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META-ANALYSIS

The effectiveness of school-based interventions to reduce problematic digital technology use and screen time: A systematic review and meta-analysis

MARK ŽMAVC[1,2], JANJA HORVAT[1], MAJA ŽIDAN[3] and ŠPELA SELAK[1*]

[1] National Institute of Public Health, Slovenia

[2] Centre for Digital Wellbeing Logout, Ljubljana, Slovenia

[3] University Rehabilitation Institute of Republic Slovenia – Soča, Slovenia

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ABSTRACT

Background and aims: A growing body of evidence suggests that excessive digital engagement can lead to adverse consequences, especially in children and adolescents. Many stakeholders point to prevention in the school environment as one way to mitigate these harms, though their effectiveness is unclear. We conducted a systematic review and meta-analysis to evaluate existing school-based preventive interventions aimed at reducing digital addiction and screen time among individuals aged 6–19 years old. *Methods:* We conducted a comprehensive literature search across various databases, including Web of Science, PubMed, Scopus, PsycINFO, and Google Scholar, to identify relevant studies published between 2013 and 2023, of which 34 met the inclusion criteria. *Results:* The reviewed interventions were particularly effective at reducing measures of problematic digital technology use ($d = 1.47$ after intervention; $d = 1.13$ at follow-up), while being less effective at reducing screen time ($d = 0.15$ after intervention; $d = 0.15$ at follow-up). Interventions which were externally led, actively included parents, targeted at-risk youth or employed a therapy-based approach were more successful at decreasing problematic digital technology use. A slightly larger decrease in screen time was observed in interventions with external leaders, targeting at risk populations and those lasting upwards of three months. *Discussion and Conclusions:* Due to the observed publication bias and modest statistical power within subgroup analyses, more empirical research is recommended to confirm the identified trends. Overall, given the promising results, policymakers should strongly consider exploring possibilities of systemic inclusion of digital addiction interventions within the school curriculum.

KEYWORDS

problematic digital technology use, digital addictions, screen time, school-based, interventions, systematic review, meta-analysis, prevention

INTRODUCTION

Digital technology use and digital addictions in children and adolescents

Use of digital technologies (DT) is on the rise, with smartphone ownership across the world doubling from 2016 to 2023 (Ericsson Mobility Visualizer, 2023). This was accompanied by more time spent in front of a screen, especially during the COVID-19 pandemic, with adolescents' social media use skyrocketing from 2–3 h before the pandemic to 5–10 h during it (Ellis, Dumas, & Forbes, 2020). A recent meta-analysis of 507 studies in the field of digital addiction (Meng et al., 2022) estimated the global prevalence rate of smartphone addiction to be 27%, 17% for social media addiction, 14% for internet addiction, and 6% for gaming addiction.

*Corresponding author.
E-mail: spela.selak@nijz.si

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Excessive DT use has been linked to various negative outcomes, especially in children and adolescents. A scoping review found associations between excessive social media use and depression, cyberbullying, psychological problems, poor sleep, hyperactivity and inattention, body image issues, low physical activity, problems with sight, headaches, and dental caries (Bozzola et al., 2022). Excessive screen time has been associated with various physical health effects such as poor sleep, obesity, poor stress regulation, as well as psychological effects such as depressive symptoms, ADHD-related behavior, and poor social coping (Lissak, 2018). Excessive mobile phone use has been associated with feelings of insecurity, impaired parent-child relationship, low mood, boredom, and behavioral problems among children and adolescents (Sahu, Gandhi, & Sharma, 2019). Anxiety, ADHD, social phobia, and obsessive-compulsive symptoms have been linked to internet gaming disorder (González-Bueso et al., 2018). Lastly, Internet addiction was correlated to drinking, smoking, and suicidal behavior among adolescents (Wang et al., 2022).

