Society of Medical Education & Research

2023, Volume 3, Issue 2, Page No: 107-115
ISSN: 3108-4826

Journal of Medical Sciences and Interdisciplinary Research

Impact of Smartphone Addiction and Physical Activity on Depressive Symptoms among Secondary School Students: A Cross-Sectional Study in Shanghai, China

Natalia Viktorovna Smirnova[1]*, Olga Sergeevna Ivanova[1]

[1]Department of Management, Graduate School of Economics, Higher School of Economics, Moscow, Russia.

***E-mail** ✉ n.smirnova.hse@yahoo.com

Abstract

This research seeks to explore the occurrence rates of smartphone dependency, levels of exercise, and signs of depression in middle school pupils, while assessing the interactive influence of smartphone dependency and exercise on depression indicators. Cluster sampling was applied across two middle schools located in Shanghai's Jing'an District, China. Single-variable comparisons examined differences in depression indicator rates according to various participant traits. Multiple logistic regression models evaluated links between smartphone dependency, exercise habits, and their interactive influence on depression indicators.

The survey included 1,316 valid participants, revealing occurrence rates of depression indicators (36.2%), smartphone dependency (19.2%), and low exercise engagement (23.3%). Factors elevating depression risk comprised not being an only child (OR=1.421, 95% CI: 1.090-1.853, P=0.009), short sleep time (OR=2.722, 95% CI: 2.070-3.578, P<0.001), and smartphone dependency (OR=2.173, 95% CI: 1.621-2.913, P<0.001). Pupils showing smartphone dependency faced higher odds of depression indicators than those without (OR=2.173, 95% CI: 1.621-2.913, P<0.001). Interactive evaluation showed that the coexistence of smartphone dependency and low exercise markedly raised depression risk (OR=2.781, 95% CI: 1.627-4.753, P<0.001). Elevated rates of intense smartphone dependency, low exercise participation, and depression indicators were observed in middle school pupils. Both smartphone dependency and low exercise were linked to greater depression likelihood. Furthermore, greater exercise engagement seemed to buffer the harmful effects of smartphone dependency on depression indicators.

Keywords: Adolescents, China, Smartphone addiction, Physical activity, Depressive symptoms

Introduction

Over the past years, with expanding wireless connectivity and improved smartphone features, younger people have increasingly adopted smartphones. This shift has highlighted smartphone dependency issues in youth. Smartphone dependency involves uncontrolled usage [1], causing physical problems such as headaches and focus difficulties, alongside psychological effects like anxiety, depression, and poorer social adjustment [2, 3]. Studies have reported a worldwide smartphone dependency rate of 28.3%, varying by cultural context from 10% to 31% [4]. Rates appear higher in Eastern cultures than in Western ones [5].

Smartphone dependency also correlates with reduced exercise among youth worldwide [6]. This reduction impedes healthy development and poses a major health issue. Hallal's work indicated that more than 80% of global youth do not reach the daily 60-minute moderate-to-vigorous exercise recommendation [7].

These problems likely connect to youth depression. Depression impacts around 350 million individuals across ages globally and is projected to become the top disease burden by 2030, challenging public health worldwide [8]. Youth depression often precedes adult

Access this article online https://smerpub.com/

Received: 28 April 2023; **Accepted:** 23 August 2023

How to cite this article: Smirnova NV, Ivanova OS. Impact of Smartphone Addiction and Physical Activity on Depressive Symptoms among Secondary School Students: A Cross-Sectional Study in Shanghai, China. J Med Sci Interdiscip Res. 2023;3(2):107-15. https://doi.org/10.51847/f1Q1DcZ1iq

forms, causing lasting social and emotional damage [9]. Youth face heightened depression vulnerability from genetic, social, and environmental influences, leading to greater rates than in other groups. Recent evidence links smartphone dependency and low exercise to mental issues like anxiety and depression. Tang *et al*. (2018) found that youth and young adults with mobile dependency showed greater emotional fragility, raising depression risk [10]. Moreover, smartphone-dependent individuals in Asian regions exhibited higher depression rates than in the United States, indicating cultural and contextual roles in how smartphone dependency and inactivity affect youth mental health. A study of UK youth aged 11-14 identified an inverse link between exercise and depression indicators: adding 60 minutes of weekly activity cut depression development risk by 8% [11]. Kim *et al*. (2020) further showed that moderate-to-vigorous exercise buffers the link between screen exposure and depression indicators [12]. Research on Chinese university students by Feng *et al*. (2014) and Wu *et al*. (2015) likewise indicated elevated depression probability and intensity in those with both smartphone dependency and low exercise [13, 14]. Yet, limited studies address the interactive effects of smartphone dependency and low exercise on depression indicators, especially in youth.

