Preventive Medicine Reports 42 (2024) 102744

Contents lists available at ScienceDirect

Preventive Medicine Reports

journal homepage: www.elsevier.com/locate/pmedr

Review article

Could physical activity alleviate smartphone addiction in university students? A systematic literature review

Neha Pirwani [a,b], Attila Szabo [a,1,*]

[a] Institute of Health Promotion and Sport Sciences, Faculty of Education and Psychology, ELTE Eötvös Loránd University, Budapest, Hungary
[b] Doctoral School of Education, Faculty of Education and Psychology, ELTE Eötvös Loránd University, Budapest, Hungary

ARTICLE INFO

Keywords:
Behavioral addiction
Dependence
Physical activity
Internet
Mobile phone

ABSTRACT

Objectives: Recently, the widespread surge in smartphone addiction (SA) has raised major global health concerns and prompted researchers to scrutinize the inverse relationship between physical activity (PA) and the risk of SA. This systematic literature review aims to synthesize the empirical research on the relationship between PA and SA among university students representing the most affected age group.

Methods: Adopting the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines, we explored five databases: PubMed, Social Sciences Research Network (SSRN), Oxford Research Archive, Journal Storage (JSTOR), and Google Scholar. We used the Mixed Methods Appraisal Tools (MMAT) for quality assessment.

Results: Thirty-one studies met the inclusion criteria. Twenty-eight of them were cross-sectional, and three were experimental. The 31 studies emerged from 12 countries, most stemming (45.16%) from China. Their findings suggest an inverse relationship between PA and SA in the examined population. However, the direct relationship may be weak based on correlational studies, while intervention research yields noteworthy effects. Still, other factors like resilience may mediate the studied relationship. Methodological concerns render the results of correlational studies tentative.

Conclusions: Regular PA could be a promising preventive measure for SA. Future work should use objective PA indices in longitudinal research designs while assessing the type and duration of smartphone applications used via device meters. In correlational studies, interviews should follow up on the high SA risk or too much device use. In conclusion, moderate evidence indicates that PA *can reduce* SA among university students.

1. Introduction

Since the iPhone launch in 2007, smartphones have become a necessity rather than a luxury. There are more mobile phone subscriptions worldwide than people on the planet (World Economic Forum, 2023). Following the COVID-19 pandemic, humans depended on their smartphones more than ever (Ausman, 2021). With people quarantined in their homes, social contact and daily living were more manageable by internet-connected smartphone applications like WhatsApp, Zoom, online shopping, etc. Indeed, smartphones are handy and practical for everyday use in many areas of life. While they have many life-facilitating features and extraordinary hedonic and utilitarian capabilities, their usage pattern might become problematic.

Global public health has recently improved through technological innovation (Ye, 2020). However, overdependency on technology, like smartphones, could pose health risks. One urgent concern is the growing addiction to smartphone-based applications (Olson et al., 2022). This addiction requires immediate attention due to its connection to decreased physical activity (PA), and it shares characteristics of other behavioral addictions such as technological disorder, internet gaming disorder, and gambling disorder (Lin et al., 2017). Primary symptoms include compulsive and excessive use and preoccupation with smartphones, lack of productivity, functional impairment, and withdrawal when not using them (Duke and Montag, 2017; Lin et al., 2014; Rozgonjuk et al., 2020). Furthermore, studies revealed that smartphone addiction (SA) harms social and mental health. Examples include

* Corresponding author at: Institute of Health Promotion and Sports Sciences, Faculty of Education and Psychology, ELTE Eötvös Loránd University, Prielle Kornélia St. 47, Suite 3, H-1117 Budapest, Hungary.
E-mail address: szabo.attila@ppk.elte.hu (A. Szabo).
[1] ORCID: 0000-0003-2788-4304.

https://doi.org/10.1016/j.pmedr.2024.102744
Received 20 February 2024; Received in revised form 4 April 2024; Accepted 23 April 2024
Available online 24 April 2024

negative self-regulation, emotional intelligence, and connections with sadness, anxiety, and disturbed sleep (Cho and Lee, 2017; Gökçearslan et al., 2016). Further, SA is also associated with stress, shyness, loneliness, suicidal behavior, reduced social engagement, and lower academic achievement (Bian and Leung, 2015; Kuss and Griffiths, 2011).

Moreover, SA can trigger physical and mental health issues, including headaches, impaired memory, and poor attention (Khan, 2008). Furthermore, a sedentary lifestyle (a significant health concern) is another component of ill-patterned smartphone use. Indeed, the odds of increasing smartphone use were nearly three times higher in college students with low PA levels (Grimaldi-Puyana et al., 2020). Insufficient PA also harms physical and mental health (Carson et al., 2016). Research shows a high prevalence of physical inactivity in school-aged youngsters. Over four-fifths (80.4 %) of Southeast Asians are sedentary (Peltzer and Pengpid, 2016). Furthermore, 81 % of teenagers, 23 % of young adults, and 55 % of older persons worldwide do not exercise enough (World Health Organization, 2018). Physical inactivity and SA seem related, leading researchers to investigate their possible association. Physical activity, including sports participation, might be considered an intervention to address SA based on research disclosing the positive effects of exercise on psychological well-being and addictive tendencies (Surawska, 2017).

Since all addictions can be considered psychological issues (Dodes, 2009), research aimed at improving mental health could be beneficial in counteracting the route of the problem. More than two decades ago, research by DiLorenzo et al. (1999) showed that a 12-week exercise program significantly improved psychological factors. The favorable effects lasted beyond a year. Later research also emphasized the psychological benefits of increased PA (Stathopoulou et al., 2006). These research results suggest that an active lifestyle may lessen the subjectively perceived life problems (Glenister, 1996) and, consequently, individuals engaged in regular PA might have a lower risk of SA and better psychological health than non-exercisers (Liu et al., 2022). Therefore, research suggests that PA could be a prevention strategy in combating SA.

This systematic literature review aims to evaluate research on *university students* within the age group most prone to SA (Csibi et al., 2019). Thus, this review has one delimitation that concerns the studied population. This review defines *physical activity* as all *planned* sports or exercises practiced for health, leisure, mastery, or competition (Caspersen et al., 1985). This widely adopted definition permits examining a broader range of competitive and leisure physical activity studies. Further, we define *smartphone addiction* broadly as a risk or predisposition to ill-patterned smartphone-based application(s) use within the *pathway model's addictive pattern path* (Billieux et al., 2015). This definition excludes the inclusion of studies on the pathway model's risky pattern and antisocial pattern path. Noteworthy is that all questionnaire-based studies assess *risk* without diagnostic implications (Szabo et al., 2015).

2. Methods

2.1. Inclusion and exclusion criteria

This systematic literature review includes articles published in English in peer-reviewed academic journals. Various research designs are considered, including longitudinal, interventional, cross-sectional, randomized control trials, and case-control studies. As noted above, the target sample comprises university students who are young adults within the age group most affected by SA (Csibi et al., 2019). We focus on studies assessing the relationship between SA and any form of PA. The review excludes non-English articles, newspaper or magazine articles, commentaries, dissertations, conference proceedings, editorials, position or methodological papers, pilot studies, books, book chapters, articles with vague methodology, and abstracts (see Table 1).

Table 1
Inclusion and Exclusion Criteria for the Eligible Studies.