Prevention in the school environment

Children and adolescents are ideal candidates for preventive interventions as they are in their formative years with their values, identity, and habits still developing (Vondráčková & Gabrhelík, 2016). The school environment can offer opportunities for raising awareness among students about the consequences of excessive internet usage and provide them with alternate activities and coping strategies (Chemnad et al., 2023; Lopez-Fernandez & Kuss, 2020). School-based interventions have the advantage of being accessible to the majority of children and adolescents, and can also target potentially vulnerable groups (Lindenberg, Kindt, & Szász-Janocha, 2020). Interventions can be aimed at particular age groups, in which problematic internet use begins to occur (Lindenberg et al., 2020) and can be adapted based on typical online behaviors within each age group (Csibi, Griffiths, Demetrovics, & Szabo, 2021). School-based interventions have been shown to be effective in reducing body mass index in adolescents (Jacob et al., 2021), obesity in children (Gonzalez-Suarez, Worley, Grimmer-Somers, & Dones, 2009), preventing and reducing mental health problems (Grande et al., 2023) including depression and anxiety (Zhang, Wang, & Neitzel, 2023), as well as preventing substance abuse (Das, Salam, Arshad, Finkelstein, & Bhutta, 2016; Tinner et al., 2022).

Previous literature reviews

To our knowledge, two previous reviews in the digital addictions field also focused on school-based preventive interventions, one targeting internet addiction and gaming (Throuvala, Griffiths, Rennoldson, & Kuss, 2019) and the other targeting screen time (Throuvala, Griffiths, Rennoldson, & Kuss, 2021), both focusing only on adolescents. The former described effect sizes for seven studies, showing mixed effectiveness, with authors identifying the following limitations: variety in measured outcome, the use of time spent on the internet/gaming as the outcome, and methodological limitations of the included studies. The review focusing on screen time also yielded mixed results regarding effectiveness. Here, interventions targeting screen time in parallel with other developmental, contextual, and motivational factors showed the most promise. Other reviews typically focused on describing the interventions without exploring the role of their characteristics and usually included both preventive and treatment interventions (Cañas & Estévez, 2021; Ding & Li, 2023).

A recent narrative review showed that the types of intervention studies being published have changed over time, with internet addiction and internet gaming addiction being popular targets since 2010, whereas smartphone and social media addiction have mostly been researched after 2015 (Cemiloglu, Almourad, McAlaney, & Ali, 2022). Overall, despite the existence of multiple systematic reviews of interventions aiming to prevent digital addiction in childhood, much remains unknown regarding factors contributing towards the effectiveness of these interventions.

Purpose of the study

Our systematic literature review and meta-analysis aimed to thoroughly assess and evaluate existing school-based preventive interventions designed to reduce problematic (i.e., excessive, addictive or otherwise harmful) DT use or screen time among children and adolescents aged 6 to 19. Our intention was to evaluate the effectiveness of all interventions using the same effect-size measure while using a meta-analytical approach to draw conclusions regarding which intervention characteristics are more likely to lead to reduction in chosen measures of DT use. The present study provides a necessary overview and insight into the effectiveness of school-based interventions in field of DT use. Additionally, we address the literature gap by expanding the age range of participants and the range of problematic DT uses beyond internet or gaming addiction, while narrowing the interventions to be school-based and preventive only.

METHOD

This review used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol (Page et al., 2021).

Eligibility criteria

Included studies had to meet the inclusion criteria agreed upon by all authors prior to the screening process and are presented in Table 1, such as the population, intervention, comparison group, outcome, context (the PICOC approach; Mengist, Soromessa, & Legese, 2020) and others.

