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

DOI:
10.1556/2006.2022.00084

FULL-LENGTH REPORT

Check for updates

PO-CHING HUANG[1], JUNG-SHENG CHEN[2], MARC N. POTENZA[3,4,5,6,7,8], MARK D. GRIFFITHS[9], AMIR H. PAKPOUR[10], JI-KANG CHEN[11], YI-CHING LIN[12], CHING-HSIA HUNG[1,13], KERRY S. O'BRIEN[14] and CHUNG-YING LIN[1,15,16,17]*

[1] Institute of Allied Health Sciences, College of Medicine, National Cheng Kung University, Tainan, Taiwan

[2] Department of Medical Research, E-Da Hospital, Kaohsiung, Taiwan

[3] Department of Psychiatry, Yale School of Medicine, New Haven, CT, USA

[4] Connecticut Mental Health Center, New Haven, CT, USA

[5] Connecticut Council on Problem Gambling, Wethersfield, CT, USA

[6] Child Study Center, Yale School of Medicine, New Haven, CT, USA

[7] Department of Neuroscience, Yale University, New Haven, CT, USA

[8] Wu Tsai Institute, Yale University, New Haven, CT, USA

[9] International Gaming Research Unit, Psychology Department, Nottingham Trent University, Nottingham, UK

[10] Department of Nursing, School of Health and Welfare, Jönköping University, Jönköping, Sweden

[11] Department of Social Work, Chinese University of Hong Kong, New Territories, Hong Kong

[12] Department of Early Childhood and Family Education, National Taipei University of Education, Taipei, Taiwan

[13] Department of Physical Therapy, College of Medicine, National Cheng Kung University, Tainan, Taiwan

[14] School of Social Sciences, Monash University, Melbourne 3800, Australia

[15] Biostatistics Consulting Center, National Cheng Kung University Hospital, College of Medicine, National Cheng Kung University, Tainan, Taiwan

[16] Department of Public Health, College of Medicine, National Cheng Kung University, Tainan, Taiwan

[17] Department of Occupational Therapy, College of Medicine, National Cheng Kung University, Tainan, Taiwan

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

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 $= 22.99$;

*Corresponding author.
E-mail: cylin36933@gmail.com

AKJournals

$P = 0.08$). 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-Blanxart, & 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 infraction, 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 postgraduate) 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		
Medicine and biosciences	119 (12.2)	48 (10.6)
Social sciences	78 (8.0)	35 (7.7)
Literature	130 (13.4)	61 (13.5)
Management	262 (26.9)	112 (24.8)
Physics and engineering	301 (30.9)	158 (35.0)
Other	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)

[a]452 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 Bergan 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 (Diddi & 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 Bergan Social Media Addiction Scale.
Problematic gaming (PG) was assessed using Internet Gaming Disorder Scale Short Form.
Significant correlation coefficients are in **bold**.