Inclusion Criteria	Exclusion Criteria
Articles published in English	Dissertations
Papers in peer-reviewed journals	Conference Proceedings
	Editorials, commentaries
Measures smartphone addiction	Literature reviews
Assesses any form of physical activity	Abstracts
Examines university/college students	Short reports
	Books (or chapters)
	Methodological papers

2.2. Search strategy

We searched five databases sequentially. They were PubMed, Social Sciences Research Network (SSRN), Oxford Research Archive (ORA), JSTOR, and Google Scholar. Over five years ago, Google Scholar located 95 % of citations in 252 subjects (Martín-Martín et al., 2018). Therefore, it may be one of the most inclusive databases. We searched Google Scholar after completing the search on the first four databases; in this way, we did not extract records already located on the other four and substantially reduced the number of duplicates. In addition to database searches, we scrutinized the bibliography of relevant papers to locate additional documents meeting the inclusion criteria. The search strategy involved three keyword clusters focusing on smartphones, PA, and university students. Table 2 presents a summary of the keywords used. The Boolean logic commands were adopted where applicable to refine and enhance the search results.

2.3. Search outcome

The review path follows the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (Liberati et al., 2009)

Table 2
Search Terms and Boolean Operators Used in the Review.

	AND	AND
Smartphone addict*, OR Smartphone depend*, OR Smartphone overuse, OR Compulsive smartphone* use OR Excessive smartphone* use OR Problematic smartphone use, OR Exaggerated smartphone* use OR Mobile phone addict*, OR Mobile phone* depend*, OR Mobile phone overuse, OR Compulsive mobile phone use OR Excessive mobile phone use OR Problematic mobile phone use OR Exaggerated mobile phone use	Physical Activity, OR Exercise*, OR Sport*, OR Training	University student*, OR Freshmen, OR Undergraduate* OR Graduate*, OR Major*

Note: The wild card (*) extends the search to any ending of the word trunk.

required for reporting systematic literature reviews. The databases explored resulted in 148 records: PubMed (57), Social Science Research Network (2), Oxford Research Archive (10), JSTOR (2), and Google Scholar (48). Twenty-nine (29) articles emerged from other sources, such as the articles' references in the searched databases. After removing four duplicates, 144 articles could be screened for eligibility. This process resulted in 36 full-text eligible articles. However, two articles were excluded as they focused on how smartphone-based applications facilitate increased physical activity. Two others were excluded because they were reviews. Finally, one was excluded because it studied adolescents. Accordingly, 31 full-text articles met the inclusion criteria in the review (Fig. 1).

2.4. Quality assessment

We employed the 'Mixed Methods Appraisal Tools' (MMAT), an efficient and reliable method (Pace et al., 2012) for assessing the quality and bias of the studies included in systematic literature reviews (Hong et al., 2018). It involves two screening questions addressing clarity: 1) Are there clear research questions? and 2) Do the data allow for the research questions to be addressed? Subsequently, each paper is evaluated with five questions specific to the research designs: i) Is the sampling strategy relevant to address the research question? ii) Is the sample representative of the target population? iii) Are the measurements appropriate? iv) Is the risk of nonresponse bias low? And v) Is statistical analysis appropriate to answer the research question? Prepared scholars can answer these questions with 'Yes,' 'No,' or 'Uncertain' (Hong et al., 2018).

In this review, two researchers independently assessed every eligible record. After 100 % agreement on screening questions, they compared their answers to the five distinct research design-specific questions, which also yielded 100 % agreement. While answering the questions, the focus was on whether the relationship between SA and PA could be identified using the methods, the sample studied, adopted measures, and analyses in the reported research. Accordingly, the quality assessment suggested that all 31 studies could be included without concern for quality or bias.

2.5. Data extraction

Information was systematically extracted and organized by categories: author and year, research design, country of origin and presence or absence of a hypothesis, participants, measures of SA and PA, tests and effects, principal findings, and whether the research had a positive or a negative outcome concerning the link between PA and NA.

3. Results

The results are summarized in Table 3. Out of 31 studies, 28 were cross-sectional, and three were experimental. Apart from two, one in Spain and the other in the US, all research was done in Asia. Fourteen originated from China, four from Turkey, three from Saudi Arabia, two from India, and one from Bangladesh, Korea, Malaysia, Pakistan, Spain, Taiwan, the US, and Thailand. The three intervention studies were performed in China. Most studies (22/31) posed a hypothesis; nine were exploratory. They employed eight validated tools to assess SA, while three relied on objective or subjective frequency data. Cross-sectional studies used seven different means of PA assessment. Sample sizes ranged from 49 (Lepp et al., 2013) to 5,511 (Islam et al., 2021) in cross-sectional studies and from 30 (Fan et al., 2021) to 96 (Xiao et al., 2021)

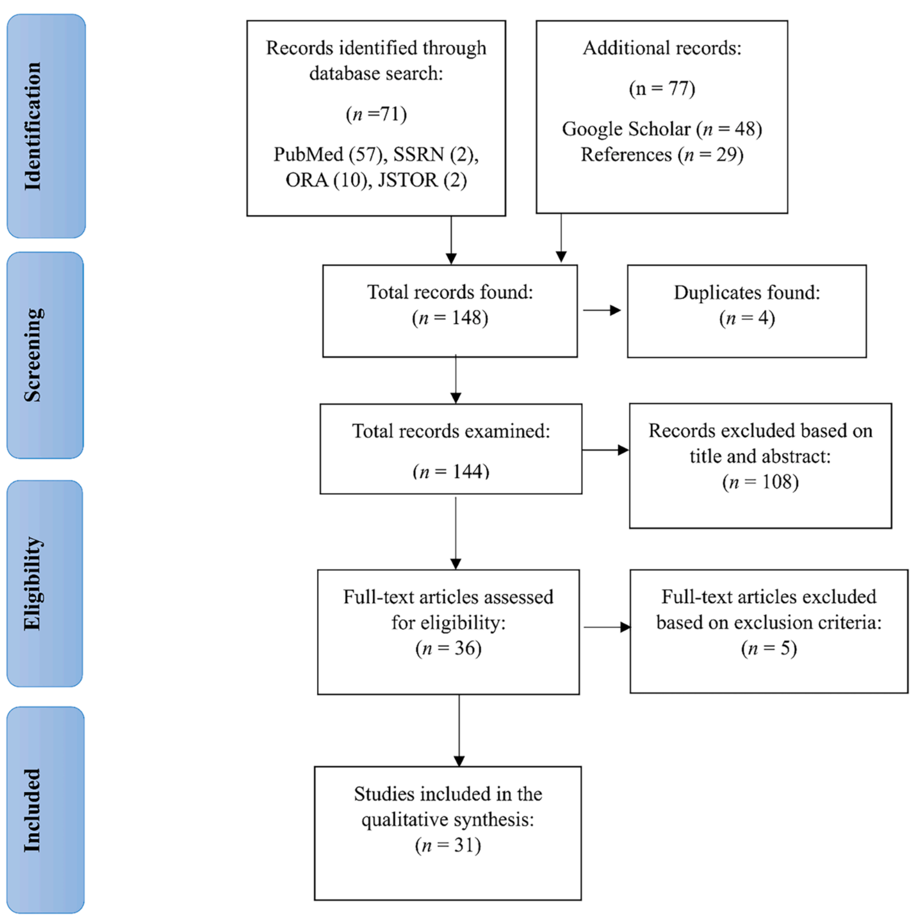

Fig. 1. Flow chart of the PRISMA review.