Information sources

The following databases were searched for the purpose of this review: Web of Science, PubMed, Scopus, PsycINFO

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Table 1. Inclusion and exclusion criteria based on the PICOC approach

	Inclusion criteria	Exclusion criteria
Population	Children and adolescents attending school aged 6–19 years	Interventions which also include other populations
Intervention	Intervention must contain topics related to problematic DT use; One of the purposes of the intervention must be related to preventing problematic DT use or reducing screen time	Interventions using a pharmacological approach; Interventions that use DTs as means for prevention in other areas (e.g. drug use); Intervention exclusively about cyberbullying, gambling and/or cyber safety
Comparator	Control group which is not receiving the target intervention (no intervention, placebo intervention, or wait list)	Studies not including a control group
Outcomes	At least one measured and reported outcome has to be a measure of problematic DT use or screen time	Studies including only attitude measures or digital literacy measures
Context	Interventions are conducted within the school environment, at least in part	Interventions fully conducted outside of the school environment
Study design	Randomized control trials (and their variations), quasi-experiments	Papers describing only the protocol of the study or its preliminary results; All other study designs.
Language	Full text must be in English	All other languages
Publication type	Peer-reviewed empirical scientific papers	All other publication types; Papers inaccessible to authors
Publication time frame	1st of January 2013 - 28th of July 2023	Papers published before 2013

Note. DT = digital technology.

and Google Scholar. Due to a large number of hits on Google Scholar, only the first 200 were screened. The most recent search on all databases was conducted on the 28th of July 2023.

The search strategy

The final search string contained keywords sorted into five categories based on the PICOC framework. Each PICOC category could be represented by various keywords (presented in Table 2) separated by the Boolean operator OR, while the categories were separated by the Boolean operator AND. Research papers on our search topic were screened for

Table 2. PICOC framework for search strategy and search strings for databases

PICOC concept	Keywords
Population	(child* OR adolescent* OR teenage* OR youth* OR student*)
Intervention	(prevent* OR intervention OR policy OR curriculum OR program*)
Comparison	(evaluat* OR control* OR compar* OR effect* OR evidence-based)
Outcome	("internet addiction" OR "digital media use" OR "internet use" OR "media use" OR "digital addiction")
Context	(school* OR classroom* OR "school-based")

the most frequently used keywords in the title, abstract, and keywords sections before developing our search string. Additionally, we scanned the records obtained from our search string and adjusted the search string accordingly. The adjustments consisted mainly of adding or removing keywords for each concept, as well as adjusting the existing keywords. After several adjustments, we arrived at a final search string that produced a reasonable quantity of what appeared to be pertinent publications across all the databases. Because of the character limit in Google Scholar, we opted for a search string consisting of the most frequently used keywords related to our research topic. In each database the final search string was applied only to titles and abstracts of published records, with the exception of Google Scholar, since it has no such filter. Additionally, a filter for publishing date (1st of January 2013 - 28th of July 2023) was added to all searches. Both versions of search strings were developed by the authors of the paper with backgrounds in psychology and psychometrics.

Selection process

The selection process was conducted independently by two authors. After excluding the duplicates and records in foreign languages with the help of the Rayyan platform (Rayyan, n.d.) each record title was screened for eligibility based on the inclusion/exclusion criteria. If eligibility was not obvious based on the title alone, the abstract was read in detail. If there was still uncertainty, the record was included in the full-text reading. If any dilemmas have arisen in regard to a particular record, it was discussed and resolved among all four authors.

During the title screening process, we looked for phrases related to DT addictions (e.g. internet overuse, problematic smartphone use, gaming disorder) or use of DTs (e.g. internet use, screen time, gaming) among children or adolescents. If the title contained phrases such as "adolescents", "children", "kids", "teenagers", in addition to mentioning an intervention or program related to DT use, the record was included in the full-text reading without abstract screening. If a study sample included participants that were just partially within our age group (e.g. adolescents and young adults), the study was not included into our review. If the target population mentioned in the title was ineligible, such

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as “college students,” “young adults,” “adults,” or “preschool children,” the record was excluded without abstract screening. If the term “meta-analysis” or “review” appeared in the study title, it did not meet our criteria for study design and was therefore excluded. Titles referring to pharmacological treatment were also not included in the further screening process. When screening publication titles for relevant keywords, the Rayyan platform was used for highlighting them, but the decision for inclusion/exclusion was still made by the authors.