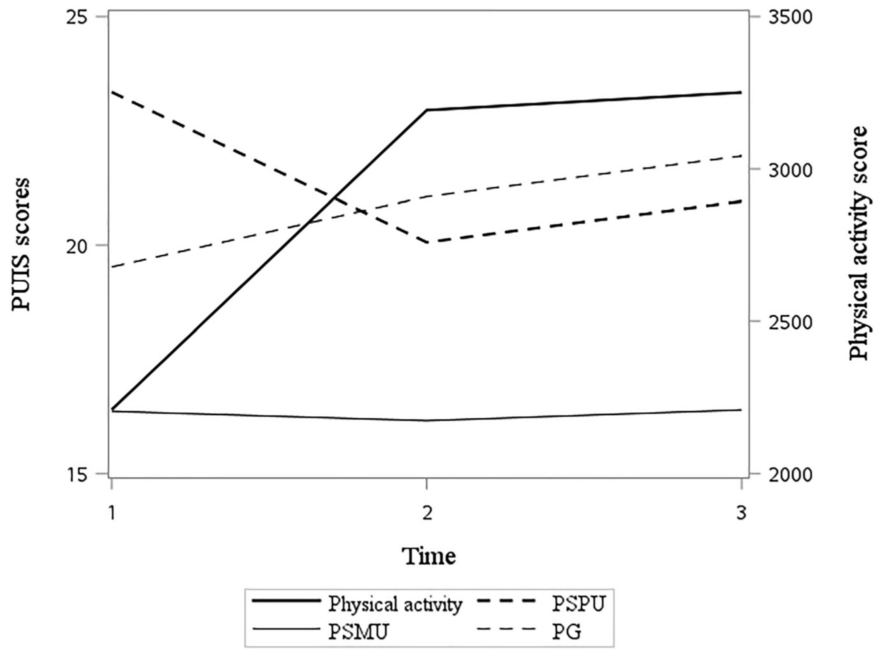

Fig. 1. Trajectories of problematic use of Internet/smartphone (PUIS) and physical activity levels across three time points. PSPU = problematic smartphone use (scores range between 6 and 36); PSMU = problematic social media use (scores range between 6 and 30); PG = problematic gaming (scores range between 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.

REFERENCES

Andreassen, C. S., Pallesen, S., & Griffiths, M. D. (2017). The relationship between addictive use of social media, narcissism, and self-esteem: Findings from a large national survey. *Addictive Behaviors*, *64*, 287–293. https://doi.org/10.1016/j.addbeh.2016.03.006.

Banyai, F., Zsila, A., Kiraly, O., Maraz, A., Elekes, Z., Griffiths, M. D., … Demetrovics, Z. (2017). Problematic social media use: Results from a large-Scale nationally representative adolescent sample. *Plos One*, *12*(1), e0169839. https://doi.org/10.1371/journal.pone.0169839.

Brailovskaia, J., Ozimek, P., & Bierhoff, H. W. (2021). How to prevent side effects of social media use (SMU)? Relationship between daily stress, online social support, physical activity and addictive tendencies - a longitudinal study. *Journal of Affective Disorders Reports*, *5*, 100144. http://doi.org/10.1016/j.jadr.2021.100144.

Brailovskaia, J., Ströse, F., Schillack, H., & Margraf, J. (2020). Less Facebook use–more well-being and a healthier lifestyle? An experimental intervention study. *Computers in Human Behavior*, *108*, 106332. https://doi.org/10.1016/j.chb.2020.106332.

Brailovskaia, J., Teismann, T., & Margraf, J. (2018). Physical activity mediates the association between daily stress and Facebook addiction disorder (FAD)–A longitudinal approach among German students. *Computers in Human Behavior*, *86*, 199–204. https://doi.org/10.1016/j.chb.2018.04.045.

Brysbaert, M., & Stevens, M. (2018). Power analysis and effect size in mixed effects models: A tutorial. *Journal of Cognition*, *1*(1), 9. http://doi.org/10.5334/joc.10.

Buckworth, J., & Nigg, C. (2004). Physical activity, exercise, and sedentary behavior in college students. *Journal of American College Health*, *53*(1), 28–34. https://doi.org/10.3200/JACH.53.1.28-34.

Chang, Y. H., Chang, K. C., Hou, W. L., Lin, C. Y., & Griffiths, M. D. (2020). Internet gaming as a coping method among schizophrenic patients facing psychological distress. *Journal of Behavioral Addictions*, *9*(4), 1022–1031. https://doi.org/10.1556/2006.2020.00081.

Chang, K. C., Chang, Y. H., Yen, C. F., Chen, J. S., Chen, P. J., Lin, C. Y., … Pakpour, A. H. (2022). 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. *Journal of Behavioral Addictions*, *11*(2), 567–576. https://doi.org/10.1556/2006.2022.00012.

Charry, K., & Tessitore, T. (2021). I tweet, they follow, you eat: Number of followers as nudge on social media to eat more healthily. *Social Science & Medicine*, *269*, 113595. https://doi.org/10.1016/j.socscimed.2020.113595.

Chen, I. H., Ahorsu, D. K., Pakpour, A. H., Griffiths, M. D., Lin, C. Y., & Chen, C. Y. (2020). Psychometric properties of three simplified Chinese online-related addictive behavior instruments among mainland Chinese primary school students. *Frontiers in Psychiatry*, *11*, 875. https://doi.org/10.3389/fpsyt.2020.00875.

Chen, I. H., Pakpour, A. H., Leung, H., Potenza, M. N., Su, J. A., Lin, C. Y., & Griffiths, M. D. (2020). Comparing generalized and specific problematic smartphone/internet use: Longitudinal relationships between smartphone application-based addiction and social media addiction and psychological distress. *Journal of Behavioral Addictions*, *9*(2), 410–419. https://doi.org/10.1556/2006.2020.00023.