This research assessed rates of smartphone dependency, exercise engagement, and depression indicators in middle school pupils. It explored influences of smartphone dependency and low exercise on depression indicators, and whether greater exercise might lessen smartphone dependency's negative mental health impacts. The goal is to inform targeted strategies for youth depression prevention.

Materials and Methods

Participants

A cross-sectional investigation occurred in Shanghai between November and December 2023. Through cluster sampling, researchers partnered with two middle schools in Jing'an District, a prosperous urban area in China. Included were pupils from junior middle years 6-8 and senior middle years 10-11. Year 9 and 12 pupils were omitted due to exam-related stresses. Following informed consent from pupils and guardians, participants completed questionnaires covering background details independently. Height and weight data came from school health checks. Variables like gender, age, school level, family type, only-child status, BMI, and sleep hours served as controls in analyses linking smartphone dependency, exercise, and depression indicators. Of 1,327 surveyed, 1,316 yielded usable data (99.2% validity rate).

Ethical considerations

The study complied with relevant local regulations and institutional guidelines.

Instruments

Smartphone dependency

Smartphone dependency was measured with the short version of the Smartphone Addiction Scale (SAS-SV), adapted by Kwon from the original Smartphone Addiction Scale (SAS) [15]. In 2019, Xiang *et al*. [16] translated and adapted this instrument into Chinese, testing its reliability and validity among youth, with results confirming strong psychometric properties for this population. Mu *et al*. similarly applied the Chinese version in their research on smartphone dependency and reported a Cronbach's α of 0.92 [17]. The instrument includes 10 items scored on a 6-point Likert scale (1 = strongly disagree to 6 = strongly agree), producing total scores between 10 and 60. Scores exceeding 32 were classified as indicating smartphone dependency. In the present study, the internal consistency reliability (Cronbach's α) was 0.920.

Exercise engagement

Exercise engagement was evaluated using the Physical Activity Rating for Children and Youth developed by the Chinese University of Hong Kong (CUHK-PARCY). This tool was derived from the Jackson Activity Coding and the Godin-Shephard Activity Questionnaire [18, 19]. It covers 11 levels of activity intensity, ranging from no activity (0 points) to intense exercise (10 points), and has demonstrated good validity and overall reliability. For this research, CUHK-PARCY scores were grouped as follows: 0–2 points signified low exercise engagement, 3–6 points indicated moderate engagement, and 7–10 points reflected high engagement [20].

Depression indicators

Depression indicators were measured with the Self-rating Depression Scale (SDS) created by Zung, which comprises 20 items scored on a 4-point scale (1 = none or rare to 4 = most or all the time) [21]. The scale contains both positively and negatively worded items; raw scores

are summed and then multiplied by 1.25 to yield a standard score (rounded to the nearest integer). Standard scores above 53 denote the presence of depression indicators. The Cronbach's α for the SDS in this study was 0.886.

Data analysis

Analyses were conducted using IBM SPSS version 26.0. Chi-square tests examined differences in depression indicators across participant characteristics. Both univariate and multivariate binary logistic regression models were applied to assess the independent influences of smartphone dependency and exercise engagement on youth depression indicators, generating odds ratios (ORs) for various categories. To investigate the interactive influence of smartphone dependency and exercise engagement on depression indicators, the variables were combined into six categories (2 smartphone dependency levels × 3 exercise engagement levels). The group without smartphone dependency and with high exercise engagement was used as the reference category for comparing depression risk across the combined groups.

Results and Discussion

Participant characteristics

Table 1 summarized the details of the 1,316 respondents, of whom 623 (47.3%) were female and 693 (52.7 percent) were male. Depression indicators were present in 477 participants (36.2% of the sample). Smartphone dependency was identified in 253 participants (19.2 percent). For exercise engagement levels, the distribution from most to least prevalent was moderate (39.1 percent), high (37.7 percent), and low (23.3%).