During the full-text reading process, we excluded papers not describing randomized control trials or quasi-experiments and did not meet our age and publication type criteria. Additionally, we excluded records that were not relevant to our field of research, unavailable in full-text, written in a foreign language, did not include the school environment or reported irrelevant outcomes. Lastly, studies for which did not provide enough data to calculate effect size were excluded.

Data collection process

The data collection process was done by three of the authors independently by reading the full text of selected papers. Additional papers identified as irrelevant during this process were marked and reasons for exclusion were listed. Any disagreements were resolved between all authors. For the purpose of systematic data collecting Google Spreadsheets was used.

Data items

Collected data items included study authors, year of publication, country, sample size, intervention leader, parent inclusion, target population, theoretical approach, duration of intervention, and effectiveness (reduction in problematic use or screen time measures).

Risk of bias assessment

Two different versions of the JBI (Joanna Briggs Institute) tool (JBI Critical Appraisal Tools, n.d.) were used for risk of bias (RoB) assessment: one for quasi-experiments - The JBI critical appraisal tool for the assessment of risk of bias for quasi-experiments (Tufunaru, Munn, Aromataris, Campbell, & Hopp, 2024) and one for randomized control trials - The revised JBI critical appraisal tool for the assessment of risk of bias for randomized controlled trials (Barker et al., 2023). Domains were assessed based on a pre-agreed scale of low, moderate, high and critical bias. If information regarding certain domains was unclear, bias was automatically assessed as high. The domains of bias assessments were summarized into the internal validity grade according to the following criteria: (1) Validity cannot be high if there is one or more RoB assessed as moderate or higher. (2) If one of RoB is assessed as critical, internal validity can only be low. (3) If there is an even split between two assessment ranks, internal validity can only be as high as the lower of the two. Additionally, statistical conclusion validity was assessed for both study types and coded as low, moderate or high according to the JBI tools. Two of the authors assessed risk of bias independently with any inconsistencies being debated amongst themselves and consulting the third author when needed.

Effect measures

To compare intervention effectiveness, standardized mean difference (commonly known as Cohen’s d) was manually calculated for each relevant outcome of each study which provided the necessary data to do so. Specifically, an effect size based on the mean pre-post change in the treatment group minus the mean pre-post change in the control group, divided by the pooled pretest standard deviation, was used, according to recommendations (Morris, 2008). Missing data on any items was reported as such.

Synthesis measures

Firstly, outcome measures reported in the included studies were separated to problematic use (including various measures of digital addiction symptoms and harmful patterns of DT use) and screen time (various measures of quantity of DT use, typically reported by device or technology). Effect sizes were calculated for each relevant outcome in a particular study. If a study reported on more than one outcome of a certain type (e.g. smartphone use, videogame playing time, reported separately on week days and weekends) individual effect sizes were averaged out to obtain a single estimate of “effect on screen time outcomes” or “effect on problematic use outcomes”. The results are present separately for the first group of interventions aiming to reduce problematic DT use ($n = 24$) and the second group of interventions aiming to reduce screen time ($n = 12$).

All statistical analyses in this paper were conducted using R Studio (R Core Team, 2021) and the relevant CRAN packages. We utilized the *metafor* package (Viechtbauer, 2010) to synthesize individual effect sizes using a random-effects model (REM), and to visualize the results. The same package was used in sensitivity analyses. Other plots or figures were generated with the *ggplot2* package (Wickham, 2016). Heterogeneity among study results was assessed through subgroup analysis using the *meta* package (Schwarzer, Carpenter, & Rücker, 2015).

Reporting bias assessment

The possibility of publication bias was explored using funnel plot analysis via the *meta* package. We also utilized Egger’s test for funnel plot asymmetry, PET (Precision-Effect Test) and PEESE (Precision-Effect Estimate with Standard Error) analyses (Stanley & Doucouliagos, 2014), all available through the *metafor* package.