Table 3
Characteristics of the Studies Included.

Author & year	Country/ clear hypothesis	Study Type	Sample	Measurement	Tests and effects	Main findings
1. Abbasi et al. (2021)	Malaysia, Hypothesis: YES	CS	250 university students (145F; 105 M)	SAS-SV	SEM, $\beta = -.169$ (moderate effect)	Regardless of the extent of PA, only hedonic smartphone use has a profound effect on SA. Negative outcome.
2. Ali & Ali (2023)	Pakistan, Hypothesis: YES (but not clear)	CS	100 university athletes and 100 non-athletes Age range: 18–25 years	IPAQ-SV, BSMAS	Independent t-tests for group differences, Cohen's $d = 1.532$ (large effect)	Athletic involvement was related to lower SA. Positive outcome.
3. Alosaimi et al. (2016)	Saudi Arabia, Hypothesis: NO	CS	2,367 university students (43.6 % M; Age range: 20–24 years)	PUMP (Arabic)	Correlation between *decreased* PA and PUMP scores. Rho = .381 (moderate effect)	Problematic smartphone use was associated with decreased PA. Positive outcome (i.e., inverse relationship between SA and PA)
4. Alotaibi et al. (2022)	Saudi Arabia, Hypothesis: YES	CS	545 university students (248 M & 297F, Age: ≤ 21 years)	SAS-SV, Exercise status	Chi-square effect size, Cramer's $V = .069$ (small effect size)	More physically inactive students exhibited SA. Positive outcome.
5. Buke, et al., (2021)	Turkey, Hypothesis: NO	CS	300 university students (134F; 166 M), Mean age: 21.4 ± 2.3 years.	SAS-SV, IPAQ	Mann–Whitney U tests and Spearman correlations. Rho = -.262 to −.295 (small to moderate effects)	No differences were found in SA (yes, no) groups regarding PA levels. SA and PA were inversely related. Positive outcome.
6. Chen et al. (2022)	China, Hypothesis: YES	CS	828 college students (367 M; 461F), Mean age: 20.1 ± 2.3 years	Self-reported PA, Smartphone-use patterns	Linear and binary logistic regression OD = .907 (.836,.984). (small effect)	Increasing PA duration in the daytime was significantly associated with reduced smartphone use in bed and less sleep delay caused by smartphone use. Positive outcome.
7. Demirbilek & Minaz (2020)	Turkey, Hypothesis: NO	CS	147 university students (64 M; 80F)	IPAQ, SAQ	Correlation (no effect)	No significant association emerged between SA and the PA. Negative outcome.
8. Ding et al. (2021)	China, Hypothesis: YES	CS	1,720 university students (985F; 735 M) Mean age: 19.56 ± 0.95 years.	PARS-3, MPATS	Mediation Analysis, path coefficient (β) = -.265 (moderate effect)	SA reduced the beneficial effects of PA on the well-being of students. Positive outcome.
9. Fan et al. (2021)	China, Hypothesis: NO (implicit possible)	EXP	30 college students (13F; 17 M) Mean age: 20.03 ± 0.96 years)	MPATS, RS400 heart rate telemeter of Finland Polar Bicycle ergometer	ANOVAs effect sizes, partial Eta squared > .40 (large effects)	Participants with SA showed response inhibition after cycling, with the most efficient response inhibition at moderate intensity. Positive outcome.
10. Grimaldi-Puyana et al. (2020)	Spain, Hypothesis: YES	CS	306 college students aged 19–25 years (mean age ± SD: 20.7 ± 1.4 years; 60 % males)	Objective screentime from the smartphone, IPAQ	Multiple logistic regression $\beta = -.150$ (moderate effect)	A relationship exists between objectively gauged smartphone use and subjectively measured PA. Positive outcome.
11. Gumusgul (2018)	Turkey, Hypothesis: NO	CS	225 university students (136 M; 119F)	SAS-SV, Turkish Translated	One-way ANOVA, Independent Sample *t*-test Cohen's $d = .325$ (small to moderate effect)	Students who engage in PA tended to have lower SA scores. Positive outcome.
12. Guo et al. (2022)	China, Hypothesis: YES	CS	1,433 university students (704 M; 729F), Mean age: 19.67 ± 1.62 years)	MPATS, PARS-3, PEAS	Correlation = −.158 (small effect)	Engaging in PA is linked to a lower likelihood of developing SA. Positive outcome.
13. Han et al. (2023)	China, Hypothesis: YES	CS	4,959 university students (1878 M; 3081F)	MPATS, PARS-3	Correlation coefficient range = -.262 to −.556 (small to moderate effect)	Participants with a higher SA tended to be less physically active. Positive outcome.

(*continued on next page*)

Table 3 (*continued*)

Author & year	Country/ clear hypothesis	Study Type	Sample	Measurement	Tests and effects	Main findings
14. Haripriya, et al. (2019)	India, Hypothesis: YES	CS	113 college students (63 M; 50F) Mean age: 22.15 years	IPAQ-SF, SAPS, PSQI	Correlation = −.335 (moderate effect)	A moderate negative correlation exists between SA and PA. Positive outcome.
15. Islam et al. (2021)	Bangladesh, Hypothesis: NO	CS	5,511 university and college students (58.9 % M) Mean age: 21.2 ± 1.7 years	SABAS, BSMAS,	ANOVAseffect sizes (*d*) for SA = .49, and for problematic social media use = .19 (small to moderate effects)	Physically inactive students scored higher on SA and problematic social media use than regularly exercising students. Positive outcome.
16. Kim et al. (2015)	Korea, Hypothesis: NO	CS	110 Chinese International University students (67 M; 43F) Mean age: 21.03 ± 1.61 years	SAPS, Pedometer, Body Composition Analyzer, Anthropometer	Regression, R^2 change (when walking steps and calories consumed were added to the model) increased by.143 (small effect)	Greater PA was related to lower SA. Positive outcome.
17. Kumar et al. (2024)	India, Hypothesis: YES	CS	138 university students, Mean age: 19.74 ± 1.51 years	SAS, IPAQ (for metabolic equivalent)	Correlation = -.377 (small to moderate effect)	More than 50 % of the students exhibited SA. A significantly negative correlation was found between SA and PA. Positive outcome.
18. Lepp et al. (2013)	USA, Hypothesis: YES	CS with body test	49 university students (22 M; 27F), Mean age (M): 20.8 ± 2.4 years; Mean age (F): 19.9 ± 1.8 years	Self-efficacy Survey, Interview, Body Composition, Exercise test	Regressions, $\beta = -.25$ (moderate effect)	High-frequency smartphone use was related to lower aerobic fitness. Positive outcome.
19. Lin et al. (2022)	China, Hypothesis: YES	CS	1,787 university students (628 M;1159F) Mean age: 18.85 years	SAS-SV-C, IPAQ-SF	Correlation = −.153 (small effect)	Inverse correlation between PA and SA. Positive outcome.
20. Lu et al. (2020)	China, Hypothesis: YES	EXP (RCT)	95 college students (31 in the mind–body [Baduanjin] exercise group)	MPAI	ANOVAs, effect size (*d*) = 6.84 from pre- to post-exercise (large effect)	The Baduanjin exercises reduced PSU (SA) after 12 weeks. Positive outcome.
21. Numanoğlu-Akbaş et al. (2020)	Turkey, Hypothesis: NO	CS	288 university students (159F; 129 M) Mean age (yrs.): 19.97 ± 1.43 (F); 20.44 ± 1.67 (M)	SAS-SV IPAQ-SF	Correlation = -.126 (small effect)	A weak negative correlation was found between SA and PA. Positive outcome.
22. Penglee et al. (2019)	USA Thailand, Hypothesis: YES	CS	242 US & 194 Thai college students (USA: 48 M; 194F) (Thai: 48 M; 146F) Age: 18+	Online Survey assessing self-reported PA levels and Smartphone use	Chi-square, effect size (Cramer's *V*) = .09 (small effect)	Higher smartphone usage was inversely associated with PA among Thai but not US students. Partially positive and partially negative findings.
23. Saffari et al. (2022)	Taiwan, Hypothesis: YES	CS	391 college students (All females) Mean age: 22.85 ± 4.03 years	IPAQ-SF SABAS	Logistic Regression, direct effect OR = .11 (small effect)	PA inversely correlated with SA, and SA also moderated the relationship between weight stigma and PA. Positive outcome.
24. Venkatesh et al., (2019)	Saudi Arabia, Hypothesis: NO	CS	189 college students (101 M; 88F) Mean age: 23.29 years	SAS-SV, Exercise volume	Students with SA exercised > 50 % less than those without SA (SD is not reported)	SA was associated with less PA volume. Positive outcome.
25. Xiao et al. (2021)	China, Hypothesis: YES	EXP	96 college students (71 M; 29F) Mean age: 19.21 ± 1.02 years.	MPAI	Basketball (Cohen's *d* at 12 weeks = 1.24, at two months = .95; Baduanjin at 12 weeks = .97, at two months = .88 (large effects)	Basketball and Baduanjin training interventions significantly decreased SA scores after 12 weeks and remained lower after two months. Positive outcome
26. Xie et al. (2019)	China, Hypothesis: YES (not concerning PA vs. SA)	CS	2,134 college students (43 % M; 57 % F), Mean age: 19.25 ± 1.42 years	PMPU PA-question from the Youth Risk Behavior Survey	The relationship between SA and PA has not been tested directly. The proportion of SA in inactive and active samples did not differ (*z* = -.114; no effect)	In a sample of 2,134 students, 26.6 % of inactive and 19,8% of physically active students had SA; The differences are not significant.

