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Smartphone screen time reduction improves mental health: a randomized controlled trial

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Abstract

Background Smartphone screen time has risen sharply in recent years. Even though an association between smartphone use and mental health is well documented, it is still unclear whether this is simply a correlation or causality. The aim of this study is to investigate the effects of smartphone screen time reduction on mental health indicators.

Methods This non-blinded, parallel randomized controlled trial (RCT) was performed to investigate the impact of a 3-week screen time reduction to ≤ 2 h/d in healthy students on stress (PSQ), well-being (WHO-5), depressive symptoms (PHQ-9), and sleep quality (ISI) at baseline (t0), post-intervention (t1), and at follow-up (t2 = 6 weeks after t1). For the intention to treat analysis, repeated measures ANOVAs and post-hoc tests (for time as well as group differences) were performed and effect sizes were presented as partial eta squared (η^2 = time × group) and group-mean differences.

Results In total, 111 out of 125 healthy students (70 females; mean age = 22.68 ± 2.6 years; mean screen time = 276 ± 115.1 min/day) were randomly assigned to intervention—(n = 58; 3 weeks of screen time reduction to ≤ 2 h/day) or control group (n = 53). Although no differences were observed at baseline (t0), significant post-intervention (t1) effects of small to medium size were observed on well-being (η^2 = .053), depressive symptoms (η^2 = .109), sleep quality (η^2 = .048), and stress (η^2 = .085). Significant group differences ($p \leq .05$) were found post-intervention (t1) for depressive symptoms (*Mean Difference* (*MD*) = 2.11, *Standard Error* (*SE*) = 0.63, 95% *Confidence Interval* (CI) [0.87, 3.36]), sleep quality (*MD* = 2.59, *SE* = 0.97, 95% CI [0.66, 4.51]), well-being (*MD* = -1.54, *SE* = 0.68, 95% CI [.-2.89, -0.18]), and stress (*MD* = 6.91, *SE* = 3.48, 95% CI [0.01, 13.81]). Screen time increased rapidly after the intervention and at follow-up the values were once again approaching the initial level.

Conclusions The study highlights mental health improvements through smartphone screen time reduction. Three weeks of screen time reduction showed small to medium effect sizes on depressive symptoms, stress, sleep quality, and well-being. The results suggest a causal relationship, rather than a merely correlative one, between daily smartphone screen time and mental health.

Trial registration The study was preregistered on Open Science Framework (trial registration number: A9K76) on November 8, 2023.

Keywords Smartphone screen time, Mental health, Screen time reduction, Depression, Sleep, Stress

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Background

Smartphones have become an integral part of our everyday lives. Worldwide, 5.6 billion people own a smartphone and almost 5 billion use social media sites. This indicates an increase of over 200 million in the last year alone [1]. Daily smartphone screen time has risen sharply in recent years with an average daily screen time of 3 h and 46 min [2]. In Austria, 38% of adolescents use their phones five or more hours per day [3].

Intensive smartphone use reflects the high utility of smartphones in modern society. Evidence also suggests positive effects of smartphone use, such as increased social connectedness among social media users [4] and providing a platform for exchange among minorized groups [5, 6]. Furthermore, individuals with mental health issues have reported finding distraction through positive smartphone content beneficial [7], and improvements in mood have been observed following increased use of entertainment apps [8]. Nevertheless, an increasing number of studies report negative effects associated with intensive smartphone use. A large-scale study (>1 million adolescents) found that more time on screens is associated with lower psychological well-being [9]. Numerous cross-sectional studies discovered that smartphone use was significantly associated with mental health symptoms with a gradually higher prevalence of psychological symptoms with each hour of daily screen time (e.g. [10–14],). However, these studies as well as the majority of research in this field are cross-sectional [15] and causal interaction remains unclear. Longitudinal, naturalistic studies observed screen time, mental health, and possible mutual changes over time. A study found that frequent social media use predicted later poor mental health and well-being [16]. Given the topic's relevance, well-founded interventional studies are only sparsely represented. A systematic review found an association between screen time in general and depressive symptoms [17]. A large-scale longitudinal study from the UK on more than 12,000 young people found that frequent social media use predicted later poor mental health and well-being [16]. Further, a review of 13 reviews found moderately strong evidence for an association between screen time and depressive symptoms [18]. A review on the use of mobile phones or wireless devices found limited evidence that such usage may be associated with poorer mental health in children and adolescents [19]. In addition, the importance of considering the purpose of use is indicated, since smartphone screentime appears to be detrimental to mental health from as little as two hours per day, depending on the purpose of use, and from four hours, regardless of the usage purpose [13].

Despite the relevance of the topic, well-designed interventional studies are only sparsely represented. A systematic review found only 12 randomized clinical trials (RCTs) on digital detox and mental health with a variety of different designs, interventions, sample sizes, or measurements. Even though there were consistent effects for depressive symptoms, the results were otherwise inconsistent [20]. Positive effects are also evident for appearance- and weight-esteem after three weeks of reduced social media time [21].

Methods

The present study aimed to investigate the effect of smartphone screen time reduction on mental health indicators. The primary a priori hypothesis was that mental health would improve after the intervention compared to the control group as well as compared to baseline.

Registration

The 'Digital Detox Study' (https://doi.org/10.17605/OSF.IO/A9K76) followed the CONSORT guidelines for randomized trials [22]. The protocol was registered on November 8, 2023, at Open Science Framework (OSF) [23] prior to enrollment and aligned with the required data set of the World Health Organization's International Clinical Trials Registry Platform [24]. In addition, the study was retrospectively registered to ClinicalTrials.gov on 19 March 2024 to comply with the criteria of the International Committee of Medical Journal Editor [25].

Hypothesis

The primary hypothesis was that mental health indicators, particularly stress, depressive symptoms, and sleep quality; would improve throughout the intervention compared to the control group as well as to baseline. No hypothesis was stated regarding follow-up effects.