Certainty assessment

Studies were grouped based on their evaluation of low, moderate or high internal and conclusion validity indicated by the RoB assessment. We examined whether study quality (i.e. risk of bias) affected intervention effectiveness through subgroup analyses.

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RESULTS

Study selection

The number of potentially relevant records identified through the literature search was 4,527 (1,439 in Web of Science, 1,810 in Scopus, 603 in PubMed, 475 in PsycINFO and 200 in Google Scholar). After the exclusion of duplicate entries, 2,591 records were screened via title and abstract. Ninety-two records were identified as possibly relevant, and after excluding four records which could not be retrieved, the remaining 88 were read in full. After the exclusion of the records due to reasons listed in Fig. 1, 34 relevant records were identified and included in the review (eight in Web of Science, nine in Scopus, five in PubMed, eight in PsycINFO and four in Google Scholar).

Study characteristics

The majority of research stemmed from Asia (65%), some from Europe (21%), with a small number coming from Australia (12%), and America (3%). Among the included papers 21% were published in 2018, followed by 18% in 2023, 12 % both in 2019, 2020 and 2022, 6% both in 2014, 2016, 2017 and 2021, and 3% in 2015. Of the 34 included studies, 15 targeted children (aged 6–12 or up to 6th grade), 11 targeted adolescents (aged 13–19 or 7th grade and above), and eight included participants spanning both age groups. The sample sizes of experimental groups were on a broad spectrum, ranging from 12 to 3610, with an average of 297 and a median of 100. Statistics related to other characteristics are included under Subgroup analysis. Table 3 describes key characteristics of reviewed interventions.

Intervention effectiveness

Meta-analysis and related statistical analysis were performed separately for two groups of interventions, depending on the measured intervention outcomes. The first group consists of interventions aimed to decrease adolescents' "problematic digital technology use", and utilized various measures of addiction symptoms and harmful patterns of DT use. The second group consisted of interventions aimed at decreasing adolescents' "screen time", and utilized various measures of quantity of DT use, typically reported by device or technology. The majority of included studies (n = 31, 91%)