Table 1. Participant characteristics and prevalence of depression indicators among middle school pupils (n=1316).

Characteristics	Total n (%)	Depression indicators		P value	χ^2
		No (n=839) n (%)	Yes (n=477) n (%)		
Gender				0.199	1.651
Female	623 (47.3)	386 (62.0)	237 (38.0)		
Male	693 (52.7)	453 (65.4)	240 (34.6)		
Age (years)				0.488	0.481
≥15	654 (49.7)	423 (64.7)	231 (35.3)		
<15	662 (50.3)	416 (62.8)	246 (37.2)		
School type				0.508	0.439
Senior secondary school	656 (49.8)	424 (64.6)	232 (35.4)		
Junior secondary school	660 (50.2)	415 (62.9)	245 (37.1)		
Family structure type				0.361	0.834
Non-nuclear family	328 (24.9)	216 (65.9)	112 (34.1)		
Nuclear family	988 (75.1)	623 (63.1)	365 (36.9)		
Only child				0.002	9.631
No	335 (25.5)	190 (56.7)	145 (43.3)		
Yes	981 (74.5)	649 (66.2)	332 (33.8)		
BMI				0.084	4.95
Obesity	203 (15.4)	119 (58.6)	84 (41.4)		
Overweight	263 (20.0)	160 (60.8)	103 (39.2)		
Normal	850 (64.6)	560 (65.9)	290 (34.1)		
Sleep duration (h)				<0.001	51.583
Insufficient (<7 h)	431 (32.8)	216 (50.1)	215 (49.9)		
Sufficient (≥7 h)	885 (67.2)	623 (70.4)	262 (29.6)		
Smartphone dependency				<0.001	34.386
Dependency present	253 (19.2)	121 (47.8)	132 (52.2)		

No dependency	1063 (80.8)	718 (667.5)	345 (32.5)		
Exercise engagement level				0.033	6.798
Low engagement	306 (23.3)	179 (58.5)	127 (41.5)		
Moderate engagement	514 (39.1)	325 (63.2)	189 (36.8)		
High engagement	496 (37.7)	335 (67.5)	161 (32.5)		

Factors associated with depression indicators in middle school pupils

Table 2 demonstrated that higher body weight categories were linked to elevated odds of depression indicators. Pupils classified as overweight (OR=1.263, 95% CI: 0.934–1.706, P=0.129) and obese (OR=1.434, 95% CI: 1.028–2.001, P=0.034) exhibited greater likelihood of depression indicators relative to those with normal weight. Key risk factors for depression indicators among middle school pupils included smartphone dependency (OR=2.173, 95% CI: 1.621–2.913, P<0.001), not being an only child (OR=1.421, 95% CI: 1.090–1.853, P=0.009), and short sleep duration (OR=2.722, 95% CI: 2.070–3.578, P<0.001).

Table 2. Logistic regression analysis of factors influencing depressive symptoms (n=1,316).

Characteristics	b	OR (95%CI)	P value
Gender			
Female	0.084	1.087 (0.847-1.395)	0.510
Male			
Age (years)			
≥15	-0.325	0.722 (0.130-4.025)	0.710
<15			
School type			
Senior secondary school	-0.265	0.767 (0.137-4.293)	0.763
Junior secondary school			
Family structure type			
Non-nuclear family	-0.141	0.868 (0.660-1.143)	0.315
Nuclear family			
The only child			
No	0.351	1.421 (1.090-1.853)	0.009
Yes			
BMI			
Obesity	0.361	1.434 (1.028-2.001)	0.034
Overweight	0.233	1.263 (0.934-1.706)	0.129
Normal			
Sleep duration (h)			
Insufficient (<7)	1.001	2.722 (2.070-3.578)	<0.001

Sufficient (≥7)			
Smartphone addiction			
Addiction	0.776	2.173 (1.621-2.913)	<0.001
Non-addiction			
Physical activity level			
Insufficient physical activity	0.290	1.337 (0.968-1.846)	0.078
Moderate physical activity level	0.183	1.201 (0.909-1.586)	0.198
High physical activity level			

Interaction between smartphone addiction and physical activity on depressive symptoms