Study design

The study was promoted via on-site information events in Krems, Austria, social media, and university notices. The inclusion criteria were: healthy students aged 18–29 years, owning a smartphone and using it at least 3 h per day, with no diagnosed or treated mental disorder, and no ongoing psychotherapy or psychopharmacological treatment. Moderately elevated levels in mental health questionnaires were not reasons for exclusion. After enrollment and screening for eligibility (November 10, 2023), participants were randomized to the control or intervention group using the method of simple randomization provided the ESMira app [26], which is based on a random number generator, like a coin toss, ensuring true randomness. They were informed of their group allocation via message in ESMira before the intervention, without prior access to it. Smartphone screen time was assessed weekly for both groups. Following a 10-day

baseline phase to monitor the participants' smartphone screen time and physical activity, mental health indicators were measured at baseline (t0; November 19, 2023), after 3 weeks of intervention (t1; December 12, 2023), and at follow-up (t2; January 21, 2024).

The intervention group received a fitness tracker to track physical activity during baseline and intervention phase.

After baseline (t0), the intervention group reduced smartphone screen time (≤2 h/d) for three consecutive weeks, while the control group continued using their smartphones as usual for the entire study duration (parallel design, no blinding). The two-hour limit was selected based on a study involving over 7000 adolescents in Austria, which found a significantly higher incidence of depressive symptoms or stress, with three to four hours of daily smartphone use, while one to two hours of usage showed no difference compared to the control group (< 1 h) [12]. A Korean study also found that smartphone use of two or more hours per day, depending on the type of use, was associated with negative effects on mental health [13]. Screen time limiters were recommended, but not obligatory. After the intervention, no further requirements were imposed on screen time (see Additional file 1: Fig. A2). The control group was offered participation in the intervention after follow-up (crossover), to minimize dropouts and missing items.

Data collection and randomization

After signing an informed consent form, participants joined the study in the ESMira [27] app via QR code. All data collection procedures, including randomization, communication, questionnaire completion, and screenshot uploads were conducted with the app. Randomization of ESMira works autonomously and is impervious to external influences.

Smartphone screen time

Smartphone screen time was assessed weekly in both groups using the smartphones' built-in screen time measurements. Each Monday, participants were prompted to upload a screenshot of their screen time from the previous week (Monday to Sunday).

Mental health indicators

Mental health indicators were evaluated in both groups at baseline (t0), post-intervention (t1), and follow-up (t2). Participants were reminded to complete the questionnaires via push notifications every Sunday.

In addition to the a priori-defined main outcomes (depression, well-being, stress, sleep), additional measures were collected to determine baseline differences between the groups and to detect possible further effects of screen time reduction on mental health.

Main outcomes

Well-being (WHO-5) The validated German version of the World Health Organization well-being questionnaire (WHO-5) was used to measure well-being with five self-rating items [28, 29]. Scores range from 0 (no well-being) to 25 points (maximal well-being). Cronbach's alphas were: t0: α = 0.75, t1: α = 0.78, t2: α = 0.82.

Depressive symptoms (PHQ-9) Depressive symptoms were assessed using the Patient Health Questionnaire (PHQ-9) [30] in the validated German version [31]. The PHQ-9 contains nine self-rating items on a four-point scale ranging from 0 ("not at all") to 3 ("nearly every day"), resulting in a total score from 0 to 27. Cronbach's alphas were: t0: α = 0.76, t1: α = 0.75, t2: α = 0.81.

Stress (PSQ-20) Stress was evaluated with the German version [32, 33] of the 20-item short form of the Perceived Stress Questionnaire (PSQ-20) [34]. Each item is rated from almost never (=1) to usually (=4), with a transformed sum score from 0 to 100. Cronbach's alphas were: t0: α = 0.93, t1: α = 0.93, t2: α = 0.94.

Sleep quality (ISI) Sleep quality was measured using the Insomnia Severity Index (ISI) [35, 36] in its validated German version [37]. The ISI comprises 7 self-reported items, each rated on a scale from 0 to 4, resulting in sum scores from 0 to 28. Cronbach's alphas were: t0: α = 0.81, t1: α = 0.83, t2: α = 0.87.

Additional outcomes

Problematic smartphone use (SAS-SV) Problematic smartphone use was measured using the validated German [38] short version of the Smartphone Addiction Scale (SAS-SV) [39]. The 10 items address the following content areas: daily-life disturbance, withdrawal, cyberspace-oriented relationship, overuse, and tolerance. Cronbach's alphas were t0: α = 0.84, t1: α = 0.87, t2: α = 0.89.

Anxiety symptoms (GAD-7) The German version [40] of the Generalized Anxiety Disorder 7 scale (GAD-7) [41] was used to measure anxiety symptoms with 7 self-rating items on a four-point scale, from 0 to 3 (maximum score 21). Cronbach's alphas for anxiety were t0: α = 0.83, t1: α = 0.87, t2: α = 0.87.

Table 1 Characteristics of the study sample and differences between the intervention and control group

