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## Research Paper

# Can physical activity foster mental health by preventing addictive social media use? – A longitudinal investigation during the COVID-19 pandemic in Germany

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## ABSTRACT

**Introduction:** The COVID-19 pandemic contributed to an increase of mental health problems like depression, anxiety, stress symptoms, and Internet-based addictive behaviors. Therefore, the present longitudinal study investigated whether physical activity might prevent addictive social media use (SMU) and thus foster positive mental health (PMH) and decrease negative mental health (NMH).

**Methods:** Data were assessed in a sample of 356 participants ( $M_{age} = 27.43$ ,  $SD_{age} = 6.59$ ) from Germany via online surveys at two measurement time points in spring 2020 (baseline, BL) and one year later in spring 2021 (follow-up, FU). Moderated mediation analyses were conducted for the investigation of the relations.

**Results:** Analyses revealed that addictive SMU (BL) mediated the relationship between physical activity (BL) and PMH (FU) as well as symptoms of depression, anxiety, and stress (FU). Moreover, the association between physical activity and addictive SMU was moderated by the level of burden caused by COVID-19 (BL), i.e., it was significant for medium and high, but not for low burden.

**Limitations:** The mostly female and relatively young sample limit the generalizability of the current findings. Moreover, the relationships should be investigated in further countries to different time points.

**Conclusions:** The findings indicate positive effects of physical activity on PMH and NMH by the reduction of tendencies of addictive SMU. Especially people who experience high levels of burden by COVID-19 may benefit from regular physical activity. This could be a cost-effective, low-threshold prevention strategy for meeting the pandemic induced challenges for mental health.

## 1. Introduction

Since the first case of the coronavirus disease (COVID-19; severe acute respiratory syndrome coronavirus 2, SARS-CoV-2) on December 30, 2019, and the subsequent declaration of its outbreak as a pandemic on March 11, 2020 (World Health Organization, 2020), there have been about 240 million confirmed cases of COVID-19 including nearly 4.9 million deaths all over the world (as of October 18, 2021; World Health Organization, 2021c). Although the access to effective vaccines (World Health Organization, 2021a) is promising and the number of people fully vaccinated is rising (World Health Organization, 2021c), the number of countries that report variants of the virus (Alpha, Beta, Gamma, Delta) continues to increase (World Health Organization,

2021b). The end of the pandemic is not yet foreseeable. The current situation is associated with extensive social, economic, and medical challenges (Gruber et al., 2021). Going along with this, a substantial increase of mental health problems was noted (Jané-Llopis et al., 2021; Newby et al., 2020; Pierce et al., 2020). Recent meta-analyses documented the detrimental effects on mental health in countries from all over the world. They reported a prevalence of at least 30% for depression, anxiety, and stress, respectively, during the COVID-19 outbreak (e.g., Salari et al., 2020; Wang et al., 2020; Wu et al., 2021).

To reduce anxiety and stress or to relieve depressed mood, people tend to reinforcing behavior such as social media use (SMU) (Király et al., 2020). Therefore, it is not astonishing that the current situation has led to an enhanced SMU (Gao et al., 2020; Hossain et al., 2020;

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Riehm et al., 2020). The need to stay in contact with family and friends might have contributed to the increase (Garfin, 2020), since search for social interaction and connection belongs to the main reasons for SMU (Brailovskaia et al., 2020a). Persons who use social media (SM) to search for positive emotions and to stay in contact with their loved ones are likely to benefit from SMU: online-based social support was found to improve positive mental health (PMH, i.e., the presence of general emotional, psychological, and social well-being; Lukat et al., 2016) as well as to reduce symptoms of depression, anxiety, and loneliness (Gil-mour et al., 2020; Verduyn et al., 2017). In contrast, people who use SM to escape negative emotions are at enhanced risk to develop addictive use tendencies (Brailovskaia et al., 2020a). The immersion into the online world to escape daily problems is a dysfunctional coping strategy, that can foster the development of a strong emotional bond to SM, which is accompanied by a strong need to stay permanently online. This phenomenon is known as addictive SMU and characterized by salience (i.e., being preoccupied by SM), mood modification (i.e., using SM to reduce negative feelings), tolerance (i.e., more SMU is needed for experiencing the same pleasure), withdrawal symptoms (i.e., suffering distress if SM are not available), conflict (i.e., due to neglecting obligations), and relapse (i.e., trying to control SMU without success) (Andreassen et al., 2017; Griffiths, 2005).