(*continued on next page*)

Table 3 (*continued*)

Author & year	Country/ clear hypothesis	Study Type	Sample	Measurement	Tests and effects	Main findings
						Negative outcome.
27. Yang, Tan et al. (2019)	China, Hypothesis: YES	CS	650 university students (158 M; 450F)	PARS-3 MPATS	Correlation = -.124 (small effect)	An inverse relationship emerged between SA and PA. Positive outcome
28. Yang, Li et al. (2021)	China, Hypothesis: YES	CS	608 university students (158 M; 450F) Mean age: 20.06 ± 1.98 years	PARS-3 MPATS	ANOVA, contrasted the exercise volume groups; effect size partial Eta squared) = .023 (small to moderate effect)	SA decreased with increasing levels of PA, with the lowest frequency (4.0 %) observed in the high-exercise group. Positive outcome
29. Zhao et al. (2022)	China, Hypothesis: YES	CS	257 college students (73 M; 184F) Age range: 18–25 years	PARS-3 MPA	Mediation, the direct effect of PE on SA was β = -.115, and resilience also mediated this relationship, β = -.027 (small to moderate effect)	Inverse direct and indirect relationships emerged between PA and SA, mediated by resilience. Positive outcome.
30. Zhong et al. (2021)	China, Hypothesis: YES	CS	418 university students (115 M; 279F)	PARS-3 CSMDQ	Regression, when PA was added to the model $\beta = -.13$, $R^2 = .03$ (small effect)	Inverse relationships emerged between PA and SA. Positive outcome.
31. Zhu et al. (2023)	China, Hypothesis: YES	CS	823 college Students (499 M; 324F) Mean age: 18.55 ± 0.83 years	IPAQ-SF SAS-SV	Correlation = − .151 (small effect)	Inverse relationships emerged between PA and SA. Positive outcome.

Note: BSMAS = Bergen Social Media Addiction Scale*;* BT = Cognitive Behavioral Therapy; CD-RISC = Connor-Davidson Resilience Scale; CS = Cross-Sectional; CSMDQ = College Students' Mobile Phone Dependence Questionnaire; CUSPAMS = Chinese University Students Physical Activity Motivation Scale; EXP = Experimental; F = female; IPAQ-SF = International Physical Activity Questionnaire-Short Form; M = male; MPA = Mobile Addiction Scale; MPAI = Mobile Phone Addiction Index; MPATS = Mobile Phone Addiction Tendency Scale; PA = Physical Activity; PARS-3 = Physical Activity Rating Scale-3; PEAS = Physical Exercise Atmosphere Scale; PMPU = Problematic Mobile Phone Use; PSU = Problematic Smartphone Use; PUMP = Problematic Use of Mobile Phones; RCT = Randomized Controlled Trial; SA = Smartphone Addiction; SAQ = Smartphone Addiction Questionnaire; SAS-SV = Smartphone Addiction Scale for Adolescents-Short Version; SEM = Structural Equation Model; USA = United States of America.

in intervention research.

3.1. Smartphone addiction and physical activity – Summary of cross-sectional studies

Most studies suggest a negative association between SA and PA. Indeed, 24/28 cross-sectional studies yielded small to moderate effects; one revealed a large effect, two yielded no effects, and the effect could not be determined for one work. For example, Han et al. (2023) found a statistically significant weak to moderate PA and SA. Such findings mirror other studies reporting correlations ranging from −.124 to −.381 (Table 3). A greater risk of SA was related to less physical exercise. In their study, Saffari et al. (2022) revealed a significant correlation between the extent of PA (ranging from low to high) among university students and the prevalence of SA. Their findings imply that students exhibiting higher levels of physical activity tend to have lower levels of SA. Hence, more exercise behavior is associated with a lower risk of SA. Similarly, Alotaibi et al. (2022) found that 67 % of their student sample was at risk of SA, who were also more likely to be physically inactive. According to Lepp et al. (2013), students characterized as high-frequency mobile phone users showed an increased tendency to prioritize sedentary phone-related tasks over engaging in physical exercise. Similarly, Kim et al. (2015) discovered that students identified as high-risk smartphone users displayed lower levels of PA.

Numanoğlu-Akbaş et al. (2020) noted a weak negative association between SA and PA without observing gender differences in SA. Similarly, Demirbilek et al. (2020) did not find gender differences in SA. Yet, Abbasi et al. (2021) assumed the existence of gender differences in SA, but their study failed to compare male and female students. Partial support for their assumption has also emerged from the current review. For example, Kim et al. (2015) found more female students exhibiting SA than male students. Echoing these findings, Yang et al. (2021) also found that female university students are more prone to SA than their male counterparts. Buke et al. (2021) found that 42 % of students suffered from SA, and females had greater mean SA than males. While interpreting these results, it must be considered that this study (and all included in the review) did not assess SA *per se* but only the risk of SA, which may never materialize in dysfunctionality. Even further, gender differences might depend on the assessment method, social factors, university location and orientation, and many other factors such as personality, unlimited internet access, family models, social relationships, etc. Thus, despite some studies indicating gender differences, more focused research is needed. Bute et al. also found that 65.3 % of the studied group did enough exercise, 32.7 % did little, and 2 % were inactive. These authors also reported a small to moderate negative correlation between SA and PA.