	Total sample	Intervention group	Control group	Sig. (2-tailed)
n	111	58	53	
Gender (male/female)	41 m / 70 f 36.9% / 63.1%	22 m / 36 f 37,9% / 62.1%	19 m / 34 f 35.8% / 64.2%	$\chi^2 = 0.052$ (1) $p = .820$
	M (SD)	***M (SD)***	***M (SD)***	
Age (years)	22.68 (2.555)	22.90 (2.440)	22.43 (2.678)	$t = -0.952$ (109) $p = .343$
Screen time (min.)	276.84 (114.275)	284.71 (133.641)	268.22 (88.896)	$t = -.771$ (99.89) $p = .443$
Physical activity (number of days/week with physical activity ≥ 60 min.)	2.87 (1.748)	2.83 (1.666)	2.93 (1.849)	$t = .294$ (109) $p = .770$
Depressive symptoms (PHQ-9)	7.70 (3.734)	7.74 (3.487)	7.64 (4.021)	$t = -0.139$ (109) $p = .890$
Sleep quality (ISI)	9.07 (4.914)	8.84 (4.811)	9.31 (5.059)	$t = 0.508$ (109) $p = .613$
Stress (PSQ-20)	40.06 (18.562)	40.39 (18.315)	39.70 (18.997)	$t = -0.195$ (109) $p = .845$
Well-being (WHO-5)	14.30 (3.869)	14.15 (3.488)	14.46 (4.276)	$t = 0.412$ (109) $p = .681$
Body appreciation (BAS-2)	36.62 (7.527)	35.42 (7.615)	37.93 (7.276)	$t = 1.768$ (109) $p = .080$
Smartphone addiction (SAS-SV)	33.39 (8.498)	33.33 (7.770)	33.47 (9.305)	$t = 0.087$ (109) $p = 0.931$
Anxiety symptoms (GAD-7)	6.32 (3.853)	6.07 (3.458)	6.60 (4.259)	$t = 0.730$ (109) $p = 0.467$
Disordered eating (SCOFF)	1.44 (1.405)	1.15 (1.151)	1.76 (1.591)	$t = 2.267$ (94.01) $p =$ **.026**

Significant *p*-values are displayed in bold. *M*: mean; *SD*: standard deviation; *p*: p-values, *t* = *t*-statistic; *n*: number of participants; χ^2: χ^2-statistic

Eating disorder (SCOFF) We used the validated German version [42, 43] of the screening tool SCOFF (Sick, Control, One stone, Fat, Food) [44] to assess relevant symptoms of eating disorders (anorexia and bulimia nervosa). Five items can be answered with "yes" = 1 or "no" = 0. The total score ranges from 0 to 5. A total score of 2 or above indicates disordered eating. Cronbach's alphas were: t0: α = 0.64, t1: α = 0.37, t2: α = 0.46.

Body Appreciation (BAS-2) To examine the respondents' body image, we used the validated German version [45] of the Body Appreciation Scale-2 (BAS-2) [46]. The scale is comprised of 10 items, which can be rated from "never" (1) to "always" (5). Higher scores indicate a more positive body appreciation. Cronbach's alphas were: t0 α = 0.94, t1: α = 0.94, t2: α = 0.95.

Activity measurement

Physical activity estimates were collected as part of the screening for eligibility (i.e. number of days per week with 60 or more minutes of physical activity per day; see Table 1). Furthermore, during both the baseline and intervention phase, the intervention group (but not the control group) used fitness trackers (Fitbit Inspire 3) to objectively assess physical activity. The fitness trackers were worn to monitor the potential influence of increased physical activity on mental health outcomes more accurately than self-reported data. Moderate to very high intense physical activity in minutes per day was documented.

Incentives

Participants were allowed to keep the fitness tracker after completing the study (value: € 99,-).

Sample size

Assuming small to medium effects (Cohen's $d = 0.45$, power 0.8, significance level < 0.05, icc = 0.05), a minimum of 40 people per group was needed to complete the post-intervention assessment (t1). Considering a drop-out rate of 20%, at least 50 people per group were recruited.

Statistics

We used the statistic software IBM SPSS Statistics Version 29 (IBM Corp., Armonk, NY, USA) [47] to analyze the data. χ^2-Test and independent samples t-tests were used to examine differences at baseline regarding age, gender, smartphone screen time, physical activity, and mental health indicators between the control and intervention group.

To examine the effect of reduced smartphone screen time on mental health indicators, repeated measurements ANOVAs (rm-ANOVA) were applied. The primary hypotheses focused on the difference between t0 (baseline) and t1 (post-intervention) in the intervention group and on the difference between control group and intervention group (intention-to-treat analysis). In a secondary analysis, the follow-up time point (t2) was also included (however, no a priori hypothesis was stated). The follow-up was 6 weeks after t1 and 12 weeks after enrollment. Group allocation (control vs.

intervention) was the between-group factor. Time was the within-group factor (t0, t1, t2). A subgroup analysis (rm-ANOVA) of those, who strictly adhered to the ≤ 2 h smartphone screen time limit was also performed (per-protocol analysis).

In case of baseline group differences, these variables were added as covariates in the rm-ANOVA. In the original pre-registration, we planned to include physical activity as a covariate. However, since there were no baseline differences between the two groups, we did not include it. If the sphericity assumption was violated, the conservative Greenhouse–Geisser correction was applied. In the post hoc tests, Bonferroni correction was applied to adjust for multiple comparisons. Missing values (missing completely at random; Little's MCAR-test: $\chi^2 = 259.38$, $df = 283$, $p = 0.840$; t0: 2.7%, t1: 5.9%, t2: 13.5%) were dealt with via maximum likelihood estimation. Maximum likelihood estimation utilizes all available information from the observed data, including partially complete cases and it seems more precise than the other estimations, especially under "missing at random" assumption. The parameters are chosen to maximize the likelihood that the assumed model results in the observed data. This contrasts with other methods like listwise deletion (Complete Case Analysis), which only consider fully observed cases. Percentage changes in the main outcomes between baseline and post-intervention were calculated for the intervention group [48]. Effect sizes were presented as partial eta squared ($\eta^2 = \text{time} \times \text{group}$) and group-mean differences. The value of η^2 ranges from 0 to 1 and can be interpreted as small- ($\eta^2 \approx 0.01$), medium- ($\eta^2 \approx 0.06$), and large effects ($\eta^2 \approx 0.14$) [49].

Ethics

The study was conducted according to the guidelines of the Declaration of Helsinki [50] and CONSORT guidelines for non-pharmacological trials [22]. The university's ethics committee approved the study protocol on October 23, 2023 (number: EK GZ 67/2021–2024). Although the study was preregistered on Open Science Framework (trial registration number: A9K76), some components, such as the randomization procedure or the exclusion criteria, are insufficiently reported there.