Although addictive SMU is currently not included in the Diagnostic and Statistical Manual of Mental Disorders (DSM-5; American Psychiatric Association, 2013) and in the International Classification of Diseases (ICD-11; World Health Organization, 2019) it is negatively linked to PMH. Its association with depression, anxiety, and loneliness is positive (Huang, 2020; Hussain and Griffiths, 2018). Moreover, it is positively related to psychological burden caused by COVID-19 (Brailovskaia and Margraf, 2021). When people lack adequate coping strategies and experience high levels of burden, they tend to dysfunctional strategies like potentially addictive SMU (Király et al., 2020). This is in line with recent research that described an enhancement of SMU and an increase in Internet-based addictive behaviors during the pandemic (Gao et al., 2020; Masaeli and Farhadi, 2021).

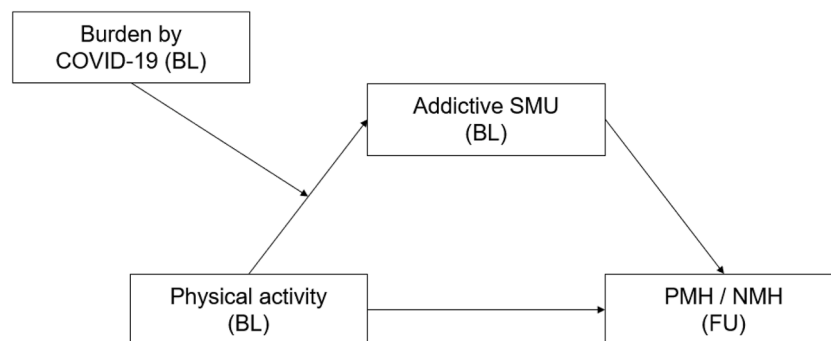
Therefore, it is important to support people at risk who lack adequate coping strategies by identifying functional, easily applicable strategies to cope with the increased stress and mental health issues resulting from the COVID-19 situation. One of them might be physical activity (Faulkner et al., 2020; Wunsch et al., 2017). Physical activity such as jogging, cycling, or swimming is well known for its positive effects (for review see e.g., Mikkelsen et al., 2017). The main reported psychological health benefits refer to improvements in subjective well-being and the reduction of symptoms of depression, anxiety, and stress (Eime et al., 2013; Rebar et al., 2015). Moreover, it has been reported that individuals who tend to physical activity as a coping strategy are more likely to engage in other positive coping strategies (e.g., problem-solving or talking to others) and less likely to apply dysfunctional strategies like the use of alcohol or drugs (Cairney et al., 2014). Therefore, physical

activity might also prevent addictive SMU. It may reduce feelings of overload by daily stressors, and thus the need to immerse into the online world (Brailovskaia et al., 2018). Furthermore, it contributes to mood improvement (Eime et al., 2013), which could prevent the use of SM to escape negative emotions.

Considering the ongoing COVID-19 outbreak, maintaining regular physical activity has been suggested to foster well-being and mitigate the negative consequences of the pandemic on mental health (Chen et al., 2020; Sallis and Pratt, 2020). In line with this, recent studies found physical activity to be positively related to subjective well-being (Brand et al., 2020) and negatively to perceived burden caused by COVID-19 (Brailovskaia et al., 2021a). These results demonstrate the advantages of physical activity for mental health also in times of COVID-19. However, due to predominantly cross-sectional study designs, conclusions regarding beneficial effects remain rather hypothetical.

Based on the presented background, the present study aimed to investigate the relationship between physical activity, addictive SMU, and mental health during the COVID-19 pandemic in Germany. Since addictive SMU can be considered as a dysfunctional coping strategy (Király et al., 2020) which might be prevented by physical activity (Brailovskaia et al., 2018), the associations were analyzed within an overall model. As the absence of mental disorders is not the same as the presence of mental health (as described by dual-factor models; e.g., Keyes, 2005), both PMH (Lukat et al., 2016) as well as negative mental health (NMH), namely depression, anxiety, and stress symptoms (Lovibond and Lovibond, 1995), were considered. Due to the lack of longitudinal research, the associations between physical activity, addictive SMU and PMH as well as NMH were investigated over a one-year period. Since this period was significantly affected by the ongoing pandemic, also perceived psychological burden caused by COVID-19 was respected in the analysis.

