below 60%). The Little's MCAR test was significant ($\chi^2 = 263.59$, $df = 36$; $P < 0.001$), indicating the data missing were not completely random. However, MAR was supported as no significant differences were found in the studied variables at baseline between participants who were retained in the study and those who were lost to follow-up ($P = 0.055$ – 0.31).

Table 1 reports demographic, PUIS and physical activity information. Participants' PSPU severity was higher at baseline (Mean = 22.80; SD = 5.44) as compared with Times 2 and 3 (Mean = 20.37 and 20.79; SD = 6.20 and 5.78); PSMU severity was lower at baseline and Time 2 (Mean = 15.90 and 15.98; SD = 4.78 and 5.32) as compared with Time 3 (Mean = 16.14; SD = 4.97); PG severity increased from baseline to Time 3 (Mean = 18.76, 19.83, and 21.41; SD = 8.24, 8.43, and 8.99); level of physical activity was lower at baseline (Mean = 2114.56; SD = 1872.09) as compared with Times 2 and 3 (Mean = 3224.31 and 3221.68; SD = 2821.06 and 3144.43). Linear mixed-effects models further showed that PSPU level became significantly lower as compared with baseline (Time 2: $B = -2.16$, SE = 0.27, effect size [ES] = -0.18 ; $P < 0.001$; Time 3: $B = -1.56$, SE = 0.25, ES = -0.12 ; $P < 0.001$); PSMU had no significant differences between the follow-ups and baseline (Time 2: $B = -0.40$, SE = 0.23,

Table 1. Participants' characteristics ($N = 974$ or 452^a)

	Mean (SD) or n (%) ($N = 974$)	Mean (SD) or n (%) ($N = 452^a$)
Age (in years)	23.70 (4.30)	23.65 (4.13)
Gender (male)	396 (40.7)	207 (45.80)
Having chronic disease (yes)	49 (5.0)	19 (4.20)
Current tobacco smoking (yes)	42 (4.3)	14 (3.10)
Current alcohol drinking (yes)	84 (8.6)	37 (8.19)
Study major		
<i>Medicine and biosciences</i>	119 (12.2)	48 (10.6)
<i>Social sciences</i>	78 (8.0)	35 (7.7)
<i>Literature</i>	130 (13.4)	61 (13.5)
<i>Management</i>	262 (26.9)	112 (24.8)
<i>Physics and engineering</i>	301 (30.9)	158 (35.0)
<i>Other</i>	84 (8.6)	38 (8.4)
PSPU at Time 1 (score range: 6–36)	22.80 (5.44)	23.35 (5.58)
PSPU at Time 2 (score range: 6–36)	–	20.06 (6.29)
PSPU at Time 3 (score range: 6–36)	–	20.96 (5.67)
PSMU at Time 1 (score range: 6–30)	15.90 (4.78)	16.36 (4.58)
PSMU at Time 2 (score range: 6–30)	–	16.15 (4.82)
PSMU at Time 3 (score range: 6–30)	–	16.39 (5.12)
PG at Time 1 (score range: 9–45)	18.76 (8.24)	19.52 (8.10)
PG at Time 2 (score range: 9–45)	–	21.06 (8.10)
PG at Time 3 (score range: 9–45)	–	21.95 (9.38)
Physical activity level at Time 1 (MET [*] minute/week)	2114.56 (1872.09)	2209.32 (1986.02)
Physical activity level at Time 2 (MET [*] minute/week)	–	3193.15 (2740.37)
Physical activity level at Time 3 (MET [*] minute/week)	–	3251.57 (3309.41)

^a452 participants completed all three measurements.

Physical activity level was assessed using International Physical Activity Questionnaire Short Form.

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

Problematic social media use was assessed using Bergen Social Media Addiction Scale.

Problematic gaming was assessed using Internet Gaming Disorder Scale Short Form.



