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Research Paper

Physical activity mediates the relationship between depressive symptoms and problematic smartphone use (PSU) in Germany

Julia Brailovskaia [*,a], Jürgen Margraf [a]

[a] Mental Health Research and Treatment Center, Department of Clinical Psychology and Psychotherapy, Ruhr-Universität Bochum, Germany

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ABSTRACT

Background: People with enhanced levels of depressive symptoms often feel sad, hopeless, and helpless. Some of them tend to escape the negative emotions by intensive smartphone use. This could enhance their risk for problematic use tendencies. Factors that can reduce this risk are of great importance. The present study investigated the association between depressive symptoms and problematic smartphone use (PSU), as well as physical activity as a potential protective factor over six weeks.
Methods: Data of 185 smartphone users from Germany (M_{age} = 29.45, SD_{age} = 11.17) were assessed via online surveys at three measurement time points (baseline, BL; 2-week follow-up, FU1; 6-week follow-up, FU2).
Results: Depressive symptoms (BL) were significantly positively linked to PSU (FU2). Physical activity (FU1) was significantly negatively associated with depressive symptoms (BL) and PSU (FU2). Furthermore, physical activity (FU1) significantly mediated their relationship. Mediation analyses that included other time sequences of the three variables were not significant.
Limitations: The present survey design does not allow true conclusions on causality.
Conclusions: A conscious enhancement of physical activity in the therapeutic setting or by preventive health programs could contribute to a reduction of PSU in persons who suffer from depressive symptoms.

1. Introduction

In the 21st century, smartphones have become a ubiquitous and essential tool for many people (Howarth, 2022). They provide up-to-date news, facilitate routine tasks, and allow permanent availability and social interaction via phone calls and social media applications such as Instagram, Twitter, Facebook, WhatsApp, and Telegram (David et al., 2018).

Especially individuals who often feel lonely and lack social support tend to intensive smartphone use (Shen and Wang, 2019). Both – the feeling of loneliness and the lack of social support – are positively associated with enhanced levels of depressive symptoms (Brailovskaia et al., 2022a; Lee and Kim, 2022; Venanzi et al., 2022). Therefore, the positive relationship between depressive symptoms and time spent on smartphone use (e.g., Elhai et al., 2020; Yang et al., 2020) is not surprising. Even though smartphones can be used for various reasons, recent research emphasized that depressed people often tend to use the smartphone to escape negative feelings, to forget their symptoms and overwhelming problems, and to experience positive emotions at least temporarily (Augner et al., 2021; Elhai et al., 2018; Jin et al., 2021; Liebherr et al., 2020; Yuan et al., 2021).

However, the positive effects of smartphone use can be only maintained as long as the use intensity remains moderate (Brailovskaia et al., 2022a). Its increase can negatively impact the individual health and behavior by the development of addictive or problematic tendencies (Huang et al., 2021; Montag and Walla, 2016). Following the Interaction of Person-Affect-Cognition-Execution (I-PACE) model for addictive behavior (Brand et al., 2019), excessive use can foster a strong emotional bond to the digital device that is closely linked to habit formation of prolonged smartphone use (Busch and McCarthy, 2021; Elhai et al., 2021). As a consequence, the person can lose control and progressively engage in excessive smartphone use in various situations as an impulsive response, even if alternative behavior would be more functional and reasonable (Brailovskaia et al., 2021; Brand et al., 2019). Non-use can provoke mood deterioration, mental and physical withdrawal (Chen, 2020). This phenomenon – that has been termed as addictive, compulsive, dependent, or problematic smartphone use (PSU) (Elhai et al., 2017) – is defined by characteristics such as salience, tolerance, mood

* Corresponding author at: Massenbergstr. 9-13, 44787 Bochum, Germany.
E-mail address: julia.brailovskaia@rub.de (J. Brailovskaia).

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modification, relapse, withdrawal, and interpersonal conflicts (Elhai et al., 2019). Notably, it has not been recognized as a formal psychiatric disorder (International Classification of Diseases, ICD-11; World Health Organization, 2018). Also, previous research warned of over-pathologization of intensive media use (Carbonell and Panova, 2017). Therefore, we will avoid terms such as "addictive smartphone use" and use the term PSU as proposed by Panova and Carbonell (2018) in the present study.