Considering earlier findings (e.g., Brailovskaia et al., 2018; Huang, 2020; Rebar et al., 2015), following hypotheses were formulated: Physical activity (baseline, BL) was expected to be positively related to PMH (follow-up, FU) (Hypothesis 1a) and negatively related to depression, anxiety, and stress symptoms (FU) (Hypotheses 1b–1d). For addictive SMU (BL), relations were assumed to be opposite, i.e., a negative association with PMH (FU) (Hypothesis 2a) and positive associations with symptoms of depression, anxiety, and stress (FU) were expected (Hypotheses 2b–2d). Furthermore, it was presumed that physical activity (BL) is negatively linked to addictive SMU (BL) (Hypothesis 3); and that the expected relationships between physical activity (BL) and PMH as well as depression, anxiety, and stress symptoms (FU) are mediated by addictive SMU (BL) (Hypotheses 4a–4d). Moreover, with reference to the relationship between psychological burden caused by COVID-19 and physical activity (Brailovskaia et al., 2021a) as well as addictive SMU (Brailovskaia and Margraf, 2021), it was hypothesized that burden caused by COVID-19 moderates the association between physical activity and addictive SMU (Hypothesis 5).



**Fig. 1.** Moderated mediation model with physical activity (predictor), addictive SMU (mediator), burden caused by COVID-19 (moderator) and PMH as well as NMH (outcomes).

Note. SMU = social media use, PMH = positive mental health, NMH = negative mental health; BL = baseline, FU = follow-up.

Specifically, the higher the burden, the closer the link between both variables. Fig. 1 illustrates the hypothesized relationships as a moderated mediation model (cf., Hayes, 2017).

## 2. Methods

### 2.1. Procedure and participants

The present sample comprised 356 participants from Germany (76% women;  $M_{age} = 27.43$ ,  $SD_{age} = 6.59$ , range: 18–71). More than half of the participants (60%) were students and 27% were employed at the BL. The remaining 13% incorporate trainees, freelancer, people in parental leave, applicants for work, a housewife, and people engaging in further activities. Data were collected at two measurement time points in April 2020 and in April 2021. At both time points governmental measures preventing the spread of COVID-19 – including stay-at-home and social-distancing measures, limitations of people gathering, and shutdown of specific institutions – were present (Bundesministerium für Gesundheit, 2021). Invitations for participating in the online survey were sent by e-mail to a randomly selected group of individuals who were current or former students at a large university in the Ruhr region and had previously agreed to be contacted for research investigations. All participants were properly instructed and gave informed consent to participate via an online form. Participation was voluntary and compensated by course credits for students. The only requirement for participation was the current membership on at least one social platform. Of the 384 persons who participated at the BL, 356 persons (93%) responded to the FU survey. T-tests revealed no significant differences between persons who participated in both surveys and those who dropped-out at FU. Data sets of the included 356 participants were complete, no data sets were excluded. The responsible Ethics Committee approved the implementation of the present study. A priori conducted power analyses using the G\*Power program (version 3.1; Faul et al., 2009) suggested that the sample size was sufficient for valid results (power > 0.80,  $\alpha = 0.05$ , effect size  $f^2 = 0.15$ ; cf., Cohen, 1992).

## 2.2. Materials

### 2.2.1. Physical activity

Following Brailovskaia et al. (2020b; original German version), the frequency of physical activity was measured by the item “How frequently did you engage in physical activity (e.g., jogging, cycling) in the last 12 months?” that is rated on a 5-point Likert-type scale (1 = never, 5 = four times a week or more). A higher value implies a more frequent physical activity. The item has been demonstrated to be a reliable and valid instrument for the assessment of physical activity in cross-sectional, longitudinal, and experimental studies (Brailovskaia et al., 2021b; 2020b; Milton et al., 2011). In the present study, the mean test-retest reliability of the used item was  $r_{mtrr} = 0.50$ .

### 2.2.2. Addictive SMU

The brief version of the Bergen Social Media Addiction Scale (BSMAS; original English version: Andreassen et al., 2017; German version: Brailovskaia et al., 2020a) served for the assessment of addictive SMU. The construct is operationalized according to the basic addiction symptoms (i.e., salience, mood modification, tolerance, withdrawal symptoms, conflict, and relapse). The six items concern experiences occurring over the past year and are rated on a 5-point Likert-type scale ranging from very rarely (1) to very often (5). Higher sum scores indicate higher levels of addictive SMU. Previous research reported a scale reliability of  $\alpha = 0.82$  for the German version of the BSMAS (Brailovskaia et al., 2020a). Current scale reliability was  $\alpha_{BL} = 0.84$ .

### 2.2.3. Burden caused by COVID-19

Following Brailovskaia and Margraf (2020; original German version)

the experience of burden caused by COVID-19 was measured with six items (e.g., “I am afraid of the current situation”, “I feel restricted in my everyday life”). They refer to the present COVID-19 situation and are rated on a 7-point Likert-type scale (1 = do not agree, 7 = totally agree). The higher the sum score, the higher the level of perceived burden. As in the study of Brailovskaia and Margraf (2020), current scale reliability was  $\alpha_{BL} = 0.75$ .