Chen, I.-H., Strong, C., Lin, Y.-C., Tsai, M.-C., Leung, H., Lin, C.-Y., … Griffiths, M. D. (2020). Time invariance of three ultra-brief internet-related instruments: Smartphone application-based addiction scale (SABAS), Bergen social media addiction scale (BSMAS), and the nine-item internet gaming disorder scale-short form (IGDS-SF9)(study Part B). *Addictive Behaviors*, *101*, 105960. https://doi.org/10.1016/j.addbeh.2019.04.018.

Cheng, O. Y., Yam, C. L. Y., Cheung, N. S., Lee, P. L. P., Ngai, M. C., & Lin, C. Y. (2019). Extended theory of planned behavior on eating and physical activity. *American Journal of Health Behavior*, *43*(3), 569–581. https://doi.org/10.5993/AJHB.43.3.11.

Cheung, W., & Huang, W. (2005). Proposing a framework to assess internet usage in university education: An empirical investigation from a student's perspective. *British Journal of Educational Technology*, *36*(2), 237–253. https://doi.org/10.1111/j.1467-8535.2005.00455.x.

Clary, G., Dick, G., Akbulut, A. Y., & Van Slyke, C. (2022). The after times: College students' desire to continue with distance learning post pandemic. *Communications of the Association for Information Systems*, *50*(1), 3. https://doi.org/10.17705/1CAIS.05003.

Csibi, S., Demetrovics, Z., & Szabo, A. (2016). Hungarian adaptation and psychometric characteristics of brief addiction to smartphone scale (BASS). *Psychiatria Hungarica*, *31*(1), 71–77.

Csibi, S., Griffiths, M. D., Cook, B., Demetrovics, Z., & Szabo, A. (2018). The psychometric properties of the smartphone application-based addiction scale (SABAS). *International Journal of Mental Health and Addiction*, *16*(2), 393–403. https://doi.org/10.1007/s11469-017-9787-2.

Dadiotis, A., Bacopoulou, F., Kokka, I., Vlachakis, D., Chrousos, G. P., Darviri, C., & Roussos, P. (2021). Validation of the Greek version of the Bergen social media addiction scale in undergraduate students. *EMBnet Journal*, *26*. https://doi.org/10.14806/ej.26.1.975.

Davis, R. A. (2001). A cognitive-behavioral model of pathological internet use. *Computers in Human Behavior*, *17*(2), 187–195. https://doi.org/10.1016/S0747-5632(00)00041-8.

Diddi, P., & Lundy, L. K. (2017). Organizational Twitter use: Content analysis of tweets during breast cancer awareness month. *Journal of Health Communication*, *22*(3), 243–253. https://doi.org/10.1080/10810730.2016.1266716.

Doh, Y. Y., & Whang, S.-M. L. (2014). From separation to integration: Identity development of Korean adult players in online game world. *Games and Culture*, *9*(1), 30–57. https://doi.org/10.1177/1555412013498301.

Duke, É. & Montag, C. (2017). Smartphone addiction, daily interruptions and self-reported productivity. *Addictive Behaviors Reports*, *6*, 90–95. https://doi.org/10.1016/j.abrep.2017.07.002.

Dzogbenuku, R. K., Doe, J. K., & Amoako, G. K. (2021). Social media information and student performance: The mediating role of hedonic value (entertainment). *Journal of Research in Innovative Teaching & Learning*, *15*(1), 132–146. https://doi.org/10.1108/JRIT-12-2020-0095.

Farič, N., Potts, H. W., Rowe, S., Beaty, T., Hon, A., & Fisher, A. (2021). Running app "Zombies, Run!" users' engagement with physical activity: A qualitative study. *Games for Health Journal*, *10*(6), 420–429. https://doi.org/10.1089/g4h.2021.0060.

Fung, X. C. C., Pakpour, A. H., Wu, Y. K., Fan, C. W., Lin, C. Y., & Tsang, H. W. H. (2019). Psychosocial variables related to weight-related self-stigma in physical activity among young adults across weight status. *International Journal of Environmental Research and Public Health*, *17*(1), 64. https://doi.org/10.3390/ijerph17010064.

Gao, L., Gan, Y., Whittal, A., & Lippke, S. (2020). Problematic internet use and perceived quality of life: Findings from a cross-sectional study investigating work-time and leisure-time internet use. *International Journal of Environmental Research and Public Health*, *17*(11), 4056. https://doi.org/10.3390/ijerph17114056.