ES = -0.04; $P = 0.08$; Time 3: $B = -0.28$, SE = 0.21, ES = -0.02; $P = 0.19$); PG became significantly higher as compared with baseline (Time 2: $B = -0.07$, SE = 0.37, ES = -0.004; $P = 0.85$; Time 3: $B = 0.75$, SE = 0.34, ES = 0.04; $P = 0.03$); and physical activity became significantly higher as compared with baseline (Time 2: $B = -972.22$, SE = 131.11, ES = 0.18; $P < 0.001$; Time 3: $B = 1027.27$, SE = 126.39, ES = 0.17; $P < 0.001$). Moreover, 58.7% (Time 1), 41.6% (Time 2), and 44.4% (Time 3) of participants had at-risk/PSPU; 20.9% (Time 1), 25.4% (Time 2), and 24.6% (Time 3) had at-risk/PSMU; 7.4% (Time 1), 7.1% (Time 2), and 12.3% (Time 3) had at-risk/PG.

The correlations between PSPU, PSMU, PG, and physical activity measures across the three assessment time points are presented in Table 2. In brief, PSPU, PSMU, and PG were significantly correlated in mostly moderate to strong magnitudes across the three assessment time points ($r = 0.116$ to 0.717 ; $P < 0.01$). The temporal associations between PUIS and physical activity are presented in Table 3 utilizing a linear mixed-effect model with adjustments for age and gender. PSPU was not significantly associated with physical activity, although trend-level positive interactions were observed (ES = 0.09 and 0.09; $P = 0.08$ and 0.08). For PSMU, there was a significant and positive interaction effect at Time 3 on physical activity (ES = 0.16; $P = 0.001$) when compared with baseline. For PG, there were significant and positive interaction effects at both Time 2 (ES = 0.16; $P = 0.001$) and Time 3 (ES = 0.12; $P = 0.02$). The trajectories of three types of PUIS and physical activity are presented in Fig. 1.

DISCUSSION

The results of the present study indicated positive temporal associations between two types of PUIS (i.e., PSMU and PG) and levels of physical activity among Taiwanese university students. More specifically, the present study used linear mixed-effect models and found that PSMU and PG were positively related to levels of physical activity across time, while PSPU showed no significant relationships with levels of physical activity across time. The present study's findings did not support the original hypothesis (i.e., negative associations between different types of PUIS and levels of physical activity would be observed across time) and previous study findings (e.g., Islam et al., 2020; Lepp et al., 2013). However, the present study's findings did not support the hypotheses constructed using the pickle jar theory. Therefore, the multitask theory (Spink, Cole, & Waller, 2008) may in part explain the finding that the use of social media and online gaming may overlap with physical activity. In other words, the health-promoting effects of social media (Didi & Lundy, 2017) or health-facilitating effects of online gaming (Kaczmarek, Misiak, Behnke, Dziekan, & Guzik, 2017; Laor, 2020) may in part help individuals engage in physical activity, although this possibility is speculative. Regarding prevalence estimates of at-risk/PUIS, the present study showed a relatively high prevalence of at-risk/PSPU

Table 2. Pearson correlations between physical activity level, problematic smartphone use (PSPU), problematic social media use (PSMU), and problematic gaming (PG) across time ($N = 452$)

	PA_T1	PSPU_T1	PSMU_T1	PG_T1	PA_T2	PSPU_T2	PSMU_T2	PG_T2	PA_T3	PSPU_T3	PSMU_T3	PG_T3
PA_T1	(-)											
PSPU_T1	-0.021	(0.84)										
PSMU_T1	0.114	0.627***	(0.86)									
PG_T1	0.112	0.503***	0.496***	(0.96)								
PA_T2	0.464**	-0.028	0.059	0.100	(-)							
PSPU_T2	0.030	0.638***	0.486***	0.299***	0.187***	(0.91)						
PSMU_T2	0.195**	0.495***	0.665***	0.366***	0.258***	0.647***	(0.90)					
PG_T2	0.206**	0.360***	0.352***	0.689***	0.280***	0.339***	0.553***	(0.96)				
PA_T3	0.514***	-0.007	0.048	0.054	0.615***	0.237***	0.366***	0.339***	(-)			
PSPU_T3	0.078	0.600***	0.540***	0.333***	0.132**	0.701***	0.569***	0.325***	0.198***	(0.89)		
PSMU_T3	0.164*	0.497***	0.646***	0.426***	0.220**	0.446***	0.680***	0.544***	0.365***	0.624***	(0.92)	
PG_T3	0.211**	0.401***	0.442***	0.655***	0.167***	0.178***	0.488***	0.747***	0.294***	0.360***	0.623***	(0.97)

T1 = Time 1; T2 = Time 2; T3 = Time 3; PA = Physical activity level.