### 2.2.4. Positive mental health

To measure the positive dimension of mental health, the unidimensional Positive Mental Health Scale (PMH-Scale; original German version: Lukat et al., 2016) was included. It consists of nine items (e.g., “I enjoy my life”) that refer to life in general and are rated on a 4-point Likert-type scale (0 = do not agree, 3 = agree), with higher sum scores indicating higher levels of PMH. In previous research (Lukat et al., 2016) and in the present study, the scale reliability of the PMH-Scale was  $\alpha_{FU} = 0.93$ .

### 2.2.5. Negative mental health

The negative dimension of mental health was assessed with the Depression Anxiety Stress Scales 21 (DASS-21; original English version: Lovibond and Lovibond, 1995; German version: Nilges and Essau, 2015). Each of the three subscales (i.e., depression, anxiety, and stress symptoms) consists of seven items (e.g., depression: “I could not seem to experience any positive feeling at all”, anxiety: “I felt scared without any good reason”, stress: “I tended to over-react to situations”). All items are rated on a 4-point Likert-type scale ranging from 0 (did not apply to me at all) to 3 (applies to me very much or most of the time). Higher sum scores indicate higher symptom severity. The current scale reliabilities of  $\alpha_{FU} = 0.92$  for depression,  $\alpha_{FU} = 0.91$  for anxiety, and  $\alpha_{FU} = 0.90$  for stress symptoms were higher than in a non-clinical German sample ( $\alpha_{depression} = 0.88$ ,  $\alpha_{anxiety} = 0.76$ ,  $\alpha_{stress} = 0.86$ ; Nilges and Essau, 2015).

## 2.3. Statistical analyses

Statistical analyses were conducted using SPSS 27 and the macro PROCESS version 3.5.3 (Hayes, 2020). After descriptive analyses, the relationship between physical activity (BL), addictive SMU (BL), burden caused by COVID-19 (BL), PMH (FU), and NMH (depression, anxiety, and stress symptoms; FU) was examined by the calculation of zero-order bivariate correlations. Next, for a simultaneous examination of the hypothesized mediation and moderation effect, four first stage moderated mediation analyses (cf., Edwards and Lambert, 2007; Hayes, 2015) were calculated (PROCESS: model 7). The moderated mediation effect was assessed by a bootstrapping procedure (10,000 samples) that provides percentile bootstrap confidence intervals (95% CI). The analyses included physical activity (BL) as predictor, addictive SMU (BL) as mediator, and burden caused by COVID-19 (BL) as moderator. PMH (FU; model 1), depression symptoms (FU; model 2), anxiety symptoms (FU; model 3), and stress symptoms (FU; model 4), respectively, were included as outcomes. All models were controlled for the covariates age and gender.

## 3. Results

Table 1 presents the descriptive statistics of the investigated variables and their correlations. Physical activity (BL) was significantly positively correlated with PMH (FU). Its correlations with addictive SMU (BL) and symptoms of anxiety (FU) were significantly negative. Its negative links to depression (FU;  $p = .070$ ) and stress (FU;  $p = .056$ ) were not significant. Addictive SMU (BL) was significantly negatively related to PMH (FU) and significantly positively related to burden caused by COVID-19 (BL) and symptoms of depression, anxiety, and stress (FU). Burden caused by COVID-19 (BL) was significantly negatively correlated with PMH (FU) and significantly positively correlated with symptoms of depression, anxiety, and stress (FU). PMH (FU) was significantly

**Table 1**

Descriptive statistics and correlations of physical activity, addictive social media use (SMU), burden caused by COVID-19 (Burden), positive mental health (PMH), depression, anxiety, and stress symptoms.

	<i>M (SD)</i>	<i>Min-Max</i>	(2)	(3)	(4)	(5)	(6)	(7)
(1) Physical activity (BL)	3.23 (1.19)	1–5	-.121*	-.045	.139**	-.096	-.121*	-.101
(2) Addictive SMU (BL)	10.85 (4.59)	6–29		.183**	-.154**	.186**	.216**	.216**
(3) Burden (BL)	23.37 (6.26)	9–40			-.188**	.127*	.161**	.187**
(4) PMH (FU)	16.46 (6.54)	0–27				-.708**	-.544**	-.645**
(5) Depression (FU)	5.91 (5.47)	0–21					.711**	.777**
(6) Anxiety (FU)	3.37 (4.84)	0–20						.714**
(7) Stress (FU)	7.40 (5.33)	0–21						

Note. *N* = 356; *M* = mean, *SD* = standard deviation, *Min* = minimum, *Max* = maximum; BL = baseline, FU = follow-up; \**p* < .05, \*\**p* < .01.

**Table 2**

Moderated mediation model with positive mental health (PMH) as outcome.