Results

Study sample

From 125, 111 students (70 females; 22.7 (± 2.6) yrs) were randomly assigned to intervention ($n = 58$) or control group ($n = 53$) (Fig. 1). Two participants were excluded (1 above the age limit, 1 in ongoing treatment) and 12 withdrew after the eligibility screening without giving reasons.

At baseline, screen time, physical activity (self-reported number of days per week with ≥ 60 min. of physical activity), age, gender, and mental health indicators (except disordered eating) did not differ between the intervention and control group (see Table 1). On average, participants spent 276.37 (± 115.1) minutes per day on smartphone use and reported exercising on 2.87 (± 1.8) days per week.

Screen time reduction

Control (268.22 ± 88.90) and intervention group (284.71 ± 133,64) did not differ in screen time at baseline ($t = -0.771$ (99.89), $p = 0.443$). During intervention (weeks 3–5), screen time differed significantly between the control and intervention group (see Additional file 2: Figure A1) with an average screen time of 129.46 ± 46.32 min./day (intervention group) and 264.19 ± 84.83 min./day (control group) (all p-values ≤ 0.001). The intervention group reduced their screen time by 155.25 ± 132.14 min/day. Significant screen time differences between intervention group (225.73 ± 89.06 min/day) and control group (270.42 ± 100.31 min./d ($t = 0.351$ (109); $p = 0.014$) only persisted to the first post-intervention week (week 6). From week 7 onwards no differences in screen time were observed.

Although all participants significantly reduced screen time during intervention phase (weeks 3–5), not all participants managed to reduce their screen time to the predetermined time limit. Therefore, an additional subgroup analysis was carried out with those who strictly adhered to the limits (≤ 2 h/d). There was no baseline difference between this subgroup compared to control group as well as to the other part of the intervention group, which did not strictly adhered to the time limit (see Additional file 3: Table 1).

Physical activity

Self-stated physical activity at the beginning of the study was reported in both groups as number of days per week with physical activity ≥ 60 min (Table 1). During baseline phase (week 1–2), moderate to vigorous physical activity averaged 43.93 ± 22.90 min./d, objectively measured by a fitness tracker (only in the intervention group, not in the control group). During intervention phase (weeks 3–5), moderate to vigorous physical activity was 42.77 ± 31.78, 47.90 ± 30.44, and 44.05 ± 25.00 min./d. Physical activity did not differ statistically between baseline and intervention phase (all p-values > 0.5). Since objective physical activity data were only obtained from the intervention group, no between-group differences could be estimated.

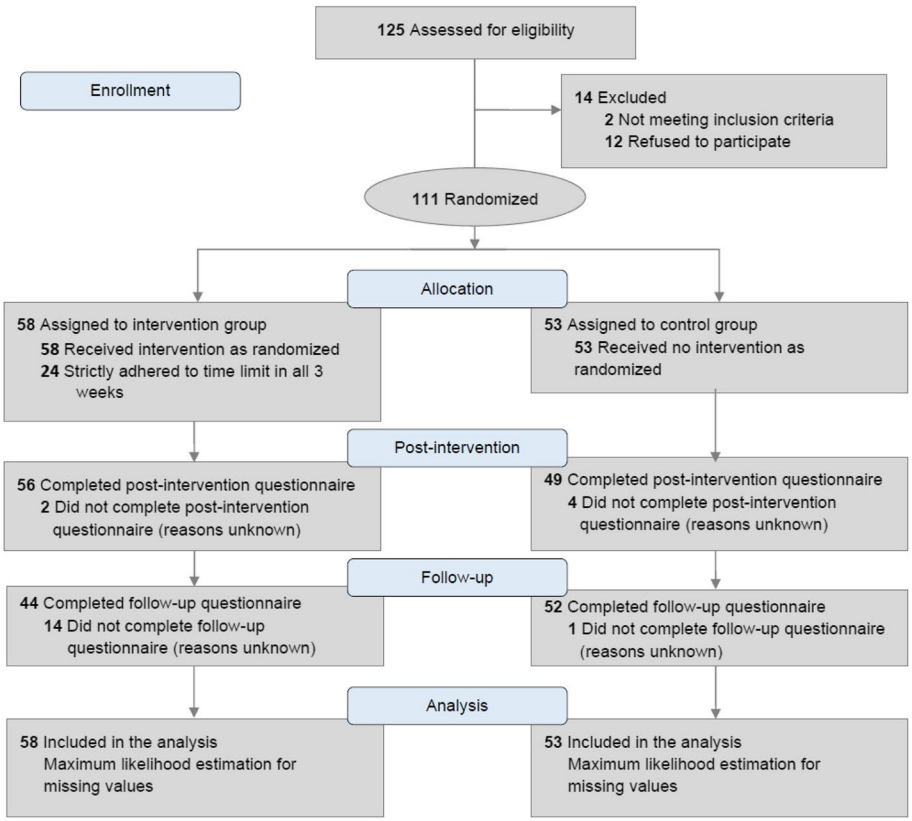

Fig. 1 Study flow chart

Mental health indicators

Time×group interactions were observed in the main mental health outcome measures (depressive symptoms, well-being, sleep quality, and stress), showing small to medium effect sizes (Table 2). Mean differences between the groups at all three time points and associated confidence intervals can be found in Table A4 in Additional file 5.

Baseline and post-intervention for the total sample

Main outcomes

Depressive symptoms: A time×group interaction was evident when comparing baseline with post-intervention in depressive symptoms ($F(1;\ 109) = 13.358$, $p < 0.001$, partial $\eta^2 = 0.109$). Post-hoc tests highlighted differences within the intervention group comparing t0 and t1 ($p < 0.001$) and t1 and t2 ($p = 0.039$). The group comparison at t1 revealed differences between the control and the intervention group ($p = 0.001$). The mean group difference at t1 was ($MD = 2.11$; $SE = 0.063$; 95% CI [0.87, 3.36]; $p = 0.001$) (further information see Additional file 5: Table A4). Depressive symptoms decreased by 27% from t0 and t1 in the intervention group (within-group effect).