Physically active students tended to have a lower risk of SA. Therefore, extant research suggests there might be a weak inverse association between physical activity practice and the risk of smartphone addiction. But why is this relationship weak? The answer is that these studies stem from 12 different countries studying young adults at different universities with different academic orientations and standards, social composition, and subject orientations. They used a variety of questionnaires and methods for assessing SA and PA. While all could answer a research question connecting somehow SA and PA, the heterogeneity of these studies makes a comparison only tentative. Although their overall results project a relatively weak (in some instances moderate) inverse relationship between SA and PA, they agree mostly since over 85 % of them confirmed this relationship through a positive research outcome. Thus, they offer a common denominator for encouraging future research efforts, especially intervention and longitudinal research, which are few but produce large effects attributable to a PA intervention.

3.2. Smartphone addiction and exercise behavior – Summary of intervention studies

Indeed, all three intervention studies conducted in China yielded large effects. For example, a 12-week Baduanjin (a traditional Chinese mind–body exercise) training effectively lowered the risk of SA in Chinese university students (Lu et al., 2020). Specifically, this randomized controlled trial aimed to compare the efficacy of Baduanjin exercises and cognitive behavioral therapy (CBT) in alleviating the risk of smartphone addiction. The study found that both interventions successfully reduced the risk of smartphone addiction. The effect of Baduanjin training on SA was large, but CBT had an even larger effect. Nevertheless, the Baduanjin training group showed a decrease in SA comparable to the CBT group. Furthermore, despite a larger within-group effect, the CBT group only showed a marginally significant decrease compared to the control group.

Xiao et al. (2021) showed that a 12-week exercise intervention had short-term and long-term positive effects on smartphone addiction. Baduanjin and basketball practice, performed thrice weekly for 90 min each time, significantly lowered SA compared to a control group. These findings suggest that both exercises have robust and immediate impacts on reducing the risk of SA. The participants continued to benefit from training even two months after the interventions since their addiction scores remained lower than their baseline scores and control group's scores, showing a lasting exercise effect in the medium-long term. The effect sizes were large (see Table 3). This study reveals the robust effect of exercise intervention on the risk of SA.

Using an acute exercise intervention protocol, Fan et al. (2021) found that a 30-minute session of acute cycling exercise brought about significant changes in response inhibition among college students with smartphone addiction. The most substantial improvement in reaction time was observed during moderate-intensity acute aerobic exercise. However, despite lesser changes after low-intensity cycling, the effect size was most prominent in this exercise condition ($d = 2.91$). Still, the effect sizes were large after moderate- and high-intensity cycling, too, being 2.49 and 2.25, respectively. These findings suggest that acute aerobic exercise has an immediate positive impact on response inhibition in individuals with a high risk of SA. The implications of these findings in the long term require further research attention.

Overall, only three intervention studies were found. None of them tested gender differences in response to their intervention. However, their intervention produced large effects without exception. These findings are promising for practical settings in devising exercise interventions to reduce or prevent SA. Nevertheless, further research is necessary, especially in regions other than Asia, since, as mentioned before, all three experimental studies were performed in China.

3.3. Smartphone addiction, physical activity, and self-control

Ding et al. (2021) found that college students who were more physically active had more controlled internet use, self-control, and higher levels of subjective well-being. Smartphone addiction was linked to lower well-being, while regular PA was associated with less excessive smartphone use, increased life satisfaction, and reduced addictive behaviors. Like others, Guo et al. (2022) found a negative relationship between PA and SA. Physical exercise positively predicted self-control, while self-control was inversely related to smartphone addiction. The interaction between physical exercise atmosphere and self-control also lowers SA. Guo et al.'s study suggests that PA, a positive exercise environment, and improved self-control can significantly reduce the likelihood of SA. Along these lines, Yang et al. (2019) proposed that physical exercise partially reduced mobile phone dependence, with self-control playing a significant mediating role. Similarly, Zhong et al. (2021) reported that PA has a dual impact on college students' mobile phone dependence: it decreases dependence directly and indirectly by improving self-control. Still, in this context, another study found that SA increases social motivation but decreases self-efficacy, a belief in one's ability to accomplish tasks. This change can hinder personal participation in PA, as self-efficacy mediates the relationship between SA and PA (Lin et al., 2022).

3.4. Smartphone addiction, physical activity, and psychological stress

Zhao et al. (2022) revealed that psychological resilience mediated the relationship between PA and SA. Thus, PA may (also) indirectly reduce the SA risk by increasing psychological resilience and lessening perceived stress. Specifically, Zhao et al.'s findings may imply that 1) not only PA might have a direct effect on SA, 2) psychological resilience is a mediator between PA and SA, while perceived stress is not, and 3) psychological resilience and perceived stress show a chain mediation role. Furthermore, research indicates a notable correlation between Problematic Mobile Phone Use (PMPU) and Insufficient Physical Activity (IPA) with depression among students. Insufficient physical activity can potentially aggravate the negative effects of SA, consequently intensifying depressive symptoms (Xie et al., 2019). Finally, Zhu et al. (2023) highlighted the significance of PA in mitigating SA, leading to a decrease in burnout levels.

4. Discussion

This review examined the connection between physical activity and SA in university students. It included thirty-one studies from twelve nations. They were mainly cross-sectional (28), and three interventions were used. Most studies (29/31) suggested an inverse association between SA and physical activity. Only two studies could not disclose an association between SA and physical activity (Demirbilek and Minaz, 2020; Zhao et al., 2022). One of these two studies had a relatively low sample size (n = 147) for cross-sectional research (Demirbilek and Minaz, 2020) and did not report the correlation value between physical activity and SA but stated that it is not significant. However, the study could not disclose differences in SA between the groups when comparing low-, medium-, and high-activity groups. Similarly, the research by Zhao et al. (2022) found that the relationship between PA and SA was mediated by resilience. This finding suggests that numerous unexplored factors might mediate the connection between PA and SA. They should be examined in future research, possibly relying on objective measures.

In line with a literature review on adolescents (Azam et al., 2020), the current findings emerging from college or university students support the contention that less PA is connected to a greater risk of SA, or vice versa. Still, the results emerging from the cross-sectional studies suggest that the connection is either weak (Han et al., 2023), mediated by other factors (Zhao et al., 2022), and that the form of exercise may play a noteworthy role (Yang et al., 2021). These results also agree with other, more general, research linking PA levels to lower internet and SA (Moskowski et al., 2018; Park, 2014). For example, they support past research on athletes, showing that increased athletic involvement might be associated with less internet addiction, and athletes demonstrate lower gaming addiction rates than non-athletes (Håkansson et al., 2018). Despite differences in sample size, national origin of the research, methods of determining exercise behavior, and SA assessment, most cross-sectional studies support an inverse relationship between PA and SA.

Out of the three intervention studies, two were longitudinal, lasting for 12 weeks, and compared the efficacy of the traditional Chinese Baduanjin exercises to either CBT (Lu et al., 2020) or basketball playing (Xiao et al., 2021). Notably, they both disclosed remarkable effects, mirrored in large effect sizes, after 12 weeks of training. The latter study (Xiao et al., 2021) demonstrated that the intervention-induced effects were still evident two months after the study. Accordingly, exercise intervention appears to be effective in reducing the risk of smartphone addiction. Even an acute intervention (Fan et al., 2021) produced positive results on response inhibition. The long-term effect of such an intervention merits further scrutiny. Due to their low number, significantly more intervention research is needed in this area, with various exercises and objective assessments of smartphone use (Grimaldi-Puyana et al., 2020) in addition to subjective measures. Screentime can be accessed via many different smartphone applications. Furthermore, specific smartphone applications can record steps or physical activity parameters. The advantages of these applications should be exploited in future research in this area.

