

**Associations between social media use, psychological stress, well-being, and alpha-amylase levels in adolescents**S. Tomczyk¹ & F. Hoferichter²¹ Department Health and Prevention, University of Greifswald, Greifswald, Germany² Department of School Pedagogy, University of Greifswald, Greifswald, Germany

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ORCID IDs:Tomczyk: <https://orcid.org/0000-0002-2846-5489>Hoferichter: <https://orcid.org/0000-0002-6537-6952>**Associations between social media use, psychological stress, well-being, and alpha-amylase levels in adolescents****Abstract**

Despite abundant research on positive and negative consequences of social media use (SMU) in adolescence, concomitant examinations of subjective and objective measures of stress or well-being, and SMU following theory-based, conceptual models of digital stress are rare. In a cross-sectional study, we examined the associations between current subjective stress (self-report; PSS-10), objective stress (salivary alpha-amylase), self-reported well-being, and SMU in 76 German adolescents (52% male; $M_{\text{age}} = 13.73$ years). Zero-order correlations and block wise hierarchical regression models examined incremental validity of SMU in predicting stress and well-being (physical, emotional) beyond sociodemographic covariates, and loneliness. Models explained up to 50% (emotional well-being) of variance in self-reported outcomes, with significant incremental values of problematic SMU ($\Delta R^2 = .12$) for emotional well-being, and subjective stress ($\Delta R^2 = .11$). In addition, stress was associated with facets of digital stress, namely objective stress, and perceived connection overload (i.e., at least daily SMU), subjective stress and approval anxiety. The findings support the digital stress framework of SMU in adolescents suggesting differential pathways of SMU towards subjective and objective stress, and (emotional) well-being. The study underlines the need for a nuanced debate and multi-method assessment in the study of social media use and stress in adolescents.

Keywords: Early Adolescence; Internet; Social Media; Stress; Alpha-amylase

Introduction

Today, social media use is common among adolescents, with its variety of platforms (e.g., Facebook, Twitter, Instagram, Snapchat) and functions (e.g., active and passive use, sharing information or photos), social media is an important tool of modern communication. However, there are perils of social media use regarding neurocognitive development, among them disturbance of social processes, increase of psychosocial stress, and even development of smartphone addiction (e.g., Crone & Konijn, 2018; Odgers & Jensen, 2020; Twigg et al., 2020; Valkenburg & Peter, 2011). A study on undergraduate Facebook users (Rus & Tiemensma, 2017), for instance, showed that using Facebook to cope with acute social stress (i.e., after the Trier Social Stress Test) delayed physiological stress recovery (indicated by high cortisol levels) compared to a control group that did not use Facebook. Interestingly, self-reports contradicted this finding, because users expressed that using Facebook when stressed makes them feel less stressed.

Thus, in the long-term, using social media, such as Facebook, in stress-related contexts can negatively affect health and increase the risk of type 2 diabetes, obesity, and cardiovascular disease (Everson-Rose & Lewis, 2005), even though users may not be aware of these effects. Similarly, there is an ongoing debate about the exact impact and mechanisms of social media use (SMU) regarding adolescent mental health in the scientific community (e.g., Odgers & Jensen, 2020; Twigg et al., 2020). So far, research mostly emphasizes a responsible and positive outlook on social media as adaptive, carefully weighing challenges and benefits of SMU, for instance, in primary prevention. To successfully identify mechanisms that inhibit stress and foster well-being, a closer look at SMU and its consequences is necessary.

Regarding stress, several meta-analyses and reviews have critically reviewed and discussed the association between SMU and adolescent stress (e.g., Odgers & Jensen, 2020; Orben, 2020; Steele et al., 2020), with Steele and colleagues (2020) describing four aspects of so-called *digital stress*: availability stress, approval anxiety, fear of missing out (FoMO), and communication overload.