Previous research described a positive relationship between depressive symptoms and PSU (Geng et al., 2021; Jo et al., 2021). Individuals with elevated depressive symptoms may excessively use smartphones as a means of coping with negative feelings and seeking positive ones (Busch and McCarthy, 2021; Yuan et al., 2021). This coping mechanism, especially the relief from negative feelings such as hopelessness and helplessness, can foster the emotional bond to the technical device and result in the development of problematic use tendencies (Brailovskaia et al., 2020; Lee and Kim, 2022). PSU can contribute to interpersonal conflicts, reduced work and academic performance, as well as sleep problems that negatively impact the mental and physical health and the life quality of depressed persons (Liebherr et al., 2020; Yang et al., 2020). Against this background, it is of great importance to identify factors that could reduce the risk of depressed individuals for PSU and thus support their health and quality of life.

Physical activity such as jogging, cycling, yoga and swimming can protect physical and mental health (Eime et al., 2013; Precht et al., 2022). The World Health Organization (2020) recommends to engage for about 150 min in moderate physical activity throughout the week to maintain a high level of health. Especially depressed individuals who often lack positive emotions and feel overwhelmed by negative ones (Venanzi et al., 2022) could benefit from physical activity that can increase the dopamine level in the brain and provide a positive rewarding experience (Knab and Lightfoot, 2010). As a consequence, they could search less for positive emotions by intensive smartphone use (Jin et al., 2021). Recent research reported that physical activity could reduce the risk for PSU (Azam et al., 2020). But individuals with enhanced PSU levels often engage in less physical activity than other people (Buke et al., 2021; Pereira et al., 2020).

Thus, we can hypothesize that depressive symptoms could contribute to PSU and that physical activity could serve as a protective factor within this association. To investigate this assumption and to contribute to the knowledge of how to reduce PSU, we aimed to assess the relationship between depressive symptoms, PSU, and physical activity by a 6-week follow-up design in the current study. Therefore, we assessed data on depressive symptoms, PSU, and physical activity at three measurement time points (baseline, BL; 2-week follow-up, FU1; 6-week follow-up, FU2) over six weeks.

Considering earlier findings on the positive relationship between depressive symptoms and PSU (e.g., Elhai et al., 2020; Liebherr et al., 2020), the negative association between depressive symptoms and physical activity (Precht et al., 2021), as well as the negative link between physical activity and PSU (Buke et al., 2021; Pereira et al., 2020), we hypothesized a positive association between depressive symptoms at BL and PSU at FU2 (Hypothesis 1a). Physical activity at FU1 was expected to be negatively related with depressive symptoms at BL (Hypothesis 1b) and PSU at FU2 (Hypothesis 1c). Furthermore, we assumed that physical activity at FU1 mediates the association between depressive symptoms at BL and PSU at FU2 (Hypothesis 2).

2. Methods

2.1. Procedure and participants

Participants were recruited by invitations that were displayed at public places (shops, bakeries), social media (Facebook, Twitter, Instagram), and various universities in Germany between April and August 2022. The invitations included the link to the first online survey. Participation – voluntary and compensated by course credits for students – required legal age due to German law (i.e., age of 18), ownership of a smartphone, and the agreement to participate in three online surveys over six weeks. The 201 participants who completed the first survey (BL) received the link to the second survey (FU1) by e-mail two weeks later, and the 193 participants who completed the FU1 received the link to the third survey (FU2) four weeks later. In total, 185 smartphone users completed all surveys (BL: 77.3% women, 22.7% men; $M_{age}(SD_{age})$=29.45(11.17), range: 18–65; occupation: 58.9% students, 40.0% employees, one unemployed and one retired person; marital status: 30.8% single, 50.8% in a relationship, 18.4% married). The responsible Ethics Committee approved implementation of the current study. All participants were properly instructed, and all gave informed consent to participate via an online form. Power analyses (G*Power program, version 3.1) revealed that the sample size is sufficient for valid results (power > 0.80, $\alpha = 0.05$, effect size: $f^2 = 0.15$; cf., Mayr et al., 2007).