Values in parentheses are Cronbach's α for the instrument scores collected at that time.

Physical activity level was assessed using International Physical Activity Questionnaire Short Form.

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

Problematic social media use was assessed using Bergan Social Media Addiction Scale.

Problematic gaming was assessed using Internet Gaming Disorder Scale Short Form.

* $P < 0.05$ ** $P < 0.01$ *** $P < 0.001$.



Table 3. Linear mixed effects model examining the temporal associations between problematic use of the Internet/smartphone (PUIS) and physical activity (N = 452)

	B (SE)/P-value		
Age	39.40 (17.37)/ 0.02	36.37 (17.14)/ 0.03	39.40 (17.04)/ 0.02
Gender (Ref: male)	13.50 (150.60)/0.93	34.04 (147.37)/0.82	189.01 (150.11)/0.21
Time 2 (Ref: Time 1)	109.11 (516.61)/0.83	586.40 (434.89)/0.18	-6.59 (330.12)/0.98
Time 3 (Ref: Time 1)	127.83 (524.56)/0.81	-334.85 (438.16)/0.44	283.24 (324.57)/0.38
PSPU	-21.35 (17.98)/0.24	-	-
PSMU	-	23.58 (20.53)/0.25	-
PG	-	-	8.19 (12.02)/0.50
PSPU * Time 2 (Ref: Time 1)	39.54 (22.85)/0.08	-	-
PSPU * Time 3 (Ref: Time 1)	40.54 (22.99)/0.08	-	-
PSMU * Time 2 (Ref: Time 1)	-	25.52 (26.17)/0.33	-
PSMU * Time 3 (Ref: Time 1)	-	85.88 (26.24)/ 0.001	-
PG * Time 2 (Ref: Time 1)	-	-	51.22 (15.81)/ 0.001
PG * Time 3 (Ref: Time 1)	-	-	36.81 (15.17)/ 0.02

Physical activity level was assessed using International Physical Activity Questionnaire Short Form. Problematic smartphone use (PSPU) was assessed using Smartphone Application-Based Addiction Scale. Problematic social media use (PSMU) was assessed using Bergen Social Media Addiction Scale. Problematic gaming (PG) was assessed using Internet Gaming Disorder Scale Short Form. Significant correlation coefficients are in **bold**.

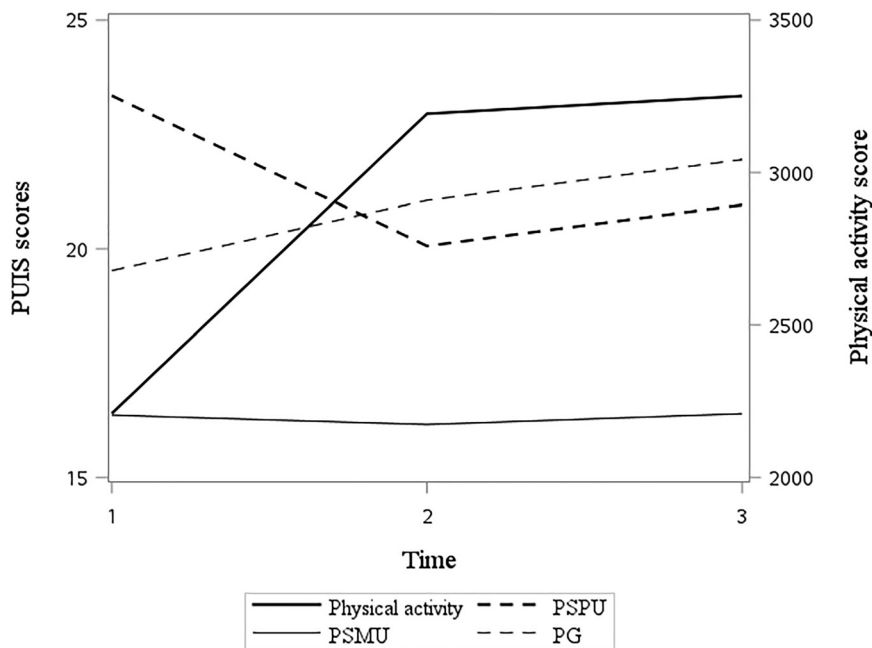
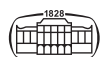