González-Pérez, Y. (2020). Disinformation in the information age. *European Journal of Hospital Pharmacy*, *27*(6), 319–321. https://doi.org/10.1136/ejhpharm-2020-002213.

Griffiths, M. (2010). Trends in technological advance: Implications for sedentary behaviour and obesity in screenagers. *Education and Health*, *28*(2), 35–38.

Griffiths, M. D., Davies, M. N., & Chappell, D. (2004). Demographic factors and playing variables in online computer gaming. *CyberPsychology & Behavior*, *7*(4), 479–487. https://doi.org/10.1089/cpb.2004.7.479.

Hamilton, M. T., Hamilton, D. G., & Zderic, T. W. (2014). Sedentary behavior as a mediator of type 2 diabetes. *Medicine and Sport Science*, *60*, 11–26. https://doi.org/10.1159/000357332.

Heiman-Patterson, T. D., Khazaal, O., Yu, D., Sherman, M. E., Kasarskis, E. J., Jackson, C. E., & Group, P. N. s. (2021). Pulmonary function decline in amyotrophic lateral sclerosis. *Amyotrophic Lateral Sclerosis & Frontotemporal Degeneration*, *22*(sup1), 54–61. https://doi.org/10.1080/21678421.2021.1910713.

International Physical Activity Questionnaire Research Committee (2015). Guidelines for data processing and analysis of the International Physical Activity Questionnaire (IPAQ)-short and long forms. Retrieved June 7, 2022, from: https://sites.google.com/site/theipaq/.

Islam, M. S., Sujan, M. S. H., Tasnim, R., Ferdous, M. Z., Masud, J. H. B., Kundu, S., … Griffiths, M. D. (2020). Problematic internet use among young and adult population in Bangladesh: Correlates with lifestyle and online activities during the COVID-19 pandemic. *Addictive Behaviors Reports*, *12*, 100311. https://doi.org/10.1016/j.abrep.2020.100311.

Kaczmarek, L. D., Misiak, M., Behnke, M., Dziekan, M., & Guzik, P. (2017). The Pikachu effect: Social and health gaming motivations lead to greater benefits of Pokémon GO use. *Computers in Human Behavior*, *75*, 356–363. https://doi.org/doi.org/10.1016/j.chb.2017.05.031.

Kamolthip, R., Chirawat, P., Ghavifekr, Gan, W. Y., Tung, S. E. H., Nurmala, I., … Lin, C.-Y. (2022). Problematic internet use (PIU) in youth: A brief literature review of selected topics. *Current Opinion in Behavioral Sciences*, *46*,101150. https://doi.org/10.1016/j.cobeha.2022.101150.

Kim, S. E., Kim, J. W., & Jee, Y. S. (2015). Relationship between smartphone addiction and physical activity in Chinese international students in Korea. *Journal of Behavioral Addictions*, *4*(3), 200–205. https://doi.org/10.1556/2006.4.2015.028.

Ko, C. H., Yen, J. Y., Yen, C. F., Lin, H. C., & Yang, M. J. (2007). Factors predictive for incidence and remission of internet addiction in young adolescents: A prospective study. *CyberPsychology & Behavior*, *10*(4), 545–551. https://doi.org/10.1089/cpb.2007.9992.

Kristman, V., Manno, M., & Cote, P. (2004). Loss to follow-up in cohort studies: How much is too much? *European Journal of Epidemiology*, *19*(8), 751–760. https://doi.org/10.1023/b:ejep.0000036568.02655.f8.

Laor, T. (2020). The race to escape: Location-based escapism and physical activity as a motivator in the consumption of the AR game Pokémon Go. *Cyberpsychology: Journal of Psychosocial Research on Cyberspace*, *14*(2). https://doi.org/10.5817/CP2020-2-6.

Lepp, A., Barkley, J. E., Sanders, G. J., Rebold, M., & Gates, P. (2013). The relationship between cell phone use, physical and sedentary activity, and cardiorespiratory fitness in a sample of U.S. college students. *International Journal of Behavioral Nutrition and Physical Activity*, *10*, 79. https://doi.org/10.1186/1479-5868-10-79.