2.2. Measures

2.2.1. Depressive symptoms

The depression subscale of the Depression Anxiety Stress Scales 21 (DASS-21; original version: Lovibond and Lovibond, 1995; German version: Nilges and Essau, 2015) assessed depressive symptoms with seven items. Items are rated on a 4-point Likert-type scale (e.g., "I couldn't seem to experience any positive feeling at all"; 0 = *did not apply to me at all*; 3 = *applied to me very much or most of the time*). Higher sum scores indicate higher depressive symptoms. Current scale reliability: Cronbach's $\alpha_{BL} = 0.88$, $\alpha_{FU1} = 0.89$, $\alpha_{FU2} = 0.90$.

2.2.2. Problematic smartphone use

Following Brailovskaia et al. (2021), we measured PSU by the modified German version of the brief Bergen Social Media Addiction Scale (BSMAS; original version: Andreassen et al., 2016). The six items (e.g., "Felt an urge to use the Smartphone more and more?") are formulated according to the six characteristics of addictive behavior (salience, tolerance, mood modification, relapse, withdrawal, conflict). They are rated on a 5-point Likert-type scale (1 = *very rarely*, 5 = *very often*). The higher the sum score, the higher PSU. Current scale reliability: $\alpha_{BL} = 0.85$, $\alpha_{FU1} = 0.85$, $\alpha_{FU2} = 0.87$.

2.2.3. Physical activity

Following Fuchs et al. (2015; original German version), participants indicated whether they had engaged in any form of physical activity during the past week (0 = *no*, 1 = *yes*). If they had done so, they could name up to three activities that they engaged in. For each activity, they indicated how many times they had engaged in it and for how long (in minutes). If available, they referred to time tracked by fitness/activity trackers. If not available, they estimated their activity time as accurately as possible. To calculate the weekly duration of physical activity, we multiplied times and minutes (times*minutes) for each activity, and we summed up the product values. We entered a zero, for participants who did not engage in any physical activity. Current mean test-retest reliability (BL to FU2): $r_{mtrr} = 0.494$.

2.3. Statistical analyses

Statistical analyses were conducted using SPSS 28 and the Process macro version 4.0 (www.processmacro.org/index.html). After descriptive analyses, we assessed the associations between the variables included in the hypotheses by zero-order bivariate correlations. Next, we ran six mediation analyses (Process: model 4). *Mediation model 1* followed the time sequence as assumed in Hypothesis 2. It included depressive symptoms (BL) as predictor, physical activity (FU1) as mediator, and PSU (FU2) as outcome; considering the mostly young and female composition of the present sample, age and gender (both at BL)

served as covariates. The basic relationship between depressive symptoms (BL) and PSU (FU2) was denoted by *c* (the total effect). The path of depressive symptoms (BL) to physical activity (FU1) was denoted by *a*, the path of physical activity (FU1) to PSU (FU2) was denoted by *b*. The combined effect of path *a* and path *b* presented the indirect effect. The direct effect of depressive symptoms (BL) and PSU (FU2) after inclusion of physical activity (FU1) in the model was denoted by *c'*. The bootstrapping procedure (10.000 samples) that provides percentile bootstrap confidence intervals (95% CI) assessed the mediation effect. The other five mediation analyses were calculated to ensure the accuracy of the hypothesized time sequence: *Mediation model 2* included depressive symptoms (BL) as predictor, PSU (FU1) as mediator and physical activity (FU2) as outcome; *mediation model 3* included physical activity (BL) as predictor, depressive symptoms (FU1) as mediator and PSU (FU2) as outcome; *mediation model 4* included physical activity (BL) as predictor, PSU (FU1) as mediator and depressive symptoms (FU2) as outcome; *mediation model 5* included PSU (BL) as predictor, depressive symptoms (FU1) as mediator and physical activity (FU2) as outcome; *mediation model 6* included PSU (BL) as predictor, physical activity (FU1) as mediator and depressive symptoms (FU2) as outcome.

3. Results

Table 1 shows the descriptive statistics of all investigated variables.

Depressive symptoms (BL) were significantly positively correlated with PSU (FU2), $r = 0.331$, $p < .001$. Physical activity (FU1) was significantly negatively correlated with depressive symptoms (BL), $r = -0.158$, $p = .032$, and PSU (FU2), $r = -0.258$, $p<.001$.