Table 3 illustrates how depressive symptom prevalence varies according to combinations of smartphone addiction and physical activity levels. Using the group with no smartphone addiction and high physical activity as the baseline: participants without smartphone addiction but with moderate physical activity had an OR of 1.168 (95% CI: 0.857–1.591, P = 0.325), while those with insufficient physical activity had an OR of 1.336 (95% CI: 0.928–1.924, P = 0.119). Among participants with smartphone addiction, the odds of depressive symptoms increased significantly: high physical activity group OR = 2.052 (95% CI: 1.250–3.367, P = 0.004), moderate physical activity group OR = 2.760 (95% CI: 1.701–4.478, P < 0.001), and insufficient physical activity group OR = 2.781 (95% CI: 1.627–4.753, P < 0.001). Notably, in the absence of smartphone addiction, differences in depressive symptom reporting across physical activity levels were not statistically significant (P > 0.05, **(Figure 1)**).

Table 3. Participant characteristics and prevalence of depression indicators among middle school pupils (n=1316).

Smartphone addiction	Physical activity	Number of depressive symptoms/ total number	Model 1		Model 2	
			OR (95%CI)	P value	OR (95%CI)	*P* value
NA	HPAL	118/410	1.000		1.000	
NA	MPAL	140/421	1.233 (0.918-1.655)	0.164	1.168 (0.857-1.591)	0.325
NA	IPA	87/232	1.485 (1.056-2.088)	0.023	1.336 (0.928-1.924)	0.119
SA	HPAR	43/86	2.475 (1.541-3.974)	<0.001	2.052 (1.250-3.367)	0.004
SA	MPAR	49/93	2.756 (1.740-4.364)	<0.001	2.760 (1.701-4.478)	<0.001
SA	IPA	40/74	2.911 (1.757-4.823)	<0.001	2.781 (1.627-4.753)	<0.001

NA= Non-addiction; SA= Smartphone addiction; HPAL= High physical activity level; MPAL= Moderate physical activity level; IPA= Insufficient physical activity. Model 1 did not account for any potential confounding factors, whereas Model 2 controlled for gender, age (in years), stage of study, family structure, whether the participant was an only child, and sleep duration.

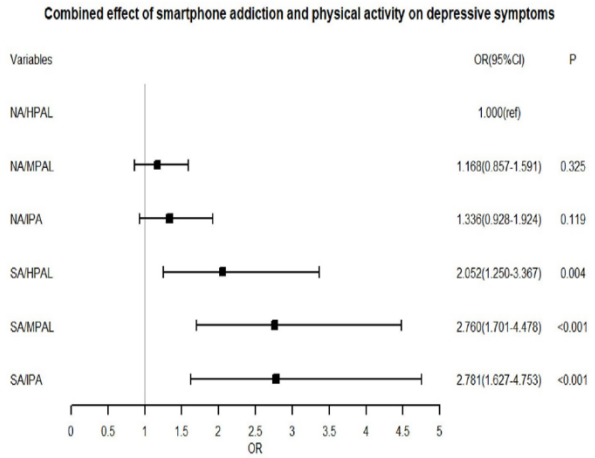

Figure 1. Interaction of smartphone addiction and physical activity on depressive symptoms. Model 2 in **Table 3** was used, adjusting for gender, age (years), school type, family structure, only-child status, and sleep duration.

Adolescence is a period of rapid psychological development, rendering individuals particularly vulnerable to external influences that may trigger varying levels of mental health issues. In this study, 36.2% of participants reported depressive symptoms, considerably higher than the 8% global prevalence reported in previous studies on adolescent depression and the 26.3% prevalence among Chinese adolescents [22, 23]. While factors such as assessment tools, economic conditions, and sociocultural context may contribute, the consistently high rate observed highlights the urgent need to strengthen mental health interventions and adolescent mental health care. Additionally, adolescents who were non-only children or had insufficient sleep exhibited significantly higher rates of depressive symptoms, aligning with previous findings [24, 25], suggesting these groups require focused attention as at-risk populations.