Accordingly, the expectation or practice of constant *availability* via social media can inhibit other activities and lead to stress due to other tasks being unfinished. On the other hand, the mere availability of social media (e.g., via one's smartphone) can buffer stress after experiencing social exclusion, since it allows participants to directly cope with socially challenging situations (Hunter et al., 2018). However, therein lies another stressor, namely self-presentation, for instance via pictures on Instagram (Yurdagül et al., 2019). Regarding Instagram use and stress, boys rely more strongly on Instagram to avoid loneliness and thus strive for higher follower counts, while girls are more likely to connect their self-esteem and body image to social media presentation, being anxious to receive negative feedback and devaluation (i.e., *approval anxiety*). This is also connected to self-effects that occur when presenting oneself in a social context, be it online or offline and sender or recipient of a message (Valkenburg, 2017). In this sense, deliberating how and when to post online as well as receiving or anticipating negative feedback can cause stress, as it is intertwined with the need for positive reinforcement and the fear of being rejected. *FoMO* describes the phenomenon of feeling left out if a social media conversation is missed, which is linked to lower emotional well-being (Fabris et al., 2020). This aspect of digital stress is associated with availability stress, but it reflects the perceived need to be online, not the perceived opportunity. *FoMO* is strongly associated with increased SMU, loneliness, and low self-esteem across age cohorts (Barry & Wong, 2020). Finally, *communication overload* refers to informational overload that needs to be sorted and processed. Communication overload occurs if the amount of information is perceived as overwhelming.

In addition to these four dimensions, Steele and colleagues (2020) stress the importance of differentiating quantity (e.g., screen time) and quality (e.g., type of activity) of SMU when evaluating its effects. Investigating the evidence base for these four pathways of digital stress reveals several shortcomings in the literature: Most studies are cross-sectional, use insufficient or unvalidated measures, and few concurrently examine subjective and objective measures of stress (Crone & Konijn, 2018; Odgers & Jensen, 2020; Steele et al., 2020), particularly in adolescents (cf. Hunter et al., 2018; Orben, 2020; Rus & Tiemensma, 2017).

Subjective measures of stress and SMU are subject to biases, such as common method bias, recall bias, and effects of social desirability (Podsakoff et al., 2003), wherefore self-serving reporting might affect the results and lead to biased conclusions. Therefore, it is important to consider complementary sources of data, such as objective measures of stress or SMU. In addition, the period of early adolescence (i.e., 10-15 years) is consistently described as being understudied while at the same „of particular interest in regards of sensitivity“ (Crone & Konijn, 2018, p. 7) towards neurodevelopmental changes (Raufelder et al., 2021).

To add to this debate, we examine the association between SMU and subjective as well as objective stress in a sample of early adolescents, controlling for relevant confounders gender, age, socioeconomic status, and loneliness. We also discern regular SMU and problematic SMU as indicated by scores on the Social Media Disorder scale (van den Eijnden et al., 2016). Following the model of digital stress (Steele et al., 2020), we expect positive associations between the four dimensions of digital stress and self-reported problematic SMU; we also test the associations with salivary alpha-amylase (sAA) as a measure of objective stress. It complements biomarkers like cortisol, as sAA is more indicative of autonomous nervous system activity, and noradrenergic activation, thus being an indicator of chronic stress and more sensitive than cortisol in stress reactivity, for instance, in pediatric populations (Ali & Nater, 2020; Nater & Rohleder, 2009; Whelan, 2020). Few studies have examined sAA and problematic SMU in adolescents, and so far, findings are mixed, stressing the need for further research (e.g., Shafi et al., 2021).

Method

This research is part of a project on adolescent's school experiences, stress, and leisure-time. It adheres to the Declaration of Helsinki regarding informed consent from parents and students and received ethical approval (Institution [anonymized for peer review]: BB 101/18) and clearance by the Ministry of Education, Science and Culture.

Participants

Sample size estimation

A priori sample size estimation assumed a moderate effect ($R^2=.25$), in line with a meta-analysis of associations between multiple mental health indicators (e.g., loneliness, distress) and problematic SMU (Huang, 2020), an alpha error probability of .05, a power of .80, and 11 predictors in total (see table 3 for the regression models). The estimation using G*Power version 3.1.9.7 resulted in an estimated sample size of $N=62$ persons. To account for potential missingness or invalid data of participants (e.g., regarding sAA), about 30% more students were sampled ($N=83$).

Recruitment

At the beginning of the school year 2018/19, we recruited adolescents through secondary schools in Northern Germany to fill in a questionnaire on their SMU and related constructs, complete autobiographical interviews regarding stress, and provide saliva samples for sAA analysis (Cozma et al., 2017). While the questionnaire was self-administered, saliva samples were collected twice – in the morning and around noon – during one day. Participants

were instructed to autonomously provide saliva samples right after wakening as well as provide another sample around midday, which was guided by trained scientific staff (i.e., graduate students of instructional design and psychology). Students provided samples before the questionnaire and the interview to avoid confounding effects and early day increased stress levels.