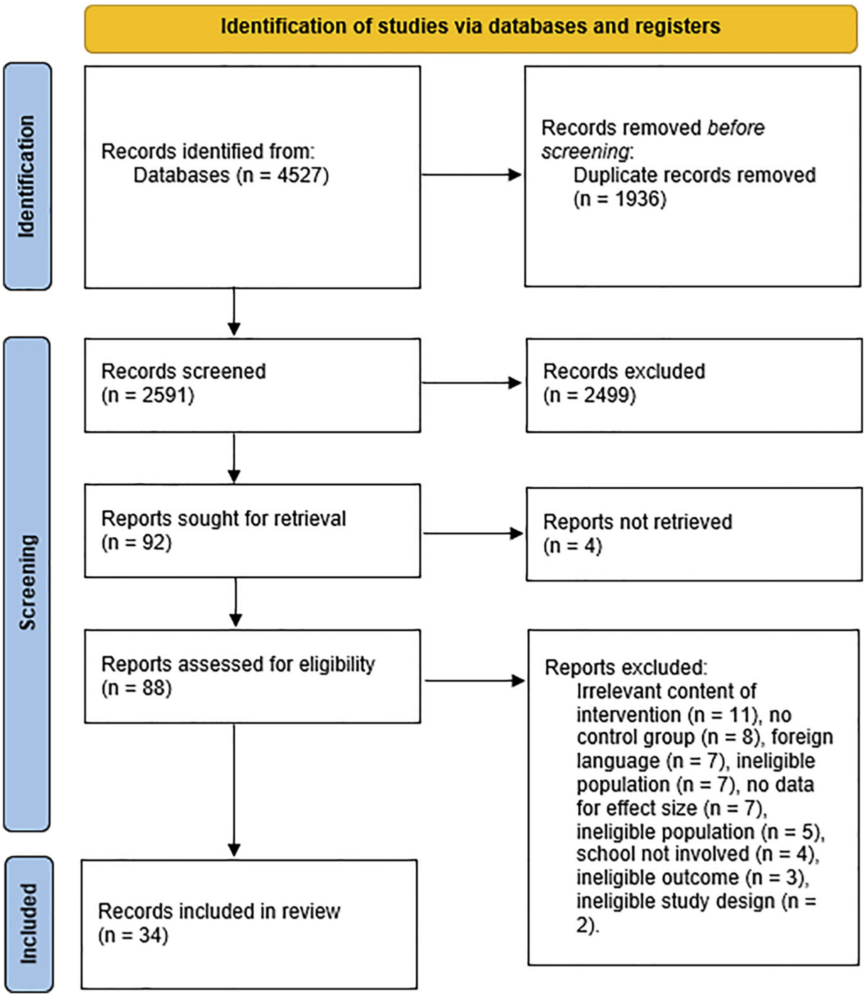

Fig. 1. PRISMA flow diagram

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Table 3. Overview of key characteristics of reviewed interventions

Authors	Year	N	Leader	Parents	Target population	Approach	Duration	Internal Validity	Conclusion Validity	Effect size (Problematic use)	Effect size (Screen time)
Bergh et al.	2014	510	Internal	No	General	Other	>3 months	Moderate	High	–	0.07
Smith et al.	2014	181	External	No	At-risk	Other	>3 months	Moderate	High	–	0.18
Vik et al.	2015	1569	Internal	No	General	Other	1–3 months	Low	Moderate	–	0.00
Berber Çelik	2017	15	External	No	At-risk	Therapy-based	1–3 months	High	Moderate	1.41	–
Lubans et al.	2016	181	External	No	At-risk	Other	>3 months	Moderate	Moderate	–	0.34
Babic et al.	2017	150	External	No	At-risk	Other	>3 months	Moderate	High	–	0.45
Li et al.	2017	398	External	No	General	Therapy-based	>3 months	Moderate	High	0.62	–
Apisitwasana et al.	2018	148	Internal	Yes	General	Other	1–3 months	Moderate	High	0.82	–
Bickham et al.	2018	143	Internal	No	General	Other	1–3 months	Low	High	–	0.25
Fiseha et al.	2020	51	External	No	General	Other	<1 month	Low	Moderate	2.77	–
Manwong et al.	2018	125	External	No	General	Other	1–3 months	Low	High	0.07	0.23
Taş & Ayas et al.	2018	12	External	No	At-risk	Therapy-based	>3 months	High	Moderate	1.08	–
Uysal & Balci et al.	2018	41	Internal	Yes	At-risk	Other	1–3 months	Moderate	Moderate	0.96	–
Yang & Kim et al.	2018	38	Internal	No	General	Other	1–3 months	Moderate	Moderate	1.64	3.18
Bonnaire et al.	2019	190	External	No	General	Other	<1 month	Moderate	High	–	0.00
Gholamian et al.	2019	60	External	Yes	At-risk	Other	<1 month	Moderate	High	3.28	–
Khoshgoftar et al.	2019	56	External	No	General	Other	>3 months	Moderate	High	0.56	–
Li et al.	2019	163	External	Yes	General	Other	<1 month	Low	Moderate	0.09	0.09
Choi et al.	2020	24	External	No	General	Other	1–3 months	Moderate	Moderate	0.44	–
Mathew et al.	2020	30	External	Yes	At-risk	Therapy-based	1–3 months	Moderate	Low	1.61	–
Pearson et al.	2020	25	External	Yes	General	Other	1–3 months	Moderate	Moderate	–	0.04
Zamanian et al.	2020	32	External	Yes	At-risk	Other	–	Moderate	Low	0.75	–
Boor Boor et al.	2021	16	External	Yes	General	Other	–	Moderate	High	3.04	–
Ortega-Barón et al.	2021	120	Internal	No	General	Other	–	Low	High	0.72	–
Agbaria	2023	80	External	No	At-risk	Therapy-based	1–3 months	Low	High	2.46	–
Bağatarhan et al.	2022	13	–	Yes	At-risk	Therapy-based	–	Moderate	Moderate	2.41	–
Haug et al.	2022	688	–	No	General	Other	>3 months	Moderate	High	0.25	–
Lindenberg et al.	2022	167	External	No	At-risk	Therapy-based	<1 month	Moderate	High	0.29	–
Akgül-Gündogdu et al.	2023	64	External	Yes	At-risk	Therapy-based	1–3 months	Moderate	High	4.67	–
Avci et al.	2023	309	Internal	No	General	Other	<1 month	Moderate	High	0.96	–
Champion et al.	2023	3610	Internal	No	At-risk	Therapy-based	1–3 months	Low	High	–	0.07
Kor & Shoshani et al.	2023	833	Internal	No	General	Other	>3 months	Moderate	High	–	0.22
Kumkronglek et al.	2023	24	External	No	General	Therapy-based	1–3 months	Low	Moderate	1.59	–
Şermet Kaya et al.	2023	22	External	Yes	At-risk	Therapy-based	>3 months	Moderate	Low	3.78	–