Well-being: There was a time×group interaction when comparing baseline with post-intervention in well-being ($F(1;\ 109) = 6.088$, $p = 0.015$ partial $\eta^2 = 0.053$), post-hoc test (t0-t1) was significant for the intervention group ($p < 0.001$), and group comparison (control vs. intervention group) was significant at t1 ($p = 0.026$). The mean group difference at t1 was ($MD = -1{,}54$; $SE = 0.68$; 95% CI [−2.89, −0.18]; p = 0.026) (Additional file 5: Table A4). Well-being increased by 14% from t0 and t1 in the intervention group (within-group effect).

Stress: There was a significant time×group interaction when comparing baseline with post-intervention in stress ($F(1;\ 109) = 10.164$; $p = 0.002$, partial $\eta^2 = 0.085$), post-hoc test (t0-t1) was significant in the intervention group ($p < 0.001$) as well as from t1 to t2 ($p = 0.027$), and group comparison was significant at t1 ($p = 0.05$). The mean group difference at t1 was ($MD = 6.91$; $SE = 3.48$; 95% CI [0.01, 13.81]; $p = 0.050$) (Additional file 5: Table A4). Stress decreased by 16% from t0 and t1 in the intervention group (within-group effect).

Sleep quality: There was a significant time×group interaction when comparing baseline with post-intervention in sleep quality ($F(1;\ 109) = 5.508$; $p = 0.021$, partial $\eta^2 = 0.048$), the post-hoc test (t0-t1) was significant in the

Table 2 Outcomes of the rm-ANOVAs for depression, well-being, stress, and sleep

Outcome	Time	CG ($n=53$)	IG ($n=58$)	Effect size	Statistics	IG ≤ 2 h ($n=24$)	Effect size	Statistics
		$M \pm SD$		partial η^2		$M \pm SD$	partial η^2	
Depression (PHQ-9)	**Pre**	7.64 ± 4.021	7.74 ± 3.487			7.75 ± 3.365		
	Post	7.76 ± 3.563	5.65 ± 3.052	.089	time: $F(1; 109) = 10.637$; $p =$ **.001**	4.63 ± 2.436	.225	time: $F(1; 75) = 21.738$; $p <$ **.001**
				.109	time × group: $F(1; 109) = 13.358$; $p <$ **.001**		.252	time × group: $F(1; 75) = 25.319$; $p <$ **.001**
	Follow-up	8.01 ± 4.446	6.69 ± 3.488	.044	time: $F(2; 218) = 5.054$; $p =$ **.007**	6.06 ± 3.117	.095	time: $F(1.84; 138.25) = 7.840$; $p <$ **.001**
				.055	time × group: $F(2; 218) = 6.330$; $p =$ **.002**		.110	time × group: $F(1.84; 138.25) = 9.305$; $p <$ **.001**
Well-being (WHO-5)	**Pre**	14.46 ± 4.276	14.15 ± 3.488			13.92 ± 3.361		
	Post	14.58 ± 3.791	16.11 ± 3.406	.066	time: $F(1; 109) = 7.750$; $p =$ **.006**	16.79 ± 2.950	.144	time: $F(1; 75) = 12.663$; $p <$ **.001**
				.053	time × group: $F(1; 109) = 6.088$; $p =$ **.015**		.125	time × group: $F(1; 75) = 10.742$; $p =$ **.002**
	Follow-up	14.29 ± 4.322	15.17 ± 3.687	.033	time: $F(2; 218) = 3.732$; $p =$ **.025**	14.66 ± 3.483	.075	time: $F(2;150) = 6.123$; $p =$ **.003**
				.027	time × group: $F(2; 218) = 2.981$; $p = .053$		.060	time × group: $F(2; 150) = 4.783$; $p =$ **.010**
Stress (PSQ)	**Pre**	39.70 ± 18.997	40.39 ± 18.315			38.41 ± 18.504		
	Post	40.96 ± 18.596	34.05 ± 18.078	.040	time: $F(1; 109) = 4.544$; $p =$ **.035**	30.07 ± 18.108	.067	time: $F(1; 75) = 5.422$; $p =$ **.023**
				.085	time × group: $F(1; 109) = 10.164$; $p =$ **.002**		.117	time × group: $F(1; 75) = 9.965$; $p =$ **.002**
	Follow-up	43.29 ± 21.420	38.32 ± 18.133	.038	time: $F(2; 218) = 4.317$; $p =$ **.014**	36.81 ± 18.085	.061	time: $F(2; 150) = 4.903$; $p =$ **.009**
				.049	time × group: $F(2; 218) = 5.635$; $p =$ **.004**		.062	time × group: $F(2; 150) = 4.997$; $p =$ **.008**
Sleep (ISI)	**Pre**	9.31 ± 5.059	8.84 ± 4.811			8.96 ± 4.045		
	Post	9.82 ± 5.502	7.23 ± 4.709	.014	time: $F(1; 109) = 1.501$; $p = .223$	5.83 ± 4.659	.074	time: $F(1; 75) = 6.020$; $p =$ **.016**
				.048	time × group: $F(1; 109) = 5.508$; $p =$ **.021**		.133	time × group: $F(1; 75) = 11.530$; $p =$ **.001**
	Follow-up	10.48 ± 6.071	7.52 ± 4.783	.009	time: $F(1.86; 203.11) = 1.010$; $p = .362$	5.87 ± 3.534	.048	time: $F(2; 150) = 3.822$; $p =$ **.024**
				.044	time × group: $F(1.86; 203.11) = 5.066$; $p =$ **.008**		.127	time × group: $F(2; 150) = 10.957$; $p <$ **.001**

Significant ($p \leq .05$) group differences are displayed in bold. PHQ-9: Patient Health Questionnaire 9; ISI: Insomnia Severity Index; PSQ-20: Perceived Stress Questionnaire; WHO-5: World Health Organization 5 well-being questionnaire; *p*: *p*-value (2-tailed); *M*: mean; *SD*: standard deviation; *F*: *F*-statistic; IG: intervention group; CG: control group; IG ≤ 2 h: strictly adherent intervention subgroup

intervention group ($p = 0.033$), the post-hoc test (t0-t2) was not significant, the group comparison was significant at t1 ($p = 0.009$) and t2 ($p = 0.005$). The mean group difference at t1 was ($MD = 2.59$; $SE = 0.97$; 95% CI [0.66, 4.51]; $p = 0.009$) (Additional file 5: Table A4). Insomnia symptoms decreased by 18% between t0 and t1 in the intervention group (within-group effect).