	<i>b</i>	<i>SE</i>	<i>t</i>	<i>p</i>	<i>95% CI</i>
Path <i>a</i> : PA → Addictive SMU	-.465	.198	-2.357	.019	[-.854, -.077]
Path <i>b</i> : Addictive SMU → PMH	-.222	.078	-2.837	.005	[-.376, -.068]
Path <i>c</i> ' (direct effect): PA → PMH	.597	.296	2.014	.045	[.014, 1.180]
Interaction: PA * Burden → Addictive SMU	-.096	.031	-3.056	.002	[-.158, -.034]
<i>Conditional indirect effects: PA → PMH</i>					
PA → Addictive SMU → PMH					
Burden:					
Low (one <i>SD</i> below mean = -6.259)	-.030	.084			[-.214, .125]
Medium (mean = 0)	.103	.066			[.002, .252]
High (one <i>SD</i> above mean = 6.259)	.237	.126			[.036, .524]
<i>Index of moderated mediation</i>	.021	.014			[.001, .053]

Note. *N* = 356; covariates: age and gender; PA = physical activity, SMU = social media use, Burden = burden caused by COVID-19 (mean centered); *b* = standardized regression coefficient, *SE* = standard error, *t* = *t*-test, *p* = significance, *CI* = confidence interval, *SD* = standard deviation.

negatively related to all NMH constructs (FU) that were all significantly positively correlated.

Tables 2 and 3 summarize the results of the bootstrapped moderated mediation analyses with physical activity as predictor, addictive SMU as mediator, burden caused by COVID-19 as moderator and PMH (model 1) as well as NMH, represented by symptoms of stress (model 4), as outcomes. Results of the analyses with symptoms of depression (model 2) and symptoms of anxiety (model 3) as outcomes are not displayed in detail since they reveal similar result patterns as model 4. All overall models were significant ( $F_{PMH}(4,351) = 3.910, p < .01$ ;  $F_{depression}(4,351) = 4.002, p < .01$ ;  $F_{anxiety}(4,351) = 5.701, p < .001$ ;  $F_{stress}(4,351) = 4.947, p < .001$ ), with explained variances of  $R^2 = 0.043$  for PMH,  $R^2 = 0.044$  for depression,  $R^2 = 0.061$  for anxiety, and  $R^2 = 0.053$  for stress symptoms. The effect of physical activity on addictive

SMU (path *a*), the effect of addictive SMU on each outcome (path *b*), and the effect of the interaction of physical activity and burden caused by COVID-19 on addictive SMU were significant in all four models. While the direct effects of physical activity on depression (*c*':  $p = .107$ ) and stress symptoms (*c*':  $p = .124$ ) were no longer significant after controlling for addictive SMU, the direct effects of physical activity on PMH (*c*':  $p = .045$ ) and anxiety (*c*':  $p = .039$ ) remained significant. However, the index of moderated mediation was significant for all models (depression:  $b = -.018, SE = .012, 95\% CI: [-.047, -.001]$ ; anxiety:  $b = -.020, SE = .013, 95\% CI: [-.051, -.001]$ ; for PMH and stress see Tables 2 and 3) revealing significant moderated mediation effects. The conditional indirect effect of physical activity on PMH as well as on all NMH constructs, respectively, mediated by addictive SMU was not significant in persons with low levels of burden caused by COVID-19. In contrast, it

**Table 3**

Moderated mediation model with stress as outcome.

	<i>b</i>	<i>SE</i>	<i>t</i>	<i>p</i>	<i>95% CI</i>
Path <i>a</i> : PA → Addictive SMU	-.465	.198	-2.357	.019	[-.854, -.077]
Path <i>b</i> : Addictive SMU → Stress	.235	.063	3.710	.000	[.111, .360]
Path <i>c</i> ' (direct effect): PA → Stress	-.370	.240	-1.542	.124	[-.843, .102]
Interaction: PA * Burden → Addictive SMU	-.096	.031	-3.056	.002	[-.158, -.034]
<i>Conditional indirect effects: PA → Stress</i>					
PA → Addictive SMU → Stress					
Burden:					
Low (one <i>SD</i> below mean = -6.259)	.032	.087			[-.127, .225]
Medium (mean = 0)	-.110	.064			[-.254, -.006]
High (one <i>SD</i> above mean = 6.259)	-.251	.122			[-.528, -.053]
<i>Index of moderated mediation</i>	-.023	.014			[-.054, -.002]

Note. *N* = 356; covariates: age and gender; PA = physical activity, SMU = social media use, Burden = burden caused by COVID-19 (mean centered); *b* = standardized regression coefficient, *SE* = standard error, *t* = *t*-test, *p* = significance, *CI* = confidence interval, *SD* = standard deviation.

was significant in persons with medium and high levels of burden. In all four models, this effect was stronger for people who reported high levels of burden than for people reporting medium levels (see Tables 2 and 3 for the models with PMH and stress as outcomes).