Fig. 1 presents the results of *mediation model 1*. Physical activity (FU1) mediated the relationship between depressive symptoms (BL) and PSU (FU2). The basic association between depressive symptoms (BL) and PSU (FU2) was significant (total effect, *c:* $p < .001$). After the inclusion of physical activity (FU1) in the model, the link between both variables was still significant (direct effect, *c':* $p = .001$). However, the total effect was higher than the direct effect (see Fig. 1) which reveals a partial mediation. The link between depressive symptoms (BL) and physical activity (FU1) (*a:* $p = .047$), and the association between physical activity (FU1) and PSU (FU2) (*b:* $p = .007$) were significant, as well as the indirect effect (*ab*), $b = 0.034$, SE = 0.018, 95% CI [.004, 0.076].

Mediation model 2 to *mediation model 6* revealed no significant findings (see Supplemental Material Table S1).

4. Discussion

Due to their symptoms, depressed individuals feel often overwhelmed by routine tasks (Wang et al., 2017). To escape the negative emotions and to experience positive ones, some of them can tend to excessive smartphone use (e.g., Elhai et al., 2020; Jin et al., 2021). The present study investigated the relationship between depressive symptoms, problematic smartphone use, and physical activity. Our follow-up design with three measurement time points over six weeks provides a first approach to the temporal order of the variables in this relationship. This contributes to a better understanding of potential consequences of excessive smartphone use and how they could be prevented.

As expected, depressive symptoms at baseline were positively associated with PSU up to six weeks later (confirmation of Hypothesis 1a). This finding corresponds to available literature which described that excessive smartphone use could provide depressed people some relief in the short-term (Liebherr et al., 2020). However, in the longer-term, it could foster the development of a close emotional bond to the technical device that is accompanied by addictive tendencies (Elhai et al., 2018; Yuan et al., 2021). These tendencies can negatively impact one's everyday life by the enhancement of interpersonal conflicts as well as physical and mental symptoms (Augner et al., 2021).

Thus, excessive smartphone use seems to be a dysfunctional coping strategy especially for depressed persons (Wang et al., 2022). Against this background, we investigated physical activity as a potential functional and protective strategy. Earlier research described the positive effects of moderate physical activity on physical and mental health (Brailovskaia et al., 2022b; Mücke et al., 2018). Moreover, it contributed to less tendencies of addictive use of social media such as Facebook in individuals who experienced enhanced levels of everyday stress (Brailovskaia et al., 2018). Our findings reveal a negative association between depressive symptoms at baseline and engagement in physical activity two weeks later (confirmation of Hypothesis 1b). Furthermore, physical activity was negatively linked to PSU assessed four weeks later (confirmation of Hypothesis 1c). In addition, physical activity at 2-week follow-up mediated the association between depressive symptoms at baseline and PSU at 6-week follow-up (confirmation of Hypothesis 2). Specifically, the higher the depressive symptoms, the lower the physical activity and the higher the PSU level. The non-significant results of the other five mediation models confirm the accuracy of this time sequence.

The present results allow the conclusion that depressed individuals could be less motivated to engage in physical activity than less depressed persons which could be explained by their negative symptoms (Azar et al., 2008). This, however, could enhance their risk for PSU. But this also means that a conscious enhancement of their physical activity in the therapeutic setting or by a low-threshold program could reduce the risk for PSU especially in depressed individuals. In either case, depressed persons need support by other people (professional or close others) who motivate them to physical activity as a functional coping strategy. Engagement in physical activity can foster the experience of positive emotions and reduce negative ones (Precht et al., 2022). Moreover, it improves physical health and reduces stress symptoms (Chow and Choi, 2019; Vancampfort et al., 2018). This could reduce the tendency of depressed individuals to escape the reality by excessive smartphone use that often interrupts their daily activities and enhances interpersonal conflicts (Winkler et al., 2020), and it could decrease their risk for PSU and its negative consequences for mental and physical health and their quality of life (Kliesener et al., 2022). Specifically, persons with enhanced depressive symptoms could be screened for the level of PSU and physical activity in a first step at the beginning of the treatment and preventive programs. In a second step, a conscious reduction of time spent daily on smartphone use and a conscious increase in daily physical activity could be integrated in these programs to foster their effectiveness.