It is important to note that apart from the experimental studies, which are few and specific in terms of exercise intervention frequency, duration, and form, most cross-sectional studies have used questionnaires assessed by researchers, not clinicians. These studies use tools that have little or no diagnostic value. Therefore, a score reflecting the *risk* of addiction may not ever turn into a clinically dysfunctional case. However, high scores may indeed reflect some predisposition to escape into addiction as a conscious or subconscious method of coping with a mental problem. Research indicates that hedonic use of smartphones poses a greater risk of SA than utilitarian use (Vujić and Szabo, 2022). Such findings are also supported by the research included in the current review (i.e., Abbasi et al., 2021; Ali and Ali, 2023; Alosaimi et al., 2016). Hence, future work should examine the connection between PA and the risk of SA by also considering the primary motivation for smartphone use, such as utilitarian or entertainment.

4.1. Limitations

While this review provides insights into the relationship between physical activity and smartphone addiction, it also has limitations. Most studies reviewed relied on subjective measures, which affect reliability since they often also reflect approximations, and some are prone to memory distortion due to retrospective measures (i.e., amount of device use). All studies measured a risk level without establishing clinical relevance. Indeed, none of the studies followed up on the questionnaire results with deep interviews, yet one study (Lepp et al., 2013) did employ an interview. Studying volunteers involves self-selection bias, rendering the generalizability of the findings questionable. Furthermore, the studies did not test the underlying mechanisms of complex relationships, such as the purpose of use vs. amount of use and clinical vs. questionnaire-based symptoms, and only two-thirds of the studies had a hypothesis. Finally, our delimitation posed to the review to only examine university students is also a limitation because it does not permit the generalizability of the findings to other age groups. Future studies relying on objective exercise and smartphone use measures and interview-based follow-ups of high-risk questionnaire scores will yield more valid and reliable findings. Longitudinal studies with such parameters might be the most promising.

5. Conclusions

The literature reviewed suggests a weak inverse relationship between PA and the risk of SA based on cross-sectional studies. In contrast, experimental studies yield robust findings. Two longitudinal studies based on two forms of physical activity and CBT yielded significant improvements in SA risk scores as mirrored by large effect sizes. One acute cycling intervention also yielded robust effects with large effect sizes on response inhibition. Further experimental research using various durations of interventions and involving more popular exercises, such as running, swimming, or gym attendance, is urgently needed. Studies outside Asia are also needed, along with cross-cultural evaluations. The subjective measures of smartphone use patterns should be complemented with objective measures in subsequent studies.

6. Declaration of generative AI in scientific writing

The authors did not use any form of AI when writing this paper.

Conflict of interest

The authors have no conflict of interest to declare.

Funding

The authors have not received funding to write this review. ELTE Eötvös Loránd University covered the open access fee.

CRediT authorship contribution statement

Neha Pirwani: Writing – original draft, Validation, Resources, Investigation, Data curation, Conceptualization. **Attila Szabo:** Writing – review & editing, Validation, Supervision, Project administration, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Review paper

References

Abbasi, G.A., Jagaveeran, M., Goh, Y.N., Tariq, B., 2021. The impact of type of content use on smartphone addiction and academic performance: Physical activity as moderator. Technol. Soc. 64, 101521 https://doi.org/10.1016/j.techsoc.2020.101521.

Ali, S.Z., Ali, A., 2023. Relationship between physical activity and WhatsApp addiction among athletes and non-athletes of university-level early adults. J. Dev. Soc. Sci. 4 (3), 436–446. https://doi.org/10.47205/jdss.2023(4-III)43.

Alosaimi, F. D., Alyahya, H., Alshahwan, H., Al Mahyijari, N., & Shaik, S. A. (2016). Smartphone addiction among university students in Riyadh, Saudi Arabia. Saudi Med. J. 37(6), 675. 10.15537/smj.2016.6.14430.

Alotaibi, M.S., Fox, M., Coman, R., Ratan, Z.A., Hosseinzadeh, H., 2022. Smartphone addiction prevalence and its association on academic performance, physical health, and mental well-being among university students in Umm Al-Qura University (UQU), Saudi Arabia. Int. J. Environ. Res. Public Health 19 (6), 3710. https://doi.org/10.3390/ijerph19063710.

Ausman, C. (2021). *Exploring the Impact of Covid-19 on Students' Use of Smartphones for Leisure Coping.* Masters Thesis, Dalhousie University, Halifax, Nova Scotia, Canada. Retrieved December 08, 2023, from: https://dalspace.library.dal.ca/bitstream/handle/10222/80639/ChristineAusman2021.pdf?sequence=3.

Azam, M., Ali, A., Mattiullah, J., & Perveen, N. (2020). Physical activity, sports participation, and smartphone addiction in adolescent students: A systematic review. *Journal of Evidence-Based Psychotherapies, 20*(1), 25-41. 10.24193/jebp.2020.1.2.

Bian, M., Leung, L., 2015. Linking loneliness, shyness, smartphone addiction symptoms, and patterns of smartphone use to social capital. Soc. Sci. Comput. Rev. 33 (1), 61–79. https://doi.org/10.1177/0894439314528779.

Billieux, J., Maurage, P., Lopez-Fernandez, O., Kuss, D.J., Griffiths, M.D., 2015. Can disordered mobile phone use be considered a behavioral addiction? An update on current evidence and a comprehensive model for future research. Curr. Addict. Rep. 2 (2), 156–162. https://doi.org/10.1007/s40429-015-0054-y.

Buke, M., Egesoy, H., Unver, F., 2021. The effect of smartphone addiction on physical activity level in sports science undergraduates. J. Bodyw. Mov. Ther. 28, 530–534. https://doi.org/10.1016/j.jbmt.2021.09.003.

Carson, V., Hunter, S., Kuzik, N., Gray, C.E., Poitras, V.J., Chaput, J.-P., Connor Gorber, S., 2016. Systematic review of sedentary behaviour and health indicators in school-aged children and youth: an update. Appl. Physiol. Nutr. Metab. 41 (6), S240–S265. https://doi.org/10.1139/apnm-2015-0630.

Caspersen, C.J., Powell, K.E., Christenson, G.M., 1985. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. Public Health Rep. 100 (2), 126–131. PMID: 3920711.

Chen, H., Zhang, G., Wang, Z., Feng, S., Li, H., 2022. The associations between daytime physical activity, while-in-bed smartphone use, sleep delay, and sleep quality: A 24-h investigation among Chinese college students. Int. J. Environ. Res. Public Health 19 (15), 9693. https://doi.org/10.3390/ijerph19159693.

Cho, K.S., Lee, J.M., 2017. Influence of smartphone addiction proneness of young children on problematic behaviors and emotional intelligence: Mediating self-assessment effects of parents using smartphones. Comput. Hum. Behav. 66, 303–311. https://doi.org/10.1016/j.chb.2016.09.063.

Csibi, S., Griffiths, M.D., Demetrovics, Z., Szabo, A., 2019. Analysis of problematic smartphone use across different age groups within the 'Components Model of Addiction'. Int. J. Ment. Heal. Addict. 19 (3), 616–631. https://doi.org/10.1007/s11469-019-00095-0.