#### 4. Discussion

The COVID-19 outbreak is “associated with some of the greatest social, economic, and medical challenges of the 21st century” (Gruber et al., 2021, p. 411). The uncertainty regarding its end, its multidimensionality that impacts almost every area of life and the reduced face-to-face interaction are a burden that contributed to a significant increase of mental health problems (Jané-Llopis et al., 2021; Newby et al., 2020; Pierce et al., 2020). The enhanced prevalence of mental health disorders and the expected long-term mental health implications (Kathirvel, 2020), point out the urgent need for new paradigms for mental health services in terms of prevention and intervention (Gruber et al., 2021). Apart from the use of telehealth platforms, brief mass-delivered interventions, and lay-provider service delivery, public health strategies, e.g., by mental health recommendations may be the key to prevent psychological distress and to buffer the detrimental effects of the pandemic (Gruber et al., 2021; Tsamakidis et al., 2021).

Against this background, the present study investigated whether physical activity, considered as a cost-effective, low-threshold prevention strategy (Brailovskaia et al., 2021a; Chen et al., 2020), might foster PMH and decrease NMH during the pandemic. Since the burden caused by COVID-19 has resulted in various dysfunctional ways of coping with daily stressors, such as substance use or potentially addictive behaviors like excessive gaming or Internet use (Masaeli and Farhadi, 2021; Sun et al., 2020), the current study explored whether physical activity, as a functional coping strategy (Faulkner et al., 2020; Wunsch et al., 2017), might prevent the dysfunctional coping strategy addictive SMU. Furthermore, the perceived psychological burden caused by COVID-19 was integrated in the analyses, since it was shown to be negatively related to physical activity (Brailovskaia et al., 2021a) as well as positively related to addictive SMU (Brailovskaia and Margraf, 2021). Further, it significantly influenced the explored one-year period of the current longitudinal design. The present results show positive effects of physical activity on PMH as well as NMH, namely depression, anxiety, and stress symptoms. This relationship is mediated by addictive SMU, i. e., the higher the physical activity, the lower the addictive SMU and the higher the PMH/the lower the NMH. Furthermore, this indirect effect is dependent on the level of burden caused by COVID-19: the higher the level of burden, the stronger the effect. This indicates that people with high levels of burden may profit most from regular physical activity that could prevent addictive SMU and thus could foster PMH and mitigate symptoms of NMH.

As expected, physical activity at baseline was positively related to PMH and negatively related to anxiety one year later (confirmation of Hypotheses 1a and 1c). The relationships between physical activity and depression as well as stress were only marginally significant (partly confirmation of Hypotheses 1b and 1d). This contradicts previous research reporting physical activity to have beneficial effects on depression, anxiety, and stress (Mikkelsen et al., 2017; Rebar et al., 2015). However, the present not significant findings might at least partly be explained by the mostly female and relatively young composition of the sample. A recent study investigated the relationship of physical activity and depression in college students (Cahuas et al., 2020). Results indicated a significantly negative association between physical activity and depression in men but not in women. This might also apply for the relationship between physical activity and stress. Furthermore, the results of another study suggested that age should be considered when estimating the effect of physical activity on mental health (Fukukawa et al., 2004). Considering these findings as well as the correlations of the present study, that allow the assumption of higher activity levels in men and younger participants, age and gender were

controlled for in the moderated mediation analyses.

Although the effect sizes of the relationships were small, the results are in line with previously published studies, that reported positive effects of physical activity on mental health in general (Mikkelsen et al., 2017) and also in times of the pandemic (e.g., Faulkner et al., 2021). Since most of the recent studies addressing physical activity were cross-sectional, the present study complements and extends their results with its longitudinal design, thus coming closer to a causal approximation concerning the direction of effects. Furthermore, the present findings reveal a positive effect of physical activity on mental health, although team-based sports, which specifically are associated with improved health outcomes compared to individual activities (Eime et al., 2013), have been banned like other community activities for some time during the investigated period in Germany. The experience of positive emotions as well as the enhancement of individual sense of control, self-efficacy, and self-esteem (Bailey et al., 2013; Eime et al., 2013) might explain, why individuals who regularly engage in physical activity experience the current COVID-19 situation as less burdensome (Brailovskaia et al., 2021a) and show higher levels of PMH and lower levels of NMH.