The changes in the main outcomes at the three measurement times can be observed in Fig. 2. The error bars in Fig. 2 represent the 95% confidence intervals (CI). Further information on the post-hoc pairwise comparison of the time points per group can be found in the Additional file 4 (Table A3) and in the Additional file 5 (Table A4) for the post-hoc pairwise comparison of the groups per time point.

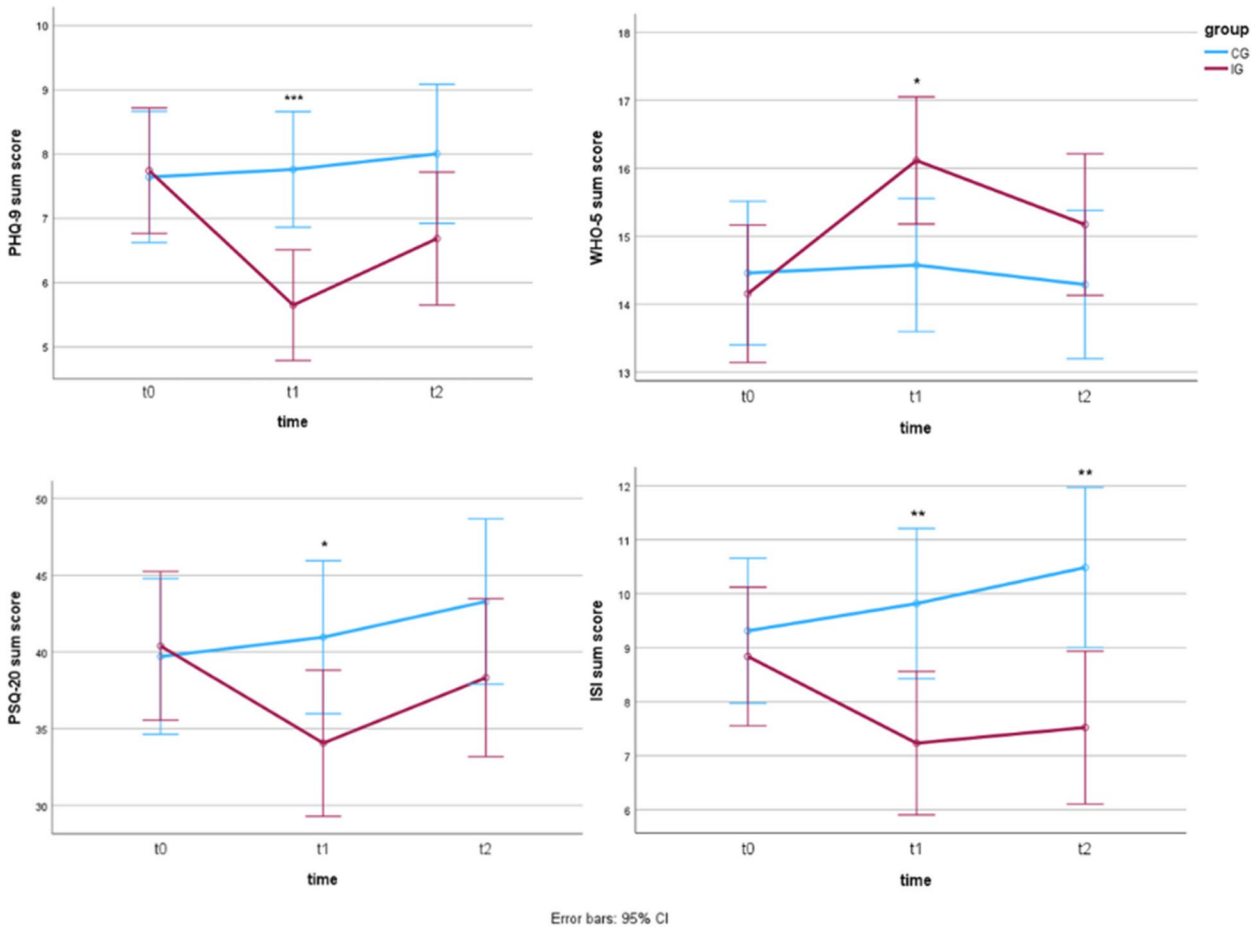

Fig. 2 Depression, stress, and sleep disorder symptoms and well-being at t0, t1, and t2 per group. *Note.* Significant between-group differences are indicated by asterisks (* $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$). PHQ-9: Patient Health Questionaire 9; ISI: Insomnia Severity Index; PSQ-20: Perceived Stress Questionnaire; WHO-5: World Health Organization well-being questionnaire; CG: control group; IG: intervention group; t0: baseline; t1: post-intervention; t2: follow-up. Error bars present 95% confidence intervals (CI)

Additional outcomes

There was no time × group interaction when comparing baseline with post-intervention in anxiety symptoms (GAD-7), disordered eating (SCOFF), and body appreciation (BAS-2). There was a significant time × group interaction when comparing baseline with post-intervention in problematic smartphone use (SAS-SV; time × group: $F(1; 109) = 27.215$; $p < 0.001$), to be seen in the Additional file 6 (Table 2).