Demirbilek, M., Minaz, M., 2020. The relationship between physical activity and smart phone use in university students. J. Educ. Sci. Environ. Health 6 (4), 282–296. https://doi.org/10.21891/jeseh.795980.

DiLorenzo, T.M., Bargman, E.P., Stucky-Ropp, R., Brassington, G.S., Frensch, P.A., LaFontaine, T., 1999. Long-Term effects of aerobic exercise on psychological outcomes. Prev. Med. 28 (1), 75–85. https://doi.org/10.1006/pmed.1998.0385.

Ding, Z. C., Yan, J., & Fu, J. (2021). Internet and mobile phone addiction self-control mediate physical exercise and subjective well-being in young adults using IoT. *Mobile Information Systems, Volume 2021*, 1-6. Article ID 9923833. 10.1155/2021/9923833.

Dodes, L.M., 2009. Addiction as a psychological symptom. Psychodyn. Pract. 15 (4), 381–393. https://doi.org/10.1080/14753630903230468.

Duke, É., Montag, C., 2017. Smartphone addiction and beyond: Initial insights on an emerging research topic and its relationship to Internet addiction. In: Montag, C., Reuter, M. (Eds.), Internet Addiction: Neuroscientific Approaches and Therapeutical Implications including Smartphone Addiction. Springer, Cham, Switzerland, pp. 359–372. https://doi.org/10.1007/978-3-319-46276-9_21.

Fan, H., Qi, S., Huang, G., Xu, Z., 2021. Effect of acute aerobic exercise on inhibitory control of college students with smartphone addiction. Evid. Based Complement. Alternat. Med. 2021, 1–9. https://doi.org/10.1155/2021/5530126.

Glenister, D., 1996. Exercise and mental health: a review. J. R. Soc. Health 116 (1), 7–13. https://doi.org/10.1177/146642409611600102.

Gökçearslan, Ş., Mumcu, F.K., Haşlaman, T., Çevik, Y.D., 2016. Modelling smartphone addiction: The role of smartphone usage, self-regulation, general self efficacy and cyberloafing in university students. Comput. Hum. Behav. 63, 639–649. https://doi.org/10.1016/j.chb.2016.05.091.

Grimaldi-Puyana, M., Fernández-Batanero, J. M., Fennell, C., & Sañudo, B. (2020). Associations of objectively-assessed smartphone use with physical activity, sedentary behavior, mood, and sleep quality in young adults: A Cross-Sectional Study. *International Journal of Environmental Research and Public Health, 17*(10), Article No. 3499. 10.3390/ijerph17103499.

Gumusgul, O., 2018. Investigation of Smartphone Addiction Effect on Recreational and Physical Activity and Educational Success. World J. Educ. 8 (4), 11–17. https://doi.org/10.5430/wje.v8n4p11.

Guo, K. L., Ma, Q. S., Yao, S. J., Liu, C., Hui, Z., Jiang, J., & Lin, X. (2022). The relationship between physical exercise and mobile phone addiction tendency of university students in China: a moderated mediation model. Front. Psychol. *13*, Article No. 730886. 10.3389/fpsyg.2022.730886.

Håkansson, A., Kenttä, G., Åkesdotter, C., 2018. Problem gambling and gaming in elite athletes. Addict. Behav. Rep. 8, 79–84. https://doi.org/10.1016/j.abrep.2018.08.003.

Han, Y., Qin, G., Han, S., Ke, Y., Meng, S., Tong, W., Shi, W., 2023. Effect of Mobile Phone Addiction on Physical Exercise in University Students: Moderating Effect of Peer Relationships. Int. J. Environ. Res. Public Health 20 (3), 2685. https://doi.org/10.3390/ijerph20032685.

Haripriya, S., Samuel, S.E., Megha, M., 2019. Correlation between Smartphone Addiction, Sleep Quality and Physical Activity among Young Adults. J. Clin. Diagn. Res. 13 (10) https://doi.org/10.7860/jcdr/2019/42168.13212.

Hong, Q. N., Pluye, P., Sergi, F., Bartlett, G., Boardman, F., Cargo, M., Dagenais, P., Marie-Pierre, G., Griffiths, F., B, N., O'Cathain, A., Rousseau, M. C., & Vedel, I. (2018). *Mixed methods appraisal tool (MMAT), version 2018.* McGill Department of Family Medicine,1–11. Retrieved December 05, 2023, from: http://mixedmethodsappraisaltoolpublic.pbworks.com/w/file/fetch/127916259/MMAT_20 18_criteria-manual_2018-08-01_ENG.pdf.

Islam, M.S., Sujan, M.S.H., Ferdous, M., Kamruzzaman, S., Sakib, M.N., Hossain, A., Pontes, H.M., 2021. Problematic smartphone and social media use among Bangladeshi college and university students amid COVID-19: the role of psychological well-being and pandemic related factors. Front. Psych. 12, 647386 https://doi.org/10.3389/fpsyt.2021.647386.

Khan, M., 2008. Adverse effects of excessive mobile phone use. Int. J. Occup. Med. Environ. Health 21 (4), 289–293. https://doi.org/10.2478/v10001-008-0028-6.

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

Kumar, S., Rajasegaran, R., Prabhakaran, S., Mani, T., 2024. Extent of Smartphone Addiction and its Association with Physical Activity Level, Anthropometric Indices, and Quality of Sleep in Young Adults: A Cross-Sectional Study. Indian J. Community Med. 49 (1), 199–202. https://doi.org/10.4103/ijcm.ijcm_706_22.

Kuss, D.J., Griffiths, M.D., 2011. Online social networking and addiction—A review of the psychological literature. Int. J. Environ. Res. Public Health 8 (9), 3528–3552. https://doi.org/10.3390/ijerph8093528.

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 US college students. Int. J. Behav. Nutr. Phys. Act. 10, 1–9. https://doi.org/10.1186/1479-5868-10-79.

Liberati, A., Altman, D.G., Tetzlaff, J., Mulrow, C., Gøtzsche, P.C., Ioannidis, J.P., Moher, D., 2009. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. Ann. Intern. Med. 151 (4), W-65. https://doi.org/10.7326/0003-4819-151-4-200908180-00136.

Lin, Y.H., Chang, L.R., Lee, Y.H., Tseng, H.W., Kuo, T.B., Chen, S.H., 2014. Development and validation of the Smartphone Addiction Inventory (SPAI). PLoS One 9 (6), e98312.

Lin, Y.H., Lin, S.H., Yang, C.C., Kuo, T.B., 2017. Psychopathology of everyday life in the 21st century: smartphone addiction. In: Internet Addiction. Springer, Cham, pp. 339–358. https://doi.org/10.1007/978-3-319-46276-9_20.

Lin, B., Teo, E.W., Yan, T., 2022. The impact of smartphone addiction on Chinese university students' physical activity: Exploring the role of motivation and self-efficacy. Psychol. Res. Behav. Manag. 15, 2273–2290. https://doi.org/10.2147/prbm.s375395.

Liu, H., Soh, K. G., Samsudin, S., Rattanakoses, W., & Qi, F. (2022). Effects of exercise and psychological interventions on smartphone addiction among university students: A systematic review. *Frontiers In Psychology, 13*, Article No. 1021285. 10.3389/fpsyg.2022.1021285.