Leung, H., Pakpour, A. H., Strong, C., Lin, Y. C., Tsai, M. C., Griffiths, M. D., … Chen, I. H. (2020). Measurement invariance across young adults from Hong Kong and Taiwan among three internet-related addiction scales: Bergen social media addiction scale (BSMAS), smartphone application-based addiction scale (SABAS), and internet gaming disorder scale-short form (IGDS-SF9) (study Part A). *Addictive Behaviors*, *101*, 105969. https://doi.org/10.1016/j.addbeh.2019.04.027.

Lin, C. Y., Brostrom, A., Nilsen, P., Griffiths, M. D., & Pakpour, A. H. (2017). Psychometric validation of the Persian Bergen social media addiction scale using classic test theory and Rasch models. *Journal of Behavioral Addictions*, *6*(4), 620–629. https://doi.org/10.1556/2006.6.2017.071.

Lin, C.-Y., Imani, V., Broström, A., Nilsen, P., Fung, X. C., Griffiths, M. D., & Pakpour, A. H. (2019). Smartphone application-based addiction among Iranian adolescents: A psychometric study. *International Journal of Mental Health and Addiction*, *17*(4), 765–780. https://doi.org/10.1007/s11469-018-0026-2.

Liou, Y. M., Jwo, C. J., Yao, K. G., Chiang, L. C., & Huang, L. H. (2008). Selection of appropriate Chinese terms to represent intensity and types of physical activity terms for use in the Taiwan version of IPAQ. *Journal of Nursing Research*, *16*(4), 252–263. https://doi.org/10.1097/01.jnr.0000387313.20386.0a.

Liu, W., Chen, J.-S., Gan, W. Y., Poon, W. C., Tung, S. E. H., Lee, L. J., … Lin, C. Y. (2022). Associations of problematic internet use and weight-related self-stigma, and nomophobia with physical activity: Findings from mainland China, Taiwan, and Malaysia. *International Journal of Environmental Research and Public Health*, *19*, 12135. https://doi.org/10.3390/ijerph191912135.

Lopez-Fernandez, O., Freixa-Blanxart, M., & Honrubia-Serrano, M. L. (2013). The problematic internet entertainment use scale for adolescents: Prevalence of problem internet use in Spanish high school students. *Cyberpsychology, Behavior, and Social Networking*, *16*(2), 108–118. https://doi.org/10.1089/cyber.2012.0250.

Macfarlane, D. J., Lee, C. C., Ho, E. Y., Chan, K. L., & Chan, D. T. (2007). Reliability and validity of the Chinese version of IPAQ (short, last 7 days). *Journal of Science and Medicine in Sport*, *10*(1), 45–51. https://doi.org/10.1016/j.jsams.2006.05.003.

Mamun, M. A., Rayhan, I., Akter, K., & Griffiths, M. D. (2020). Prevalence and predisposing factors of suicidal ideation among the university students in Bangladesh: A single-site survey. *International Journal of Mental Health and Addiction*, *20*, 1958–1971. https://doi.org/10.1007/s11469-020-00403-z.

Matusitz, J., & McCormick, J. (2012). Sedentarism: The effects of internet use on human obesity in the United States. *Social Work in Public Health*, *27*(3), 250–269. https://doi.org/10.1080/19371918.2011.542998.

McGowan, B. S., Wasko, M., Vartabedian, B. S., Miller, R. S., Freiherr, D. D., & Abdolrasulnia, M. (2012). Understanding the factors that influence the adoption and meaningful use of social media by physicians to share medical information. *Journal of Medical Internet Research*, *14*(5), e117. https://doi.org/10.2196/jmir.2138.

Monacis, L., de Palo, V., Griffiths, M. D., & Sinatra, M. (2017). Social networking addiction, attachment style, and validation of the Italian version of the Bergen Social Media Addiction Scale. *Journal of Behavioral Addictions*, *6*(2), 178–186. https://doi.org/10.1556/2006.6.2017.023.

Montag, C., Bey, K., Sha, P., Li, M., Chen, Y.-F., Liu, W.-Y., … Reuter, M. (2015a). Is it meaningful to distinguish between generalized and specific internet addiction? Evidence from a cross-cultural study from Germany, Sweden, Taiwan and China. *Asia-Pacific Psychiatry*, *7*(1), 20–26. https://doi.org/10.1111/appy.12122.

Montag, C., Błaszkiewicz, K., Sariyska, R., Lachmann, B., Andone, I., Trendafilov, B. M., … Markowetz, A. (2015b). Smartphone usage in the 21st century: Who is active on WhatsApp? *BMC Research Notes*, *8*, 331. https://doi.org/10.1186/s13104-015-1280-z.