Measures

Gender (1 (*female*), 2 (*male*)), age and socioeconomic status ('How many books do you have at home?'; 1 (*none or few*) to 5 (*more than 200*)) were assessed with single items, school type was coded in accordance with pursued level of education (0 (*lower-track secondary school*, i.e. 10 school years), 1 (*higher-track secondary school*, i.e. 12/13 school years)).

Loneliness was measured using the UCLA Loneliness scale (Russell et al., 1978) with 20 items on a four-point scale from 1 (*often*) to 4 (*never*) and excellent internal consistency (Cronbach's $\alpha = .94$).

Social media use was captured via the short version of the Social Media Disorder scale (van den Eijnden et al., 2016) to obtain a score for problematic SMU. Here, nine items rated on a four-point scale from 1 (*totally disagree*) to 4 (*totally agree*) reflect the nine Diagnostic and Statistical Manual of Mental Disorders (DSM-5) dimensions of Internet Gaming Disorder within the past few months. In the current study, the scale had good internal consistency ($\alpha = .84$), and the sum score of all nine items (9-36 points) was used with higher values indicating more SMU-related problems.

Moreover, five items were presented to capture distinct aspects of digital stress with regards to SMU (Steele et al., 2020): approval anxiety ('How often do you upload pictures?'; 1 (*never*) to 5 (*daily*)), connection overload ('How often do you use social media?'; 1 (*rarely*) to 4 (*hourly*) and 'If you use social media daily, how much time do you spent of social media?'; 1 (*no daily social media use*) to 5 (*more than two hours per day*)), availability stress ('How fast do you react to social media messages?'; 1 (*the next day*), 2 (*within the next few hours*), 3 (*as soon as possible*)), and FoMO ('How many hours would you be able to endure without using social media applications?'; 1 (*more than a day w/o problems*) to 5 (*not at all*)). Items were purposefully designed to indirectly reflect digital stress to avoid common method bias in overtly eliciting self-reported stress assessments regarding SMU (cf. Podsakoff et al., 2003). Due to the small sample size and skewed distribution, items were dichotomized for the analysis to reflect more frequent SMU (1) versus less frequent SMU (0). Please see Table 1 for a detailed description of response options and recoding of each item. Finally, age of first SMU (in years) was included as a proxy of early adoption.

Psychosocial outcomes comprised subjective and objective stress, physical and emotional well-being. Subjective stress was assessed by the Perceived Stress Scale-10 (PSS) (Cohen et al., 1994), consisting of 10 items with a five-point response scale from 1 (*never*) to 5 (*very often*) with good internal consistency ($\alpha = .88$), objective stress was measured by sAA (nmol/l). Using salivettes, two samples were simultaneously collected from each person and the average of their laboratory-determined level of sAA was used for further analysis. Moreover, sAA was log-transformed to approximate normal distribution. Finally, subscales of the KINDL-R (Ravens-Sieberer & Bullinger, 1998) were used to examine physical (4 items; $\alpha = .86$) and emotional well-being (4 items; $\alpha = .71$) during the past week, rated on a five-point Likert scale from 1 (*never*) to 5 (*all the time*).

Statistical analysis

First, missing value analysis and outlier analysis were performed. Descriptive statistics and gender-based comparisons were computed, followed by zero-order correlations of the included variables. Subsequently, hierarchical regression models analyzed the impact of SMU on subjective and objective indicators of stress and well-being. For each of the four outcomes

(subjective stress, objective stress, physical and emotional well-being), a hierarchical regression model was conducted: First, outcomes were regressed on covariates gender, age, socioeconomic status and school type. Second, loneliness was included as an independent predictor, since it is connected to well-being, FoMO, and SMU (e.g., Barry & Wong, 2020; Odgers & Jensen, 2020; Steele et al., 2020). Third, Social Media Disorder Scale sum scores were added and fourth SMU items reflecting digital stress were added to examine their incremental validity. Regression models were computed with SPSS 25.0, beta coefficients, adjusted R-squared values and incremental R-squared values were reported as effect sizes for each model. All tests were based on $p = .05$.