Lu, C., Zou, L., Becker, B., Griffiths, M. D., Yu, Q., Chen, S. T., ... & Zhang, Y. (2020). Comparative effectiveness of mind-body exercise versus cognitive behavioral therapy for college students with problematic smartphone use: a randomized controlled trial. International Journal of Mental Health Promotion, 22(4), 271-282. 10.32604/ijmhp.2020.014419.

Martín-Martín, A., Orduna-Malea, E., Thelwall, M., Delgado López-Cózar, E., 2018. Google Scholar, Web of Science, and Scopus: A systematic comparison of citations in 252 subject categories. J. Informet. 12 (4), 1160–1177. https://doi.org/10.1016/j.joi.2018.09.002.

Moskowski, A., Ta, H., Glover, T., Leatherwood, S., Brunton, C., Hathaway, E., & Fedewa, M. (2018). Sedentary behavior is associated with physical activity and cell phone addiction in young adults. Abstracts of the SEACSM Conference.

Numanoğlu-Akbaş, A., Suner-Keklik, S., & Yakut, H. (2020). Investigation of the relationship between smart phone addiction and physical activity in university students. *Baltic Journal of Health and Physical Activity, 12*(6), 7. 10.29359/bjhpa.2020.suppl.1.07.

Olson, J. A., Sandra, D. A., Colucci, É. S., Bikaii, A. A., Nahas, J., Chmoulevitch, D., Raz, A., & Veissière, S. P. L. (2022). Smartphone addiction is increasing across the world: A meta-analysis of 24 countries. Comput. Human Behav. 129, April 2022, Article No. 107138. 10.1016/j.chb.2021.107138.

Pace, R., Pluye, P., Bartlett, G., Macaulay, A.C., Salsberg, J., Jagosh, J., Seller, R., 2012. Testing the reliability and efficiency of the pilot Mixed Methods Appraisal Tool (MMAT) for systematic mixed studies review. Int. J. Nurs. Stud. 49 (1), 47–53. https://doi.org/10.1016/j.ijnurstu.2011.07.002.

Park, S., 2014. Associations of physical activity with sleep satisfaction, perceived stress, and problematic Internet use in Korean adolescents. BMC Public Health 14 (1), 1143. https://doi.org/10.1186/1471-2458-14-1143.

Peltzer, K., & Pengpid, S. (2016). Leisure time physical inactivity and sedentary behaviour and lifestyle correlates among students Aged 13–15 in the Association of South east Asian Nations (ASEAN) Member States, 2007–2013. *International Journal of Environmental Research and Public Health, 13*(2), Article No. 217. 10.3390/ijerph13020217.

Penglee, N., Christiana, R.W., Battista, R.A., Rosenberg, E., 2019. Smartphone use and physical activity among college students in health science-related majors in the United States and Thailand. Int. J. Environ. Res. Public Health 16 (8), 1315. https://doi.org/10.3390/ijerph16081315.

Rozgonjuk, D., Sindermann, C., Elhai, J.D., Christensen, A.P., Montag, C., 2020. Associations between symptoms of problematic smartphone, Facebook, WhatsApp, and Instagram use: An item-level exploratory graph analysis perspective. J. Behav. Addict. 9 (3), 686–697. https://doi.org/10.1556/2006.2020.00036.

Saffari, M., Chen, J.S., Wu, H.C., Fung, X.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. Int. J. Environ. Res. Public Health 19 (5), 2631. https://doi.org/10.3390/ijerph19052631.

Stathopoulou, G., Powers, M.B., Berry, A.C., Smits, J.A., Otto, M.W., 2006. Exercise interventions for mental health: a quantitative and qualitative review. Clin. Psychol. Sci. Pract. 13 (2), 179–193. https://doi.org/10.1111/j.1468-2850.2006.00021.x.

Surawska, M. (2017). Sport activity as a significant element of preventing addictions. *Polish Journal of Applied Sciences, 2(*3), 112-116. 10.19260/PJAS.2016.2.3.05.

Szabo, A., Griffiths, M. D., Marcos, R. D. L. V., Mervó, B., & Demetrovics, Z. (2015). Methodological and conceptual limitations in exercise addiction research. *The Yale Journal of Biology and Medicine, 88*(3), 303-308. Retrieved February 06, 2024, from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4553651/.

Venkatesh, E., Al Jemal, M.Y., Al Samani, A.S., 2019. Smart phone usage and addiction among dental students in Saudi Arabia: a cross sectional study. International Journal of Adolescent. Med. Health 31 (1). https://doi.org/10.1515/ijamh-2016-0133.

Vujić, A., & Szabo, A. (2022). Hedonic use, stress, and life satisfaction as predictors of smartphone addiction. *Addictive Behaviors Reports, 15,* Article No. 100411. 10.1016/j.abrep.2022.100411.

World Economic Forum (2023). *Charted: There are more mobile phones than people in the world.* Retrieved December 08, 2023 from: https://www.weforum.org/agenda/2023/04/charted-there-are-more-phones-than-people-in-the-world/.

World Health Organization (2018). Prevalence of insufficient physical activity. Retrieved December 23, 2023, from: http://www.who.int/gho/ncd/risk_factors/physical_activity_text/en/.

Xiao, T., Jiao, C., Yao, J., Yang, L., Zhang, Y., Liu, S., Zhang, J., 2021. Effects of basketball and Baduanjin exercise interventions on problematic smartphone use and mental health among college students: a randomized controlled trial. Evid. Based Complement. Alternat. Med. 2021 https://doi.org/10.1155/2021/8880716.

Xie, H., Tao, S., Zhang, Y., Tao, F., Wu, X., 2019. Impact of problematic mobile phone use and insufficient physical activity on depression symptoms: a college-based follow-up study. BMC Public Health 19, 1–7. https://doi.org/10.1186/s12889-019-7873-z.

Yang, G., Tan, G.X., Li, Y.X., Liu, H.Y., Wang, S.T., 2019. Physical exercise decreases the mobile phone dependence of university students in China: The mediating role of self-control. Int. J. Environ. Res. Public Health 16 (21), 4098. https://doi.org/10.3390/ijerph16214098.

Yang, G., Li, Y., Liu, S., Liu, C., Jia, C., Wang, S., 2021. Physical activity influences the mobile phone addiction among Chinese undergraduates: The moderating effect of exercise type. J. Behav. Addict. 10 (3), 799–810. https://doi.org/10.1556/2006.2021.00059.

Ye, J. (2020). The Role of Health Technology and Informatics in a Global Public Health Emergency: Practices and Implications From the COVID-19 Pandemic. *JMIR Medical Informatics, 8*(7), Article No. 19866. 10.2196/19866.

Zhao, Z., Zhao, S., Wang, Q., Zhang, Y., & Chen, C. (2022). Effects of physical exercise on mobile phone addiction in college students: The chain mediation effect of psychological resilience and perceived stress. Int. J. Environ. Res. Public Health, 19 (23), Article No. 15679. 10.3390/ijerph192315679.

Zhong, W., Wang, Y., Zhang, G., 2021. The impact of physical activity on college students' mobile phone dependence: the mediating role of self-control. Int. J. Ment. Heal. Addict. 19, 2144–2159. https://doi.org/10.1007/s11469-020-00308-x.

Zhu, L., Hou, J., Zhou, B., Xiao, X., Wang, J., Jia, W., 2023. Physical activity, problematic smartphone use, and burnout among Chinese college students. PeerJ 11, e16270.