The rapid adoption of smartphones among adolescents for communication, study, and entertainment has raised concerns about smartphone addiction, especially given adolescents' still-developing self-regulation. In this study, 19.2% of participants met criteria for smartphone addiction. Beyond its physical consequences, including impaired vision and disrupted sleep, smartphone addiction contributes to psychological issues such as anxiety, depression, and reduced social adaptability [2, 26], representing a growing global public health concern [27]. Smartphone addiction was also identified as an independent risk factor for depressive symptoms, with affected adolescents reporting higher symptom levels than their non-addicted peers, consistent with Park *et al*. (2018) [28]. The social replacement hypothesis suggests that excessive smartphone use may replace real-world interactions, leading to negative emotions such as depression [26, 29], while circadian rhythm disruptions caused by smartphone use can further impair neuroendocrine function, increasing susceptibility to depressive symptoms [30]. These findings underscore the importance of interventions targeting adolescent smartphone addiction, such as encouraging in-person social interactions and providing guidance on healthy smartphone use [31–33].

Insufficient physical activity frequently co-occurs with smartphone addiction. In this study, 37.7% of participants reported high physical activity, 39.1% moderate, and 23.3% insufficient, falling short of UN recommendations for adolescents. Physical inactivity contributes not only to physical health issues such as overweight and obesity but also to mental health problems, including depressive symptoms [11]. Promoting physical activity is therefore essential for improving both physical and mental health, and public health initiatives should facilitate access to sports and outdoor activities within schools and communities [34, 35].

Examining the combined influence of smartphone addiction and physical activity, participants experiencing both factors reported higher depressive symptom prevalence than those with either factor alone, consistent with prior studies [36, 37]. Adolescents with smartphone addiction showed elevated depressive symptoms regardless of physical activity level, suggesting that smartphone addiction exerts a stronger negative effect than physical inactivity, though higher physical activity may partially buffer this impact. This may reflect the possibility that smartphone addiction reduces engagement in physical activity, diminishing its protective effects on mental health [38]. Consequently, interventions should address both smartphone addiction and physical inactivity simultaneously. Schools, healthcare providers, and parents should implement programs to educate adolescents about balancing smartphone use and physical activity, encourage daily physical exercise through team sports or outdoor activities, and establish healthy boundaries for smartphone use to create supportive environments that reduce the risk of depressive symptoms.

This study fills a theoretical gap by analyzing the joint effects of smartphone addiction and physical activity,

offering practical insights for policymakers to design comprehensive, multifaceted strategies to address rising adolescent depression. It also identifies additional risk factors, including non-only-child status and sleep deprivation, highlighting the need for tailored interventions. Considering interactions among behavioral and demographic factors emphasizes the value of a holistic approach to adolescent mental health. Limitations include the cross-sectional design, which precludes causal inference, the restricted sample from two schools selected via cluster sampling, which may limit generalizability, and reliance on self-reported data aside from height and weight, which may introduce bias. Future research should employ longitudinal designs and objective measurement tools to improve accuracy.

Conclusion

Depressive symptoms are highly prevalent among adolescents, with smartphone addiction and insufficient physical activity presenting significant risks. A synergistic effect of these factors on depressive symptoms was observed, with smartphone addiction exerting a particularly strong influence. While increasing physical activity can partially counteract the negative impact of smartphone addiction, controlling smartphone use remains critical. Comprehensive interventions addressing both smartphone addiction and physical inactivity are therefore essential to effectively reduce the occurrence and progression of depressive symptoms in adolescents.