Results

After excluding three participants due to box-plotted outliers in the sAA assessment from the original sample ($n=83$), missing value analysis indicated few missings (0-3 per variable, 15 in total) that were equally distributed across variables and persons, except for age (21 missing values). Therefore, scale values were substituted by individual means if levels of missing values were below 25% for said scale (Roth et al., 1999), leading to an analysis sample of $N=76$ (52.6% male) with the remaining participants being excluded. Due to high levels of missing data, age was not included as a covariate in the main analyses. Overall, 80% of participants reported at least daily SMU and started using social media between the ages of 11 to 12. Males had a lower socioeconomic status than females but reported higher physical well-being and they did not differ in their self-reported SMU (see Table 1).

Bivariate correlations (see Table 2) pointed to significant moderate associations between approval anxiety and subjective stress ($r=.32, p<.01$), as well as problematic SMU ($r=.20, p<.05$). Problematic SMU was also correlated with subjective stress ($r=.44, p<.001$), emotional well-being ($r=-.38, p<.001$), and loneliness ($r=.25, p<.05$). Objective stress was not directly associated with sociodemographic variables, loneliness, well-being or SMU.

Hierarchical regression models

Following a four-step estimation process, models explained between 15% (physical well-being) and 48% (emotional well-being) of variance in psychosocial variables (table 3), and 39% of subjective stress, but they did not significantly explain variance in objective stress. Loneliness was the strongest predictor of self-rated well-being and stress, but problematic social media use (i.e., Social Media Disorder scale score) was incremental in predicting subjective stress ($\Delta R^2 = .11$) and emotional well-being ($\Delta R^2 = .12$) beyond these effects. Moreover, approval anxiety and connection overload had small but significant associations with subjective and objective stress, when controlling for covariates.

Table 1

Sociodemographic data, social media use and psychosocial variables compared by gender (male, female) in a sample of German adolescents (N=76)

	Female (n=36) M (SD) or n (%)	Male (n=40) M (SD) or n (%)	Total (n=76) M (SD) or n (%)	
Age (n _{female} = 33; n _{male} = 24)	13.58 (0.55)	13.93 (0.77)	13.73 (0.67)	$t(55) = 1.99, n. s.$
Socioeconomic status	4.19 (0.95)	3.25 (1.26)	3.70 (1.21)	$t(71.97) = 3.72, p < .001$
School type				$\chi^2(1) = 7.96, p < .01$
Lower-track secondary school	10 (27.8)	24 (60.0)	34 (44.7)	
Higher-track secondary school	26 (72.2)	16 (40.0)	42 (55.3)	
Loneliness	40.69 (15.98)	41.99 (14.46)	41.37 (15.11)	$t(74) = 0.37, n. s.$
Social Media Disorder	13.14 (4.10)	13.60 (4.38)	13.38 (4.23)	$t(74) = 0.47, n. s.$
Age of first social media use	11.22 (1.20)	11.33 (1.77)	11.28 (1.52)	$t(74) = 0.30, n. s.$
Approval anxiety				
How often do you upload pictures?*				$\chi^2(3) = 0.74, n. s.$
Never	9 (25.0)	12 (30.0)	21 (27.6)	
Rarely	16 (44.4)	19 (47.5)	35 (46.1)	
<i>Sometimes</i>	8 (22.2)	7 (17.5)	15 (19.7)	
<i>Weekly</i>	3 (8.3)	2 (5.0)	5 (6.6)	
<i>Daily</i>	0 (0.0)	0 (0.0)	0 (0.0)	
Connection overload				$\chi^2(3) = 1.84, n. s.$
How often do you use social media?*				
Rarely	2 (5.6)	3 (7.5)	5 (6.6)	
Multiple times per week	3 (8.3)	7 (17.5)	10 (13.8)	
<i>Daily</i>	21 (58.3)	22 (55.0)	43 (56.6)	
<i>Hourly</i>	10 (27.8)	8 (20.0)	18 (23.7)	
Connection overload				$\chi^2(4) = 1.48, n. s.$
If you use social media daily, how much time do you spent on social media?*				
I am not using social media daily	2 (5.6)	4 (10.0)	6 (7.9)	
Less than 30 minutes per day	6 (16.7)	8 (20.0)	14 (18.4)	