Additional subgroup analysis: Baseline and post-intervention for the subsample that strictly adhered to the screen time limits in all three weeks ($n = 24$)

Main outcomes

There was a significant time × group interaction in this subsample when comparing baseline with post-intervention in depressive symptoms ($F(1;75) = 25.319$, $p < 0.001$, partial $\eta^2 = 0.252$, decrease of 40%), well-being ($F(1; 75) = 10.742$; $p = 0.002$, partial $\eta^2 = 0.125$, increase of 21%), stress ($F(1; 75) = 9.965$, $p = 0.002$, partial $\eta^2 = 0.117$, decrease of 22%), and sleep quality ($F(1; 75) = 11.530$, $p = 0.001$, partial $\eta^2 = 0.133$, improvement of 35%).

Additional outcomes

There was no time × group interaction when comparing baseline with post-intervention in anxiety symptoms and disordered eating. There was a significant time × group interaction when comparing baseline with post-intervention in body appreciation (time × group: $F(1; 75) = 5.926$; $p = 0.017$, partial $\eta^2 = 0.073$) and problematic smartphone use (time × group: $F(1; 75) = 23.200$; $p < 0.001$, partial $\eta^2 = 0.236$), to be seen in the Additional file 6 (Table 2).

Further information on the post-hoc pairwise comparison of the time points per (sub)groups (Additional file 7: Table A7) and post-hoc pairwise comparison of the (sub) groups per time point (Additional file 8: Table A6) can be found in the Additional files.

Discussion

The study highlights mental health improvements through smartphone use reduction. Compared to the control group, the intervention group showed an improvement in depressive symptoms, stress, insomnia symptoms, and well-being. The changes in primary outcome correspond to small to medium effect sizes in the total sample and large effect sizes in the subsample that strictly adhered to the time limits for depressive symptoms. However, as only healthy students were included, the mean values at baseline were in the lower range and the mean differences were rather small.

In the intervention group, physical activity, measured by fitness trackers, was monitored throughout the intervention period to account for possible changes due to reduced screen time but it did not statistically change during that period. However, since it was only measured in the intervention group, the interpretation of this result is only possible to a limited extent. Interestingly, screen time returned to the initial level rapidly after the intervention and there were no between-group differences at follow-up. Only insomnia symptoms showed significant effects at follow-up. However, this effect might be explained by a decrease in the control group.

While the current study showed positive effects on insomnia symptoms, a study on 23 judo athletes found no effect of two days of electronic device removal on their sleep [51]. Consistent with the positive effect on depressive symptoms in the present study are the results of a study on social media reduction, in which a reduction to 30 min of social media per day not only found a reduction in loneliness but also the same effect on depressive symptoms [52]. A RCT showed that children became more physically active when their recreational screen use was reduced [53]. In the present study, an association between screen time reduction and physical activity was not confirmed. As physical activity was not assessed in the control group, these results can only be interpreted to a limited extent. Nevertheless, the effects appear to be independent or at least not primarily due to changes in physical activity levels.

Numerous observational studies on the associations between general screen use and psychological well-being have documented small effect sizes (e.g., [54–56]). This is in contrast to the present RCT that found larger effect sizes, especially when looking at the subgroup that strictly adhered to the 2-h time limit (per-protocol analysis). These different effect sizes cannot be conclusively explained but may be attributed to the differing study designs (observational cross-sectional study vs. longitudinal intervention study), varying sample sizes (large-scale analysis vs. small sample size in the current study), or different target groups (children and adolescents vs. young adults). In any case, the current results would have to be replicated in larger samples in order to draw generalizable conclusions.

The study design does not permit conclusions about the reasons for the rapid increase in screen time; however, this trend may be partially explained by the strong appeal of smartphones among young people and the pervasive fear of missing out (FOMO) [57]. Additionally, minor individual improvements detected by the mental health questionnaires may not have been perceived by the participants themselves. Accordingly, the subjective advantages of smartphones and social media, such as staying in touch with friends, emotional support, seeking mental health information, and community building, could outweigh the effects on mental health [5, 58, 59]. Effective self-regulation of social media use can particularly improve psychological well-being by supporting mood management, emotion-focused coping, and the fulfillment of intrinsic needs. [60].

In addition to the duration of screen time, the content consumed, and the manner of usage [61–63] appear to be particularly relevant for their association with well-being. Besides the benefits that social media offers, there are also harmful aspects. Social comparisons regarding physical appearance, alongside preoccupation with one's photos and feedback, are associated with poorer body image, disordered eating, and depressive symptoms, particularly in girls [64–70]. Additionally, especially poorly self-regulated social media use can lead to goal conflicts, distraction from intended activities and, consequently, negative well-being [60].

Overall, it should be taken into account that the use of social media ranges from, for example, searching for information, passing the time, social interaction, entertainment, expressing opinions, sharing information, relaxing and even monitoring others or gaining knowledge about them [71]. Reviews have shown that active social media use (i.e. posting) has a small positive effect and passive use (i.e. browsing) has a slightly negative effect on well-being [15, 61, 72]. A further differentiation into active private use (sending messages), passive private use (reading messages), and passive public use (browsing) did not affect the well-being of young people on average, but inter-individual differences emerged [73]. Therefore, the way individuals use their smartphones appears to be an important factor.

Given that social media sites are integral to intensive smartphone use, there is growing advocacy for stricter regulations, especially for children and young people [51]. For example, Australia is already taking first steps by proposing a complete ban on social media use for adolescents under the age of 16.