Fig. 1. Trajectories of problematic use of Internet/smartphone (PUIS) and physical activity levels across three time points. PSPU = problematic smartphone use (scores range between 6 and 36); PSMU = problematic social media use (scores range between 6 and 30); PG = problematic gaming (scores range between 9 and 45). The unit of physical activity level was metabolic equivalent of task (MET) multiplied by minutes for a week

and relatively low prevalence of at-risk/PSMU and at-risk/PG when compared to other mainly Asian studies: 44.4% (at-risk/PSPU), 24.6% (at-risk/PSMU), and 12.3% (at-risk/PG) in the present findings versus 26.4%–40% (at-risk/PSPU) (Kim, Kim, & Jee, 2015; Yuchang, Cuicui, Junxiu, & Junyi, 2017; Tateno et al., 2019), 26.2%–44.5% (at-risk/PSMU), and 15.4%–26.0% (at-risk/PG) (Tang, Koh, & Gan, 2017).

The positive association found between PSMU and physical activity measures may potentially be explained by some positive features of social media. Social media may create accessible, sharable and creatable online platforms for individuals to communicate with others (McGowan et al., 2012). The features of social media, such as entertainment (Dzogbenuku, Doe, & Amoako, 2021), information promotion (McGowan et al., 2012; Neely, Eldredge, & Sanders, 2021)



and online social support (Brailovskaia et al., 2021; Precht et al., 2022; Zhao et al., 2021) often attract individuals (Banyai et al., 2017). The studies conducted by Brailovskaia and colleagues (Brailovskaia et al., 2018, 2020, 2021) showed that online social support mediated the association between daily stress and PSMU (Brailovskaia et al., 2018; 2021) and that physical activity had a mediating effect on suppressing addictive behavior derived from online social support (Brailovskaia et al., 2021). In other words, reduction of social media use could result in increasing physical activity levels (Brailovskaia, Teismann, & Margraf, 2020). However, the results of the present study found a collaborative increment of both PSMU and physical activity level. Health promotion effects may be disseminated via social media (e.g., Facebook or Twitter) and benefit individuals by providing health resources (Diddi & Lundy, 2017), supportive interactions (Brailovskaia et al., 2021; Laor, 2020; Precht et al., 2022; Zhao et al., 2021) and motivations for health-change behaviors (Charry & Tessitore, 2021; Kaczmarek et al., 2017). Such beneficial effects may potentially contribute to the PSMU-physical activity relationships observed in the present study.

Additionally, possible effects related to the COVID-19 pandemic should be considered. A previous study found that the psychological burden of COVID-19 pandemic mediated the relationship between physical activity and PSMU (Precht et al., 2022). However, physical activity before the COVID-19 pandemic may have effectively suppressed PSMU (Brailovskaia et al., 2021). Therefore, in specific circumstances, physical activity may represent a cost-effective intervention to avoid excessive social media use (Precht et al., 2022).

Positive associations found between PG and physical activity measures may be explained by some positive features of gaming. Internet gaming may provide interactive environments for single or group participation (Doh & Whang, 2014). The appealing features including “entertainment and leisure”, “social contact and grouping”, “excitability and strategies seeking” and “escape from reality” may be attractive to individuals (Griffiths, Davies, & Chappell, 2004; Tone, Zhao, & Yan, 2014; Xu, Turel, & Yuan, 2012). Specific types of online game (e.g., augmented reality games or exergames) may have health-facilitating effects via interactive activities (Laor, 2020) that may motivate individuals to engage in healthy behaviors (Kaczmarek et al., 2017). For example, ‘Adventure Sync’ in *Pokémon Go* rewards players by recording the number of daily walking steps and the exergame, *Zombies, Run!* Prompts the players to exercise due to the interactive missions and running scenarios. The narrative structure of these online games is used to modify the perceptions of individuals and distract them from the physical activity they may be exerting during the playing of the game (Farič et al., 2021). Subsequently, these games may motivate the players to engage in outdoor activity (Zsila et al., 2018). Therefore, these aspects may in part explain the observed PG-physical activity relationships, although further study is warranted to examine these possibilities.