30-60 minutes per day	11 (30.6)	8 (20.0)	19 (25.0)	
<i>1-2 hours per day</i>	8 (22.2)	9 (22.5)	17 (22.4)	
<i>More than 2 hours per day</i>	9 (27.5)	11 (27.5)	20 (26.3)	$\chi^2(2) = 1.61, n. s.$
Availability stress				
How fast do you react to social media messages?*				
The next day	1 (2.8)	0 (0.0)	1 (1.3)	
Within the next few hours	27 (75.0)	28 (70.0)	55 (72.4)	
<i>As soon as possible</i>	8 (22.2)	12 (30.0)	20 (26.3)	
Fear of missing out				$\chi^2(1) = 2.31, n. s.$
How many hours would you be able to endure without using social media applications?*				
More than a day without problems	23 (63.9)	31 (77.5)	54 (71.1)	
<i>6-12 hours</i>	6 (16.7)	3 (7.5)	9 (11.8)	
<i>3-6 hours</i>	5 (13.9)	5 (12.5)	10 (13.2)	
<i>1-3 hours</i>	2 (5.6)	1 (2.5)	3 (3.9)	
<i>Not at all</i>	0 (0.0)	0 (0.0)	0 (0.0)	
Subjective stress	29.24 (6.75)	26.29 (7.17)	27.69 (7.09)	$t(74) = 1.84, n. s.$
Perceived Stress Scale-10				
Objective stress (sAA)	1213.06 (957.20)	1409.85 (1202.36)	1316.63 (1090.46)	$t(74) = 0.78, n. s.$
Physical well-being (KINDL-R)	14.51 (4.09)	15.44 (3.81)	14.38 (4.06)	$t(74) = 2.19, p = .032$
Emotional well-being (KINDL-R)	14.86 (3.06)	15.70 (2.68)	15.30 (2.88)	$t(74) = 1.27, n. s.$

Notes. Significant differences are printed in bold. *Items were dichotomized (0/1, positive values in italic) for further analysis due to the small sample size and skewed distribution

Table 2

Bivariate correlations of sociodemographic variables, loneliness, social media use, stress, and well-being in German adolescents (N=76)

	1	2	3	4	5	6	7	8	9	10	11	12	13
1 Socioeconomic status	1												
2 School type (ref. lower-track secondary school)	.47***	1											
3 Loneliness	-.12	-.08	1										
4 Social Media Disorder	-.12	-.18	.25*	1									
5 Age of first social media use	.08	.06	-.03	-.01	1								
6 Approval anxiety (uploading pictures on social media)	-.01	.06	.03	.20*	.07	1							
7 Connection overload (Min. daily SMU)	-.09	-.02	-.21*	.17	.09	.13	1						
8 Connection overload (at least 1 hour of daily SMU)	-.22*	-.16	.07	.20*	.01	-.06	.27**	1					
9 Availability anxiety	-.13	-.06	-.05	.11	.09	.12	.13	.24*	1				
10 FOMO (tolerance of less than a day without SMU)	-.13	-.21*	-.05	.21*	.06	.19*	.09	.20*	.26*	1			
11 Subjective stress (PSS-10)	.14	.03	.49***	.44***	-.01	.32**	.09	.15	.09	.16	1		
12 Objective stress (sAA)	.09	.00	-.09	.19	.09	.02	.18	-.05	-.04	.16	.04	1	
13 Physical well-being	-.15	-.23*	-.33**	-.21*	-.05	-.11	-.21*	-.13	-.13	.01	-.53***	.06	1
14 Emotional well-being	.20*	.03	-.46***	-.38**	.08	-.02	.08	-.13	.11	-.01	-.36***	.09	.23*

Notes. sAA – salivatory alpha-amylase; SM – social media; SMU – social media use; PSS-10 – Perceived Stress Scale-10 item version; * $p < .05$, ** $p < .01$, *** $p < .001$; school type – 0 = lower-track secondary school, 1 = higher-track secondary school; correlations comprised pointbiserial correlations (dichotomous and continuous variables), Pearson's correlation (continuous variables), and Kendall's tau (ordinal variables)

Table 3

Hierarchical regression models of subjective stress (PSS-10), objective stress (sAA), and well-being (physical and emotional) predicted by sociodemographic data, loneliness and social media use (quantity and quality) in a sample of German adolescents (N=76)