As in the present study on screen time reduction, a positive effect on well-being was observed in a study that investigated the effect of one week of social media abstinence [52]. Accordingly, another study found a positive effect on stress after one week of abstinence from social networking sites [53]. These results fit with the results of a study, showing that a five-day abstinence from Facebook led to lower cortisol levels [54]. No effect of social media abstinence on affective well-being, loneliness, and quality of day was shown in a daily diary study [55]. In addition, a large-scale study of nearly 16,000 children aged 3–6 years has already found an increasing proportion of social media to screen time as they get older and has also shown that this non-child-directed content leads to a higher risk of mental health problems, while a higher proportion of educational programs lowers that risk [56]. Around 5 million adults up to the age of 65 worldwide and 32.6% and 36.1% of adults in Germany and Austria have been affected by cyberbullying. Women and young people are particularly affected and the serious consequences for health in the form of suicide risk or alcohol, drug, and medication abuse cannot be underestimated [57]. The association between cyberbullying and depression is also shown in a review of 36 studies [58].

The interactions of smartphone screen time, social media use, and mental health are not yet sufficiently clear. Undoubtedly, they are complex and potentially bi-directional [74]. However, there are several potential explanations. The consumption of social media sites may lead to overstimulation of the brain's reward center and may trigger pathways akin to addiction [75]. Similarly, a third of 11–15-year-old girls claim to be "addicted" to a social media platform [76]. Inappropriate or harmful content is easily accessible, posing particular risks to young people with mental health problems [63].

To interpret the current results accurately, it is crucial to consider the study's limitations. First, only self-reported mental health indicators were used. Some of the questionnaires (e.g., PHQ-9, GAD-7, or ISI) are recognized screening instruments for mental illness, but social desirability biases cannot be ruled out. Although widely used in different settings and populations, the accuracy of measuring changes in the lower range remains uncertain. Secondly, only smartphone screen time was assessed. Many students possess multiple digital devices. Although the participants were instructed not to switch to other devices, we cannot completely rule out this option. Thirdly, the sample was relatively small and not representative of the general population, considering the participants' age, education level, relatively low baseline values in the mental illness indicators, and frequent physical activity. Fourthly, physical activity was objectively only measured in the intervention group. Furthermore, screen time was monitored through screenshot uploads, whereas direct import of smartphone data would be more accurate. In the uploaded screenshots only the duration of the smartphone use, not its content, had been specified, which represents a further limitation regarding the types of uses discussed above. Although the calculated sample size was met for the primary research interest, the follow-up analysis was limited due to high drop-outs. Moreover, since the sample was relatively healthy and most individuals scored at the lower end of the mental health questionnaires at baseline, a floor effect cannot be ruled out. This means that further improvements may not have been possible or could not be detected by the questionnaires. Accordingly, the positive health effects reported may be underestimated. Beyond the psychometrics, there is a risk of self-selection bias in studies on smartphone use reduction. Individuals who derive significant benefits from or are strongly attached to their smartphones may be less likely to participate. The extent to which the bias applies cannot be stated. With regard to the subgroup analysis, it should be noted that the adherent group is a relatively small sample for which no power analysis was initially carried out. Due to the small sample size, the risk of a type II error is increased, which means that relevant group differences may not have been recognized and thus may not have been included in subsequent analyses.

Conclusions

The study highlights mental health improvements through smartphone use reduction. The rapid return to high usage post-intervention underscores the challenges young people face in managing their smartphone use. With increasing global smartphone screen time and social media use, these findings hold particular significance. If larger studies confirm a causal link between screen time and mental health, a serious rethinking of our smartphone behavior would be called for. Consequently, factors that positively and sustainably influence screen time and social media usage (e.g. types of usage) must be considered.

The allure of social media makes self-regulation of screen time behavior challenging, supporting stricter regulations, especially for children and young people [77]. Our study demonstrates both the substantial mental health benefits of reduced smartphone screen time and the challenges in maintaining it.

Abbreviations

RCT	Randomized controlled trial
WHO-5	World Health Organization well-being questionnaire
PHQ-9	Patient Health Questionnaire
PSQ-20	Perceived Stress Questionnaire
ISI	Insomnia Severity Index
SAS-SV	Smartphone Addiction Scale short version

GAD-7	Generalized Anxiety Disorder 7 scale
SCOFF	Screening tool (Sick, Control, One stone, Fat, Food) for eating disorders
BAS-2	Body Appreciation Scale-2
H	Hours
min.	Minute(s)
d	Day
yrs	Years
N/n	Number of participants
M	Male
F	Female
M	Mean
SD	Standard deviation
P	*p*-Value
T	*t*-Statistic
χ^2	χ^2-Statistic.
CG	Control group
IG	Intervention group
t0	Time point 0 (baseline measurement time point)
t1	Time point 1 (post-intervention measurement time point)
t2	Time point 2 (follow-up measurement time point)
CI	Confidence interval
η^2	Eta squared

Supplementary Information

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Additional file 1: Study design overview

Additional file 2: Illustration of the average weekly screen time per group

Additional file 3: Comparison of baseline characteristics between the intervention group's adherent and non-adherent subgroup and the adherent group and control group

Additional file 4: Pairwise comparison of time points per control and intervention group

Additional file 5: Pairwise comparison of control and intervention group per time point

Additional file 6: Outcomes of the rm-ANOVAs for the additional mental health measures

Additional file 7: Pairwise comparison of time points per control and intervention group that adhered to £2h screen time limit

Additional file 8: Pairwise comparison of control and intervention group that adhered to £2h screen time limit per time point

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Authors' contributions
Conceptualization: CP, KH, EH Methodology: CP, KH, EH Data curation: KH, AH, JS Formal analysis: KH, EH, RD Visualization: KH Project administration: KH, CP Supervision: CP, KH Writing – original draft: CP, KH Writing – review & editing: KH, CP, EH, RD, DM, AH, JS All authors read and approved the final manuscript.

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Data Availability
The author confirms that all data generated or analysed during this study are included in this published article. The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
The ethics committee of the University of Continuing Education Krems approved the study protocol on October 23, 2023 (number: EK GZ 67/2021–2024). Informed consent was obtained from all individual participants included in the study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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