No across-time PSPU-physical activity associations were found in the present study. As a form of generalized PUIS

(Davis, 2001), PSPU substantially overlaps with specific forms of PUIS that are not limited to PSMU and PG (Islam et al., 2020). The summation of a variety of forms of specific PUIS may be reflected in more severe PSPU, particularly as smartphone use is widespread (Wang, Xiang, & Fesenmaier, 2016). In other words, there is a likelihood that various types of specific PUIS were conducted through smartphones and therefore reflected as PSPU. However, no association was found between PSPU and physical activity in the present study, although PSPU decreased over time and physical activity increased over time.

The present study has several limitations. First, the present study used self-report assessments, which are prone to recall, social-desirability, and misrepresentation biases. Second, the present study lacks information regarding the types of smartphone application used. Therefore, it was not possible to investigate possible effects between types of applications used with respect to physical activity. Third, the study involved university students in Taiwan. The extent to which the findings may apply to other jurisdictions, age groups and non-university young adults requires further investigation. Fourth, possible effects related to the COVID-19 pandemic or other factors cannot be excluded. Nevertheless, the present study provided novel insight that PSMU and PG were positively linked to physical activity among Taiwanese university students. In other words, use of social media and online gaming may lead to an increase in physical activity among some individuals. However, excessive use of social media and online gaming may generate other health and behavior problems (Liu et al., 2022). Therefore, it is important to identify specific factors related to social media use and online gaming that benefit individuals’ physical activity but that do not lead to the development of other health and behavioral problems. In addition, further research topics derived from the present study including investigation of the correlations between different types of smartphone applications to physical activity and investigation of the purpose or perception of use of social media or online gaming are suggested to help explore the underlying mechanisms of how these addictive behaviors are related to physical activity.

CONCLUSION

The present study investigated the temporal associations between physical activity and PSPU, PSMU and PG among Taiwanese university students. The results showed that specific forms of PUIS of PSMU and PG correlated positively with physical activity, while the generalized form of PUIS of PSPU was not associated with physical activity. The findings suggest a need for more investigation into the underlying mechanisms regarding how PSMU and PG are linked to more physical activity. While it seems inappropriate to promote excessive use of social media or gaming, the links to more physical activity are noteworthy. Future studies should investigate underlying mechanisms regarding the associations between specific forms of PUIS and physical



activity in order to help university students lead more active healthy lifestyles.

Funding sources: This research was supported in part by (received funding from) the Ministry of Science and Technology, Taiwan (MOST 110-2410-H-006-115), the Higher Education Sprout Project, the Ministry of Education at the Headquarters of University Advancement at the National Cheng Kung University (NCKU), and the 2021 Southeast and South Asia and Taiwan Universities Joint Research Scheme (NCKU 31).

Authors' contribution: Conceptualization: P-CH, J-SC, C-YL; methodology: J-SC, MNP, MDG, AHP, C-HH, C-YL; software: P-CH, J-SC, J-KC, C-YL; validation: J-SC, MNP, MDG, AHP, Y-CC, J-KC, C-HH; formal analysis: C-YL; investigation: Y-CL, C-YL; resources: J-SC, C-YL; data curation: C-YL; writing – original draft preparation: P-CH, C-YL; writing – review and editing: J-SC, MNP, MDG, AHP, Y-CL, C-HH, C-YL; visualization: P-CH, C-YL; supervision: C-YL; project administration: C-YL; funding acquisition: C-YL. All authors had full access to all data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Conflict of interest: The authors declare no conflict of interest. Dr. Potenza has consulted for Opiant Pharmaceuticals, Idorsia Pharmaceuticals, AXA, Baria-Tek, Game Day Data, and the Addiction Policy Forum; has been involved in a patent application with Yale University and Novartis; has received research support (to Yale) from Mohegan Sun Casino and the Connecticut Council on Problem Gambling; has participated in surveys, mailings or telephone consultations related to drug addiction, impulse-control disorders or other health topics; has consulted for and/or advised gambling and legal entities on issues related to impulse-control/addictive disorders; has performed grant reviews for research-funding agencies; has edited journals and journal sections; has given academic lectures in grand rounds, CME events and other clinical or scientific venues; and has generated books or book chapters for publishers of mental health texts. Dr. Potenza is an Associate Editor of the Journal of Behavioral Addictions.

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