Our study has some limitations that should be considered when interpreting the results. First, our German sample was mostly female and rather young. This could limit the results' generalizability to other populations. We controlled for age and gender in the mediation analyses which partly tackled this limitation. Nevertheless, future studies should replicate our findings in more age and gender balanced samples from other countries. Second, the follow-up online survey design allows only a first approach to true conclusions on causality. Our findings should be

Table 1
Descriptive statistics of depressive symptoms, physical activity, and problematic smartphone use (baseline to follow-up 2).

	M(SD)	Min–Max
Depressive Symptoms (BL)	3.98 (4.06)	0–19
Depressive Symptoms (FU1)	3.59 (3.92)	0–18
Depressive Symptoms (FU2)	3.51 (3.94)	0–20
Physical Activity (BL)	169.32 (196.20)	0–1080
Physical Activity (FU1)	151.98 (185.46)	0–1000
Physical Activity (FU2)	168.51 (212.54)	0–930
PSU (BL)	12.25 (4.97)	6–27
PSU (FU1)	11.69 (4.87)	6–28
PSU (FU2)	11.91 (5.02)	6–29

Notes. $N = 185$; physical activity in minutes per week; PSU = Problematic Smartphone Use; BL = baseline; FU = follow-up; *M* = Mean; *SD* = Standard Deviation; *Min* = Minimum, *Max* = Maximum.

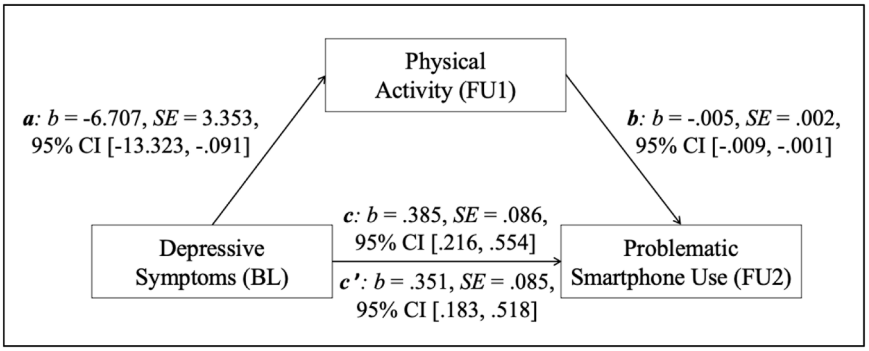

Fig. 1. Mediation model including depressive symptoms at baseline as predictor, physical activity at follow-up 1 as mediator, and problematic smartphone use at follow-up 2 as outcome.
Note. $N = 185$; c = total effect, c' = direct effect; b = standardized regression coefficient, SE = standard error, CI = confidence interval; BL = baseline, FU = follow-up.

extended by experimental investigations. For example, it could be investigated by an experimental study design, whether a conscious increase of physical activity can influence the link between depressive symptoms and PSU. Third, we focused only on physical activity as a protective factor against PSU and found a partial mediation effect. Thus, future studies should search for further protective factors and combine them with enhanced physical activity to strengthen the positive effect. Fourth, we assessed data via self-report that can be prone to perception mistakes and social desirability. We asked the participants to provide physical activity time tracked by specific devices if available. But we do not know how many of them did so. In future research, the physical activity time of all participants should be assessed by activity/fitness trackers and a social desirability measure (e.g., Balanced Inventory of Desirable Responding, BIDR; Musch et al., 2002) should be included.

To conclude, the current study reveals that higher levels of depressive symptoms could contribute to PSU. Physical activity could act as a mediator to reduce this risk. Other time sequences of the three variables revealed no significant mediation effects. Future experimental research should investigate the causality of the found mediation by intentionally enhancement of physical activity in individuals with increased levels of depressive symptoms. Experimental confirmation of our approach would emphasize its usefulness in therapeutic context and preventive health protection programs.

Author statement

Contributors

Julia Brailovskaia and Jürgen Margraf conducted the study design. Julia Brailovskaia wrote the first draft of the manuscript. Julia Brailovskaia conducted statistical analysis, literature searches, data collection and data preparation. Jürgen Margraf reviewed and edited the first draft. All authors contributed to and have approved the final manuscript. All authors state their compliance with the Code of Ethics of the World Medical Association (Declaration of Helsinki).

Declaration of Competing Interest

None.

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Supplementary materials

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