Note: d = effect size estimate, calculated as Cohen's d (i.e., 0.2 = small, 0.5 = medium, 0.8 = large effect; Cohen, 1988).

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measured only one outcome and were thus included in only one of the groups. Three studies (Li, Chau, & Cheng, 2019; Manwog et al., 2018; Yang & Kim, 2018) measured both outcomes and were considered in both groups, however Yang & Kim had to be removed from the screen time group based on sensitivity analysis. This left 24 interventions in the group measuring problematic digital technology use and 12 in the group measuring screen time.

Problematic digital technology use. Overall, school-based interventions significantly and substantially decreased problematic DT use in children and adolescents *(d* = 1.472, *SE* = 0.253, *z* = 5.820, *p* < 0.001, *95% CI*: 0.976–1.968). Notably, the heterogeneity statistics indicate large heterogeneity between interventions ($Q(23) = 599.546$, $p < 0.001$, $\tau^2 = 1.453$, *SE* = 0.452). The I^2 value of 98.5% further suggests that most of the observed variance in effect sizes across interventions is due to real differences in effect sizes rather than sampling error. Looking at the forest plot (Fig. 2), some interventions reported very high effect sizes (up to *d* = 4.67), while no single study reported negative effects.

Of the 24 studies reporting problematic DT use outcomes of school-based interventions, 11 also provided the follow-up data, e.g. three months after intervention finished. The follow-up effect of these interventions was still significant and substantial, though smaller than before (*d* = 1.133, *SE* = 0.358, *z* = 3.168, *p* = 0.002, *95% CI*: 0.432–1.834).

Screen time. On the other hand, school-based interventions produced a modest but significant decrease in adolescents' screen time (*d* = 0.149, *SE* = 0.040, *z* = 3.744, *p* < 0.001, *95% CI*: 0.071–0.227). Again, the heterogeneity statistics indicate substantial heterogeneity between interventions ($Q(11) = 34.673$, $p < 0.001$, $\tau^2 = 0.011$, *SE* = 0.008). The I^2 value of 73.84% suggests moderate to high variability among interventions according to criteria by Higgins and colleagues (Higgins, 2003). Looking at the forest plot (Fig. 3), it is apparent that the interventions differ significantly less in terms of their effectiveness compared to those in Fig. 2, as the individual effect sizes and confidence intervals are all situated within *d* = 1.2.

Of the 12 studies reporting screen time outcomes of school-based interventions, four also provided follow-up data. The follow-up effects of these interventions were similar in size, though not statistically significant (*d* = 0.145, *SE* = 0.092, *z* = 1.578, *p* = 0.1146, *95% CI*: −0.035–0.324).