Montag, C., Wegmann, E., Sariyska, R., Demetrovics, Z., & Brand, M. (2021). How to overcome taxonomical problems in the study of internet use disorders and what to do with "smartphone addiction"?. *Journal of Behavioral Addictions*, *9*(4), 908–914. https://doi.org/10.1556/2006.8.2019.59.

Mottram, A. J., & Fleming, M. J. (2009). Extraversion, impulsivity, and online group membership as predictors of problematic Internet use. *CyberPsychology & Behavior*, *12*(3), 319–321. https://doi.org/10.1089/cpb.2007.0170.

Müller, S. M., Wegmann, E., Oelker, A., Stark, R., Müller, A., Montag, C., … Brand, M. (2022). Assessment of criteria for specific Internet-use disorders (ACSID-11): Introduction of a new screening instrument capturing ICD-11 criteria for gaming disorder and other potential Internet-use disorders. *Journal of Behavioral Addictions*, *11*(2), 427–450. https://doi.org/10.1556/2006.2022.00013.

Neely, S., Eldredge, C., & Sanders, R. (2021). Health information seeking behaviors on social media during the COVID-19 pandemic among American social networking site users: Survey study. *Journal of Medical Internet Research*, *23*(6), e29802. https://doi.org/10.2196/29802.

Novikov, P. (2020). Impact of COVID-19 emergency transition to on-line learning onto the international students' perceptions of educational process at Russian university. *Journal of Social Studies Education Research*, *11*(3), 270–302. Retrieved May 22, 2022 from https://www.learntechlib.org/p/217752/.

Park, S. (2014). Associations of physical activity with sleep satisfaction, perceived stress, and problematic internet use in Korean adolescents. *BMC Public Health*, *14*, 1143. https://doi.org/10.1186/1471-2458-14-1143.

Pechtl, S. M. L., Kim, L. P., & Jacobsen, K. H. (2022) Physical inactivity and sedentariness: Languorous behavior among adolescents in 80 countries. *Journal of Adolescent Health*, *70*(6), 960–960. https://doi.org/10.1016/j.jadohealth.2021.12.017.

Pontes, H. M., Andreassen, C. S., & Griffiths, M. D. (2016). Portuguese validation of the Bergen Facebook addiction scale: An empirical study. *International Journal of Mental Health and Addiction*, *14*(6), 1062–1073. https://doi.org/10.1007/s11469-016-9694-y.

Pontes, H. M., & Griffiths, M. D. (2015). Measuring DSM-5 internet gaming disorder: Development and validation of a short psychometric scale. *Computers in Human Behavior*, *45*, 137–143. https://doi.org/10.1016/j.chb.2014.12.006.

Poon, L. Y. J., Tsang, H. W. H., Chan, T. Y. J., Man, S. W. T., Ng, L. Y., Wong, Y. L. E., … Pakpour, A. H. (2021). Psychometric properties of the internet gaming disorder scale-short-form (IGDS9-SF): Systematic review. *Journal of Medical Internet Research*, *23*(10), e26821. https://doi.org/10.2196/26821.

Precht, L.-M., Stirnberg, J., Margraf, J., & Brailovskaia, J. (2022). Can physical activity foster mental health by preventing addictive social media use? - a longitudinal investigation during the COVID-19 pandemic in Germany. *Journal of Affective Disorders Reports*, *8*, 100316. http://doi.org/10.1016/j.jadr.2022.100316.

Qin, L., Cheng, L., Hu, M., Liu, Q., Tong, J., Hao, W., … Liao, Y. (2020). Clarification of the cut-off score for nine-item internet gaming disorder scale-short form (IGDS9-SF) in a Chinese context. *Frontiers in Psychiatry*, *11*, 470. https://doi.org/10.3389/fpsyt.2020.00470.

Reutrakul, S., & Van Cauter, E. (2014). Interactions between sleep, circadian function, and glucose metabolism: Implications for risk and severity of diabetes. *Annals of the New York Academy of Sciences*, *1311*, 151–173. https://doi.org/10.1111/nyas.12355.

Saffari, M., Chen, H.-P., Chang, C.-W., Fan, C.-W., Huang, S.-W., Chen, J.-S., … Lin, C.-Y. (2022). Does sleep quality mediate the associations between problematic internet use and quality of life in people with substance use disorder? *BJPsych Open*, *8*, e155. http://doi.org/10.1192/bjo.2022.557.