	Subjective stress				Objective stress				Physical well-being			Emotional well-being				
<u>Step 1</u>																
Gender (ref. female)	-.21	-.22	-.23	-.19	.12	.12	.12	.20	.19	.20	.20	.19	.02	.02	.03	.04
Age																
Socioeconomic status	.06	.11	.08	.13	.25	.26	.25	.31	.05	.01	.02	-.01	.27	.22	.25	.26
School type (ref. lower-track secondary school)	-.00	-.02	.05	.03	.08	.08	.10	.10	-.21	-.20	-.22	-.20	.12	.10	.17	.18
<u>Step 2</u>																
Loneliness scale		.51	.45	.47		.05	.04	.11		-.34	-.32	-.36		.42	.36	.32
<u>Step 3</u>																
Social Media Disorder			.33	.26			.09	.01			-.09	-.06			.32	.35
<u>Step 4</u>																
Age of first social media use				-.05				-.01				-.03				.04
Approval anxiety (uploading pictures on social media)				.23				.06				-.04				.05
Connection overload (at least daily SMU)				.06				.24				.16				.10
Connection overload (at least 1 hour of daily SMU)				.05				-.02				-.03				-
Availability anxiety				.05				.03				-.11				.14
Fear of missing out				-.01				.14				.08				.02
Adjusted R ²	.02	.28	.38	.40	.03	.02	.02	.02	.06	.16	.16	.14	.02	.19	.28	.26

Notes. Coefficients are standardized (beta), significant values are printed in bold; SMU – social media use; adjusted R² refers to the explained variance of each step, significance of F changes (ΔR^2) and the regression model overall (R²) are printed in bold

Discussion

In this study we examined associations between social media use (SMU), problematic SMU, and subjective as well as objective stress, and well-being in German adolescents, following the concept of digital stress (Steele et al., 2020). In sum, approval anxiety and connection overload emerged as significant predictors of subjective and objective stress, respectively, pointing to differential associations. Problematic SMU but not general SMU or indicators of digital stress were associated with well-being.

These findings are in line with previous work (Cozma et al., 2017; Odgers & Jensen, 2020; Steele et al., 2020) that differentiates quality and quantity of SMU when investigating digital stress. Certain forms of social media use, such as sharing pictures, seem to have an impact beyond clinical measures (i.e. Social Media Disorder scale), which warrants further research. Image-heavy social media platforms, such as Instagram, have been discussed regarding eating disorders or body-related and thereby image-related disorders (Odgers & Jensen, 2020; Orben, 2020; Yurdagül et al., 2019), and our findings stress the need for a more refined assessment and analysis of SMU, particularly in at risk groups (e.g., socioeconomically disadvantaged, lonely youth). Since subjective stress was also predicted by problematic SMU as well as loneliness, it seems important to provide a broader assessment of psychopathology when investigating social media use and psychosocial stress in adolescents including various types of SMU as well as additional variables like loneliness, as they seem interlinked across age cohorts (Barry & Wong, 2020).

The association of SMU and objective stress was less pronounced, except for connection overload. Since neurocognitive research shows that social media use might be linked to increased reward sensitivity (Crone & Konijn, 2018), an increased frequency of SMU (as observed here) vis-à-vis an increased intensity/screen time might indicate a quest for rewards, where frequenting social media applications could serve as a mere cue for neurocognitive processes, regardless of the time spent on said application. However, since the association was small and the remaining associations were mostly non-significant, this hypothesis requires further research. Similarly, time spent on social media was not associated with stress, reiterating the call for retiring screen time as an indicator of problematic use (Orben, 2020). The lack of significance in the association between SMU and sAA also aligns with previous research (Shafi et al., 2021), where this association was pronounced in depressed but not healthy adolescents.

As additional outcomes, physical and emotional well-being were not associated with digital stress indicators but with problematic SMU and loneliness. This supports the concept of social media addiction (indicated by the Social Media Disorder scale) as a mental health burden that is associated with impaired well-being and increased loneliness in this age group (Barry & Wong, 2020; van den Eijnden et al., 2016). However, it also leads to the question of how digital stress emerges in adolescents with and without problematic patterns of SMU. Based on this scale, future research could compare pathways of digital stress in adolescent samples with and without problematic SMU patterns (e.g., following a cut-off) to identify potential targets for indicated prevention.