In contrast, persons with enhanced tendencies of addictive SMU display lower PMH as well as higher symptoms of depression, anxiety, and stress (confirmation of Hypotheses 2a–2d). Since addictive SMU was assessed one year previously to PMH and NMH, this result is in line with former studies that found addictive SMU to positively predict symptoms of depression and stress, and to negatively predict PMH (e.g., Brailovskaia and Margraf, 2017; Brailovskaia et al., 2019a). Likewise, experimental studies targeting a reduction of time spent on SM reported an increase of PMH as well as a decrease of NMH (Brailovskaia et al., 2020b; Hunt et al., 2018; Tromholt, 2016). Moreover, longer media exposure was shown to be related to negative affect, depression, anxiety, and stress during the pandemic (Chao et al., 2020; Riehm et al., 2020; Wang et al., 2020). In general, excessive use of SM might replace activities that contribute to mental health and thus enhance the level of daily stress and burden (Brailovskaia et al., 2018). Specifically, during the COVID-19 outbreak, people also use SM to stay updated about the current situation and hereby could be confronted with misinformation, rumors, or conspiracy theories (Depoux et al., 2020). This could harm their mental health. Negative emotional states that are shared via SM can be transferred to others via emotional contagion (Kramer et al., 2014). However, it is also important to mention that other studies reported depression, social anxiety, and loneliness to positively predict addictive SMU (e.g., Atroszko et al., 2018; Zhang et al., 2020). A recent systematic review indicated that depression, anxiety, and stress are among the reasons for the increase in Internet-based addictive behaviors during the pandemic (Masaeli and Farhadi, 2021). Since most conclusions regarding the relationship between addictive SMU and mental health rely on cross-sectional investigations, a greater number of longitudinal research and experimental studies is needed for true causal conclusions (Sharma et al., 2020).

In line with the assumption that physical activity is a functional coping strategy that could reduce the risk of developing tendencies of addictive SMU (Brailovskaia et al., 2018), the present study found a negative association between physical activity and SMU (both at BL; confirmation of Hypothesis 3). While both constructs were assessed at the same time point, another recent study reported a prospective positive effect of physical activity, i.e., persons who engaged in more physical activity shortly before the outbreak of COVID-19 were at less risk for addictive SMU during the lockdown (Brailovskaia et al., 2021b). This might be explained by the enhancement of self-esteem and resilience (Eime et al., 2013) as well as the reduction of feelings of overload by daily stressors (Brailovskaia et al., 2018), which can prevent the use of SM to cope with negative emotions. In addition, by providing an alternative source of positive experiences, physical activity could lead to mood improvement and thus reduce the tendency to search for rewarding positive emotions online (Brailovskaia et al., 2021b; Eime

et al., 2013). Furthermore, the engagement in physical activity might reduce the available time to immerse into the online world (Brailovskaia et al., 2020b).

The relationship between physical activity (BL) and PMH as well as depression, anxiety, and stress symptoms (FU) was mediated by addictive SMU (BL) (confirmation of Hypotheses 4a–4d). This mediation complements previously described potential psychological mechanisms of physical activity on mental health (Mikkelsen et al., 2017). By reducing the likelihood of addictive SMU tendencies, physical activity could foster PMH and mitigate NMH. Moreover, this indirect effect was moderated by the perceived burden caused by COVID-19 (confirmation of Hypothesis 5). The higher the burden, the closer the link between physical activity and addictive SMU. This indicates that people who experience high levels of burden could profit most from regular physical activity, supporting the assumption that physical activity can be acknowledged as a functional strategy to cope with daily stressors (Brailovskaia et al., 2021a; Wunsch et al., 2017). Especially in times of the COVID-19 outbreak, when numerous people experience burden and suffer from mental health problems (Brailovskaia and Margraf, 2020; Salari et al., 2020), this insight is of great importance. In addition to the emphasis of a conscious usage of online activities, mental health recommendations should encourage individuals to engage in regular physical activity. Activities like stretching or resistance training require no specific equipment, can be carried out alone and practiced by nearly everyone, everywhere and at any time (Chen et al., 2020). Therefore, physical activity is a cost-effective and low-threshold prevention strategy that is applicable during the lockdown or social-distancing measures and available for the general population. In combination with further helpful strategies such as keeping regular daily routines and staying in contact with family and friends, it could be even more beneficial for mitigating the negative effects of the COVID-19 outbreak on mental health. Since the current study considered the frequency of physical activity only, the findings do not allow conclusions regarding the minimum duration, intensity, or type of physical activity for positive effects. Notably, at least 150 min of moderate- or 75 min of vigorous-intensity physical activity as well as two sessions of strength training per week are recommended (World Health Organization, 2010). In times of COVID-19, especially running, walking, and cycling (Lesser and Nienhuis, 2020) as well as stretching and resistance training (Xiang et al., 2020) have been indicated to be beneficial for mental health. Future studies should complement the results of the present study by investigating experimental longitudinal designs that allow the manipulation of different characteristics of physical activity. Moreover, they should assess physical activity and addictive SMU at different points in time, so that truly causal conclusions can be drawn, and physical activity can be suggested as a strategy for the prevention of the development of addictive SMU. Thereby, it is worthwhile to consider not only the effects of physical activity on addictive SMU but also on other dysfunctional coping strategies such as substance use (Gregg et al., 2014) or problematic video gaming (Di Blasi et al., 2019) to gain insight into further possible preventive effects.