Saffari, M., Chen, J. S., Wu, H. C., Fung, X. C. C., Chang, C. C., Chang, Y. L., … Lin, C. Y. (2022). Effects of weight-related self-stigma and smartphone addiction on female university students' physical activity levels. *International Journal of Environmental Research and Public Health*, *19*(5), 2631. https://doi.org/10.3390/ijerph19052631.

Shapira, N. A., Goldsmith, T. D., Keck, P. E., , Jr., Khosla, U. M., & McElroy, S. L. (2000). Psychiatric features of individuals with problematic internet use. *Journal of Affective Disorders*, *57*(1–3), 267–272. https://doi.org/10.1016/s0165-0327(99)00107-x.

Sinkkonen, H. M., Puhakka, H., & Merilainen, M. (2014). Internet use and addiction among Finnish adolescents (15–19 years). *Journal of Adolescence*, *37*(2), 123–131. https://doi.org/10.1016/j.adolescence.2013.11.008.

Skues, J., Williams, B., Oldmeadow, J., & Wise, L. (2016). The effects of boredom, loneliness, and distress tolerance on problem internet use among university students. *International Journal of Mental Health and Addiction*, *14*(2), 167–180. https://doi.org/10.1007/s11469-015-9568-8.

Snijders, T. A. B. (2005). Power and sample size in multilevel linear models. In B. S. Everitt, & D. C. Howell (Eds.), *Encyclopedia of statistics in behavioral science* (pp. 1570–1573). Chichester, UK: John Wiley and Sons. http://doi.org/10.1002/0470013192.bsa492.

Soraci, P., Ferrari, A., Urso, A. & Griffiths, M. D. (2021). Psychometric properties of the Italian version of the smartphone application-based addiction scale (SABAS). *International Journal of Mental Health and Addiction*, *19*, 1261–1273. https://doi.org/10.1007/s11469-020-00222-2.

Spada, M. M. (2014). An overview of problematic internet use. *Addictive Behaviors*, *39*(1), 3–6. https://doi.org/10.1016/j.addbeh.2013.09.007.

Spink, A., Cole, C., & Waller, M. (2008). Multitasking behavior. *Annual Review of Information Science and Technology*, *42*(1), 93–118.

Tang, C. S., Koh, Y. W., & Gan, Y. (2017). Addiction to internet use, online gaming, and online social networking among young adults in China, Singapore, and the United States. *Asia Asia Pacific Journal of Public Health*, *29*(8), 673–682. https://doi.org/10.1177/1010539517739558.

Tateno, M., Kim, D. J., Teo, A. R., Skokauskas, N., Guerrero, A. P. S., & Kato, T. A. (2019). Smartphone addiction in Japanese college students: Usefulness of the Japanese version of the smartphone addiction scale as a screening tool for a new form of internet addiction. *Psychiatry Investigation*, *16*(2), 115–120. https://doi.org/10.30773/pi.2018.12.25.2.

Tone, H.-J., Zhao, H.-R., & Yan, W.-S. (2014). The attraction of online games: An important factor for internet addiction. *Computers in Human Behavior*, *30*, 321–327. https://doi.org/10.1016/j.chb.2013.09.017.

Tsitsika, A. K., Andrie, E. K., Psaltopoulou, T., Tzavara, C. K., Sergentanis, T. N., Ntanasis-Stathopoulos, I., … Tsolia, M. (2016). Association between problematic internet use, socio-demographic variables and obesity among European adolescents. *European Journal of Public Health*, *26*(4), 617–622. https://doi.org/10.1093/eurpub/ckw028.

Tung, S. E. H., Gan, W. Y., Chen, J.-S., Kamolthip, R., Pramukti, I., Nadhiroh, S. R., … Griffiths, M. D. (2022). Internet-related instruments (Bergen social media addiction scale, smartphone application-based addiction scale, internet gaming disorder scale-short form, and nomophobia questionnaire) and their associations with distress among Malaysian university student. *Healthcare*, *10*, 1448. https://doi.org/10.3390/healthcare10081448.

Vandelanotte, C., Sugiyama, T., Gardiner, P., & Owen, N. (2009). Associations of leisure-time internet and computer use with overweight and obesity, physical activity and sedentary behaviors: Cross-sectional study. *Journal of Medical Internet Research*, *11*(3), e28. https://doi.org/10.2196/jmir.1084.