The study has some limitations, for instance, its cross-sectional nature, the small convenience sample and the use of self-reports for most measures that might be biased (Podsakoff et al., 2003). Socioeconomic status was measured with one item that did not ideally represent its multidimensional nature, therefore future studies should include more comprehensive measures, for example, following the Alkire-Foster method. Moreover, the questionnaires measuring well-being (KINDL-R) and loneliness (UCLA Loneliness scale) share conceptual overlap, which might inflate their association. While the analysis of sAA followed established guidelines and averaged two samples to receive a more reliable estimate (Cozma et al., 2017), measurement was limited to two time points during one day, therefore it is not possible to assess temporal stability and longitudinal changes in association with SMU. Future studies should implement longitudinal, ambulatory and interventional designs to study the trajectory of SMU and biomarkers like sAA and cortisol to gain further insight into differential neurodevelopmental processes (e.g., Ali & Nater, 2020; Shafi et al., 2021; Whelan, 2020).

Conclusions

Patterns of social media use (SMU) seem to have unique pathways to subjective and objective stress and well-being beyond clinical assessment of problematic SMU based on DSM-5 criteria. Differentiating activity types, using more fine-grained measures to describe frequency and intensity of SMU and connecting them to subjective as well as objective measures of stress is a promising area for future research. Despite its methodological flaws, the current study stresses the importance of considering quality and quantity of SMU and including multi-layered measures of health-related outcomes.

References

- Ali, N., & Nater, U. M. (2020). Salivary Alpha-Amylase as a Biomarker of Stress in Behavioral Medicine. *International Journal of Behavioral Medicine*, 27(3), 337-342. <https://doi.org/10.1007/s12529-019-09843-x>
- Barry, C. T., & Wong, M. Y. (2020). Fear of missing out (FoMO): A generational phenomenon or an individual difference? *Journal of Social and Personal Relationships*, 37(12), 2952-2966. <https://doi.org/10.1177/0265407520945394>
- Cohen, S., Kamarck, T., & Mermelstein, R. (1994). Perceived stress scale. *Measuring stress: A guide for health and social scientists*, 10.
- Cozma, S., Dima-Cozma, L. C., Ghiciuc, C. M., Pasquali, V., Saponaro, A., & Patacchioli, F. R. (2017). Salivary cortisol and α -amylase: subclinical indicators of stress as cardiometabolic risk. *Brazilian Journal of Medical and Biological Research*, 50(2), e5577-e5577. <https://doi.org/10.1590/1414-431x20165577>
- Crone, E. A., & Konijn, E. A. (2018). Media use and brain development during adolescence. *Nature Communications*, 9(1), 588-588. <https://doi.org/10.1038/s41467-018-03126-x>
- Everson-Rose, S. A., & Lewis, T. T. (2005). Psychosocial factors and cardiovascular diseases. *Annual Review of Public Health*, 26(1), 469-500. <https://doi.org/10.1146/annurev.publhealth.26.021304.144542>
- Fabris, M. A., Marengo, D., Longobardi, C., & Settanni, M. (2020, 2020/07/01/). Investigating the links between fear of missing out, social media addiction, and emotional symptoms in adolescence: The role of stress associated with neglect and negative reactions on social media. *Addictive Behaviors*, 106, 106364. <https://doi.org/10.1016/j.addbeh.2020.106364>
- Huang, C. (2020). A meta-analysis of the problematic social media use and mental health. *International Journal of Social Psychiatry*, 20764020978434. <https://doi.org/10.1177/0020764020978434>
- Hunter, J. F., Hooker, E. D., Rohleder, N., & Pressman, S. D. (2018). The use of smartphones as a digital security blanket: The influence of phone use and availability on psychological and physiological responses to social exclusion. *Psychosomatic Medicine*, 80(4), 345-352. <https://doi.org/10.1097/psy.0000000000000568>
- Nater, U. M., & Rohleder, N. (2009, May). Salivary alpha-amylase as a non-invasive biomarker for the sympathetic nervous system: current state of research. *Psychoneuroendocrinology*, 34(4), 486-496. <https://doi.org/10.1016/j.psyneuen.2009.01.014>
- Ogders, C. L., & Jensen, M. R. (2020). Annual research review: Adolescent mental health in the digital age: facts, fears, and future directions. *Journal of Child Psychology and Psychiatry*, 61(3), 336-348. <https://doi.org/10.1111/jcpp.13190>
- Orben, A. (2020, 2020/01/10). Teenagers, screens and social media: a narrative review of reviews and key studies. *Social Psychiatry and Psychiatric Epidemiology*. <https://doi.org/10.1007/s00127-019-01825-4>
- Podsakoff, P., MacKenzie, S., Lee, J. Y., & Podsakoff, N. (2003). Common method biases in behavioral research: A critical review of the literature and recommended remedies. *Journal of Applied Psychology*, 88, 879-903. <https://doi.org/10.1037/0021-9101.88.5.879>