Acknowledgments: None

Conflict of Interest: None

Financial Support: None

Ethics Statement: None

References

1. Toda M, Ezoe S, Nishi A, Mukai T, Goto M, Morimoto K. Mobile phone dependence of female students and perceived parental rearing attitudes. Soc Behav Personality. (2008) 36:765–70. doi: 10.2224/sbp.2008.36.6.765
2. Yang X, Zhou Z, Liu Q, Fan C. Mobile phone addiction and adolescents' anxiety and depression: The moderating role of mindfulness. J Child Family Stud. (2019) 28:822–30. doi: 10.1007/s10826-018-01323-2
3. Salehan M, Negahban A. Social networking on smartphones: When mobile phones become addictive. Comput Hum Behavior. (2013) 29:2632–9. doi: 10.1016/j.chb.2013.07.003
4. Wang J-L, Rost DH, Qiao R-J, Monk R. Academic stress and smartphone dependence among Chinese adolescents: A moderated mediation model. Children Youth Serv Rev. (2020) 118:105029. doi: 10.1016/j.childyouth.2020.105029
5. Sicheng X, Bin Z, Yongzhi J, Huaibin J, Yun C. Global prevalence of mobile phone addiction: A meta-analysis. Stud Psychol Behavior. (2021) 19:802–8.
6. Nilsson A, Brage S, Riddoch C, Anderssen SA, Sardinha LB, Wedderkopp N, et al. Comparison of equations for predicting energy expenditure from accelerometer counts in children. Scand J Med Sci Sports. (2008) 18:643–50. doi: 10.1111/j.1600-0838.2007.00694.x
7. Hallal PC, Andersen LB, Bull FC, Guthold R, Haskell W, Ekelund U. Global physical activity levels: surveillance progress, pitfalls, and prospects. Lancet. (2012) 380:247–57. doi: 10.1016/S0140-6736(12)60646-1
8. Malhi GS, Mann JJ. Depression. Lancet. (2018) 392:2299–312. doi: 10.1016/S0140-6736(18)31948-2
9. Kisch J, Leino EV, Silverman MM. Aspects of suicidal behavior, depression, and treatment in college students: results from the spring 2000 national college health assessment survey. Suicide life-threatening behavior. (2005) 35 1:3–13. doi: 10.1521/suli.35.1.3.59263
10. Tang CSK, Wu AMS, Yan ECW, Ko JHC, Kwon JH, Yogo M, et al. Relative risks of Internet-related addictions and mood disturbances among college students: a 7-country/region comparison. Public Health. (2018) 165:16–25. doi: 10.1016/j.puhe.2018.09.010
11. Rothon C, Edwards P, Bhui K, Viner RM, Taylor S, Stansfeld SA. Physical activity and depressive symptoms in adolescents: a prospective study. BMC Med. (2010) 8:32. doi: 10.1186/1741-7015-8-32
12. Kim S, Favotto L, Halladay J, Wang L, Boyle MH, Georgiades K. Differential associations between