Wang, D., Xiang, Z., & Fesenmaier, D. R. (2016). Smartphone use in everyday life and travel. *Journal of Travel Research*, *55*(1), 52–63. https://doi.org/10.1177/0047287514535847.

Weinberg, B. D., Milne, G. R., Andonova, Y. G., & Hajjat, F. M. (2015). Internet of Things: Convenience vs. privacy and secrecy. *Business Horizons*, *58*(6), 615–624. https://doi.org/10.1016/j.bushor.2015.06.005.

Wimmer, H., Powell, L., Kilgus, L., & Force, C. (2017). Improving course assessment via web-based momework. *International Journal of Online Pedagogy and Course Design*, *7*(2), 1–19. https://doi.org/10.4018/IJOPCD.2017040101.

Wright, J. (2002). Time management: The pickle jar theory. *A List Apart*, *146*, 1–5.

Wu, T. Y., Lin, C. Y., Arestedt, K., Griffiths, M. D., Brostrom, A., & Pakpour, A. H. (2017). Psychometric validation of the Persian nine-item Internet Gaming Disorder Scale – Short Form: Does gender and hours spent online gaming affect the interpretations of item descriptions? *Journal of Behavioral Addictions*, *6*(2), 256–263. https://doi.org/10.1556/2006.6.2017.025.

Xu, P., Chen, J. S., Chang, Y. L., Wang, X., Jiang, X., Griffiths, M. D., … Lin, C. Y. (2022). Gender differences in the associations between physical activity, smartphone use, and weight stigma. *Frontiers in Public Health*, *10*, 862829. https://doi.org/10.3389/fpubh.2022.862829.

Xu, Z., Turel, O., & Yuan, Y. (2012). Online game addiction among adolescents: Motivation and prevention factors. *European Journal of Information Systems*, *21*(3), 321–340. https://doi.org/10.1057/ejis.2011.56.

Yam, C. W., Pakpour, A. H., Griffiths, M. D., Yau, W. Y., Lo, C. M., Ng, J. M. T., … Leung, H. (2019). Psychometric testing of three Chinese online-related addictive behavior instruments among Hong Kong university students. *Psychiatric Quarterly*, *90*(1), 117–128. https://doi.org/10.1007/s11126-018-9610-7.

Yang, S. Y., Chen, M. D., Huang, Y. C., Lin, C. Y., & Chang, J. H. (2017). Association between smartphone use and musculoskeletal discomfort in adolescent students. *Journal of Community Health*, *42*(3), 423–430. https://doi.org/10.1007/s10900-016-0271-x.

Yen, J. Y., Ko, C. H., Yen, C. F., Wu, H. Y., & Yang, M. J. (2007). The comorbid psychiatric symptoms of internet addiction: Attention deficit and hyperactivity disorder (ADHD), depression, social phobia, and hostility. *Journal of Adolescent Health*, *41*(1), 93–98. https://doi.org/10.1016/j.jadohealth.2007.02.002.

Yohannes, A. M., Doherty, P., Bundy, C., & Yalfani, A. (2010). The long-term benefits of cardiac rehabilitation on depression, anxiety, physical activity and quality of life. *Journal of Clinical Nursing*, *19*(19–20), 2806–2813. https://doi.org/10.1111/j.1365-2702.2010.03313.x.

Yuchang, J., Cuicui, S., Junxiu, A., & Junyi, L. (2017). Attachment styles and smartphone addiction in Chinese college students: The mediating roles of dysfunctional attitudes and self-esteem. *International Journal of Mental Health and Addiction*, *15*(5), 1122–1134. https://doi.org/10.1007/s11469-017-9772-9.

Zhao, J., Han, H., Zhong, B., Xie, W., Chen, Y., & Zhi, M. (2021). Health information on social media helps mitigate Crohn's disease symptoms and improves patients' clinical course. *Computers in Human Behavior*, *115*, 106588. https://doi.org/10.1016/j.chb.2020.106588.

Zsila, A., Orosz, G., Bőthe, B., Tóth-Király, I., Király, O., Griffiths, M. D., & Demetrovics, Z. (2018). An empirical study on the motivations underlying augmented reality games: The case of Pokémon Go during and after Pokémon fever. *Personality and Individual Differences, 133*, 56–66. https://doi.org/10.1016/j.paid.2017.06.024.