Considering the current alarming mental health situation, the present study contributes to the exploration of efficient public health strategies in terms of prevention and intervention. The use of a longitudinal design extended available cross-sectional results considering merely associations and revealed beneficial effects of physical activity on mental health one year later. Furthermore, the moderated mediation analyses allowed the investigation of another potential psychological mechanism of physical activity on mental health, i.e., fostering PMH and decreasing NMH by reducing addictive SMU. As the mediation effects depended on the level of perceived burden caused by COVID-19, this points out the potential of engaging in regularly sportive activity during the pandemic, especially for people at risk for high levels of burden.

Some limitations of the present study should be considered. First, although the longitudinal character of the study allows an approximation regarding causal effects as well as underlying mechanisms,

longitudinal experimental studies are necessary for real causal conclusions. Designs that include several times of measurements and a manipulation of physical activity as a protective factor are desirable. Second, the composition of the sample that mainly consisted of female students limits the generalizability of the current findings. Previously it was shown that particularly young adults are at enhanced risk for engaging in intensive SMU when experiencing high levels of daily stress and missing social support in the offline world (Brailovskaia et al., 2019b). Moreover, women, younger adults, and students were more likely to report NMH during the pandemic (Jané-Llopis et al., 2021). Therefore, age and gender were controlled for in the analyses. However, future studies should replicate the present results in more age and especially gender balanced samples. Furthermore, they should assess and control for further demographics that might influence the investigated variables and their associations such as socio economic status, education level, as well as the belonging to a vulnerable group like healthcare professionals, persons with pre-existing mental health issues and those who recovered from a COVID-19 infection. Third, the present findings are specific to the COVID-19 situation in Germany in spring 2020 and 2021. Due to the dynamic circumstances of the pandemic as well as different courses and preventive measures in other countries, the explored relationships should likewise be investigated in other countries to different points in time. Finally, the small effect sizes of the relationships between physical activity and addictive SMU at baseline and PMH as well as NMH one year later, respectively, should be mentioned. Physical activity was assessed very general with only one item; future studies should employ well-established, reliable instruments, e.g., the International Physical Activity Questionnaire (IPAQ; Craig et al., 2003).

To conclude, the present study provides the first longitudinal findings from Germany based on moderated mediation analyses considering physical activity, addictive SMU, burden caused by COVID-19 and PMH as well as NMH, namely symptoms of depression, anxiety, and stress. The results indicate positive effects of physical activity on PMH as well as NMH by reducing tendencies of addictive SMU. As this effect depended on the perceived burden caused by COVID-19, people experiencing high levels of burden might benefit most from regular physical activity. Especially persons at risk but also the general population should be encouraged – e.g., by mental health communications in the media or on official governmental sites – to engage in regular sportive activities to cope with daily stressors and to benefit from their positive effect on mental health. Future studies are suggested to support the provided recommendations by means of longitudinal experimental designs that include several measurement time points. The manipulation of the duration, intensity, and type of physical activity in different experimental groups is recommended for the assessment and comparison of the effects on mental health as well as the identification of further positive coping strategies. Endeavor in this area of research and in health communications on physical activity seem worthwhile, since physical activity can be considered as a cost-effective, promising strategy for meeting the pandemic caused challenges for mental health – now and in the future.

#### Data availability

The dataset generated and analyzed during the current study is available from the corresponding author upon reasonable request.

#### Code availability

Not applicable.

#### Ethics approval

This study was performed in line with the principles of the Declaration of Helsinki and has received ethical approval from the responsible Ethics Committee.

## Consent to participate

Informed consent was obtained from all individual participants included in the study.

## Consent for publication

All individual participants have consented to the inclusion of their data in this study.

## Declarations

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## CRedit authorship contribution statement

**Lena-Marie Precht:** Visualization, Investigation, Formal analysis, Writing – original draft, Data curation. **Jan Stirnberg:** Visualization, Writing – review & editing. **Jürgen Margraf:** Visualization, Writing – review & editing. **Julia Brailovskaia:** Visualization, Data curation, Writing – review & editing.

## Declaration of Competing Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.

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