- Raufelder, D., Neumann, N., Domin, M., Lorenz, R. C., Gleich, T., Golde, S., Romund, L., Beck, A., & Hoferichter, F. (2021). Do belonging and social exclusion at school affect structural brain development during adolescence? *Child Development*(n/a). <https://doi.org/10.1111/cdev.13613>
- Ravens-Sieberer, U., & Bullinger, M. (1998). News from the KINDL-questionnaire -- A new version for adolescents. *Quality of Life Research*, 7, 653.
- Roth, P. L., Switzer, F. S., & Switzer, D. M. (1999). Missing data in multiple item scales: a Monte Carlo analysis of missing data techniques. *Organizational Research Methods*, 2(3), 211-232. <https://doi.org/10.1177/109442819923001>
- Rus, H. M., & Tiemensma, J. (2017, 2017-September-19). Social media under the skin: Facebook use after acute stress impairs cortisol recovery [Original Research]. *Frontiers in Psychology*, 8(1609). <https://doi.org/10.3389/fpsyg.2017.01609>
- Russell, D., Peplau, L. A., & Ferguson, M. L. (1978, Jun). Developing a measure of loneliness. *Journal of Personality Assessment*, 42(3), 290-294. https://doi.org/10.1207/s15327752jpa4203_11
- Shafi, R. M. A., Nakonezny, P. A., Miller, K. A., Desai, J., Almorsy, A. G., Ligezka, A. N., Morath, B. A., Romanowicz, M., & Croarkin, P. E. (2021, 2021/04/01/). Altered markers of stress in depressed adolescents after acute social media use. *Journal of Psychiatric Research*, 136, 149-156. <https://doi.org/https://doi.org/10.1016/j.jpsychires.2021.01.055>
- Steele, R. G., Hall, J. A., & Christofferson, J. L. (2020, 2020/03/01). Conceptualizing digital stress in adolescents and young adults: Toward the development of an empirically based model. *Clinical Child and Family Psychology Review*, 23(1), 15-26. <https://doi.org/10.1007/s10567-019-00300-5>
- Twigg, L., Duncan, C., & Weich, S. (2020, 2020/04/01/). Is social media use associated with children's well-being? Results from the UK Household Longitudinal Study. *Journal of Adolescence*, 80, 73-83. <https://doi.org/10.1016/j.adolescence.2020.02.002>
- Valkenburg, P. M. (2017). Understanding self-effects in social media. *Human Communication Research*, 43(4), 477-490. <https://doi.org/10.1111/hcre.12113>
- Valkenburg, P. M., & Peter, J. (2011, 2011/02/01/). Online communication among adolescents: An integrated model of its attraction, opportunities, and risks. *Journal of Adolescent Health*, 48(2), 121-127. <https://doi.org/10.1016/j.jadohealth.2010.08.020>
- van den Eijnden, R. J. J. M., Lemmens, J. S., & Valkenburg, P. M. (2016, 2016/08/01/). The Social Media Disorder Scale. *Computers in Human Behavior*, 61, 478-487. <https://doi.org/10.1016/j.chb.2016.03.038>
- Whelan, E. (2020). Does a Social Media Abstinence Really Reduce Stress? A Research-in-Progress Study Using Salivary Biomarkers. In F. Davis, R. Riedl, J. vom Brocke, P. M. Léger, A. Randolph, & T. Fischer (Eds.), *Information Systems and Neuroscience. Lecture Notes in Information Systems and Organisation* (Vol. 32). Springer. https://doi.org/https://doi.org/10.1007/978-3-030-28144-1_2
- Yurdagül, C., Kircaburun, K., Emirtekin, E., Wang, P., & Griffiths, M. D. (2019, 2019/12/10). Psychopathological consequences related to problematic Instagram use among adolescents: The mediating role of body image dissatisfaction and moderating role of gender. *International Journal of Mental Health and Addiction*. <https://doi.org/10.1007/s11469-019-00071-8>

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Declaration of interest statement

The authors declare that they have no conflicts of interest.

Data availability statement

Data is available from the authors upon reasonable request.