passive and active forms of screen time and adolescent mood and anxiety disorders. Soc Psychiatry Psychiatr Epidemiol. (2020) 55:1469–78. doi: 10.1007/s00127-020-01833-9
13. Feng Q, Zhang QL, Du Y, Ye YL, He QQ. Associations of physical activity, screen time with depression, anxiety and sleep quality among Chinese college freshmen. PLoS One. (2014) 9:e100914. doi: 10.1371/journal.pone.0100914
14. Wu X, Tao S, Zhang Y, Zhang S, Tao F. Low physical activity and high screen time can increase the risks of mental health problems and poor sleep quality among Chinese college students. PLoS One. (2015) 10:e0119607. doi: 10.1371/journal.pone.0119607
15. Kwon M, Kim DJ, Cho H, Yang S. The smartphone addiction scale: development and validation of a short version for adolescents. PLoS One. (2013) 8:e83558. doi: 10.1371/journal.pone.0083558
16. Ben XMWZM. Reliability and validity of Chinese version of the smartphone addiction scale in adolescents. Chin J Clin Psychol. (2019) 27:959–64.
17. Mu Ziwei RF, Yu W, Xiao W, Wan Y. Relationship among bullying, mobile phone addiction and depressive symptoms in college students. Chin Ment Health J. (2024) 38:820–6.
18. Baumgartner TA, Jackson AS eds. Measurement for Evaluation in Physical Education and Exercise Science (1987) Boston, MA: WCB McGrawHill.
19. Godin G, Shephard RJ. A simple method to assess exercise behavior in the community. Can J Appl Sport Sci. (1985) 10:141–6.
20. Kong AP, Choi KC, Li AM, Hui SS, Chan MH, Wing YK, et al. Association between physical activity and cardiovascular risk in Chinese youth independent of age and pubertal stage. BMC Public Health. (2010) 10:303. doi: 10.1186/1471-2458-10-303
21. Zung WW. A self-rating depression scale. Arch Gen Psychiatry. (1965) 12:63–70. doi: 10.1001/archpsyc.1965.01720310065008
22. Shorey S, Ng ED, Wong CHJ. Global prevalence of depression and elevated depressive symptoms among adolescents: A systematic review and meta-analysis. Br J Clin Psychol. (2022) 61:287–305. doi: 10.1111/bjc.12333
23. Li JY, Li J, Liang JH, Qian S, Jia RX, Wang YQ, et al. Depressive symptoms among children and adolescents in China: A systematic review and meta-analysis. Med Sci Monit. (2019) 25:7459–70. doi: 10.12659/MSM.916774
24. Khan A, Ahmed R, Burton NW. Prevalence and correlates of depressive symptoms in secondary school children in Dhaka city, Bangladesh. Ethn Health. (2020) 25:34–46. doi: 10.1080/13557858.2017.1398313
25. Cao Y, Huang L, Si T, Wang NQ, Qu M, Zhang XY. The role of only-child status in the psychological impact of COVID-19 on mental health of Chinese adolescents. J Affect Disord. (2021) 282:316–21. doi: 10.1016/j.jad.2020.12.113
26. Kraut R, Patterson M, Lundmark V, Kiesler S, Mukopadhyay T, Scherlis W. Internet paradox. A social technology that reduces social involvement and psychological well-being? Am Psychol. (1998) 53:1017–31. doi: 10.1037//0003-066x.53.9.1017
27. Sohn SY, Rees P, Wildridge B, Kalk NJ, Carter B. Prevalence of problematic smartphone usage and associated mental health outcomes amongst children and young people: a systematic review, meta-analysis and GRADE of the evidence. BMC Psychiatry. (2019) 19:356. doi: 10.1186/s12888-019-2350-x
28. Park S, Kim H, Lee E, Lea E. Relationship between mobile phone dependence and depression of adolescents using autoregressive cross-lagged model. Forum For Youth Culture. (2018) 55:53–75. doi: 10.17854/ffyc.2018.07.55.53
29. Mendt S, Gunga H-C, Felsenberg D, Belavy DL, Steinach M, Stahn AC. Regular exercise counteracts circadian shifts in core body temperature during long-duration bed rest. NPJ Microgravity. (2021) 7:1. doi: 10.1038/s41526-020-00129-1
30. Vrshek-Schallhorn S, Doane LD, Mineka S, Zinbarg RE, Craske MG, Adam EK. The cortisol awakening response predicts major depression: predictive stability over a 4-year follow-up and effect of depression history. psychol Med. (2012) 43:483–93. doi: 10.1017/S0033291712001213
31. Shek DT, Yu L, Leung H, Wu FK, Law MY. Development, implementation, and evaluation of a multi-addiction prevention program for primary school students in Hong Kong: the B.E.S.T. Teen Program. Asian J Gambl Issues Public Health. (2016) 6:5. doi: 10.1186/s40405-016-0014-z

32. Turel O, Mouttapa M, Donato E. Preventing problematic Internet use through video-based interventions: a theoretical model and empirical test. Behav Inf Technol. (2015) 34:349–362. doi: 10.1080/0144929X.2014.936041
33. Sul S. Determinants of internet game addiction and therapeutic role of family leisure participation. J Inclusion Phenomena Macrocyclic Chem. (2015) 82:271–8. doi: 10.1007/s10847-015-0508-9
34. McKenzie TL, Sallis JF, Rosengard P, Ballard K. The SPARK programs: A public health model of physical education research and dissemination. J Teach Phys Education. (2016) 35:381–9. doi: 10.1123/jtpe.2016-0100
35. Bulger S, Illg K, Jones E. Achieving alignment in the preparation of CSPAP leaders in PETE programs. J Phys Education Recreation Dance. (2017) 88:37–42. doi: 10.1080/07303084.2017.1260982
36. Liu M, Zhang J, Hu E, Yang H, Cheng C, Yao S. Combined patterns of physical activity and screen-related sedentary behavior among Chinese adolescents and their correlations with depression, anxiety and self-injurious behaviors. Psychol Res Behav Manage. (2019) 12:1041–50. doi: 10.2147/PRBM.S220075
37. Xie H, Tao S, Zhang Y, Tao F, Wu X. Impact of problematic mobile phone use and insufficient physical activity on depression symptoms: a college-based follow-up study. BMC Public Health. (2019) 19:1640. doi: 10.1186/s12889-019-7873-z
38. Kim S-E, Kim J-W, Jee Y-S. Relationship between smartphone addiction and physical activity in Chinese international students in Korea. J Behav Addictions. (2015) 4:200–5. doi: 10.1556/2006.4.2015.028