Sensitivity analysis

A sensitivity analysis was conducted to assess the robustness of meta-analyses results by sequentially excluding each study and recalculating the overall effect size. In the first group of

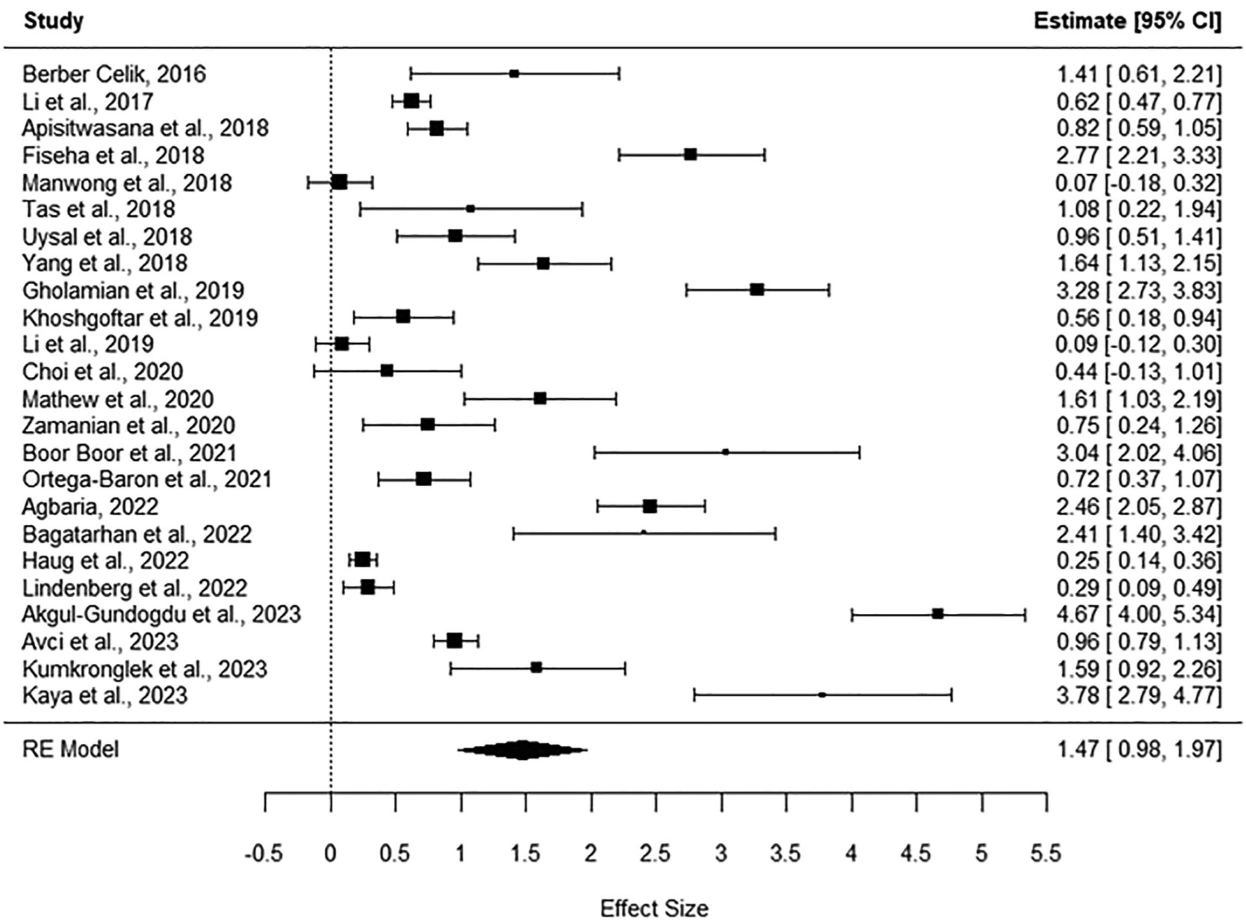

Fig. 2. Forest plot of interventions aimed at decreasing problematic DT use

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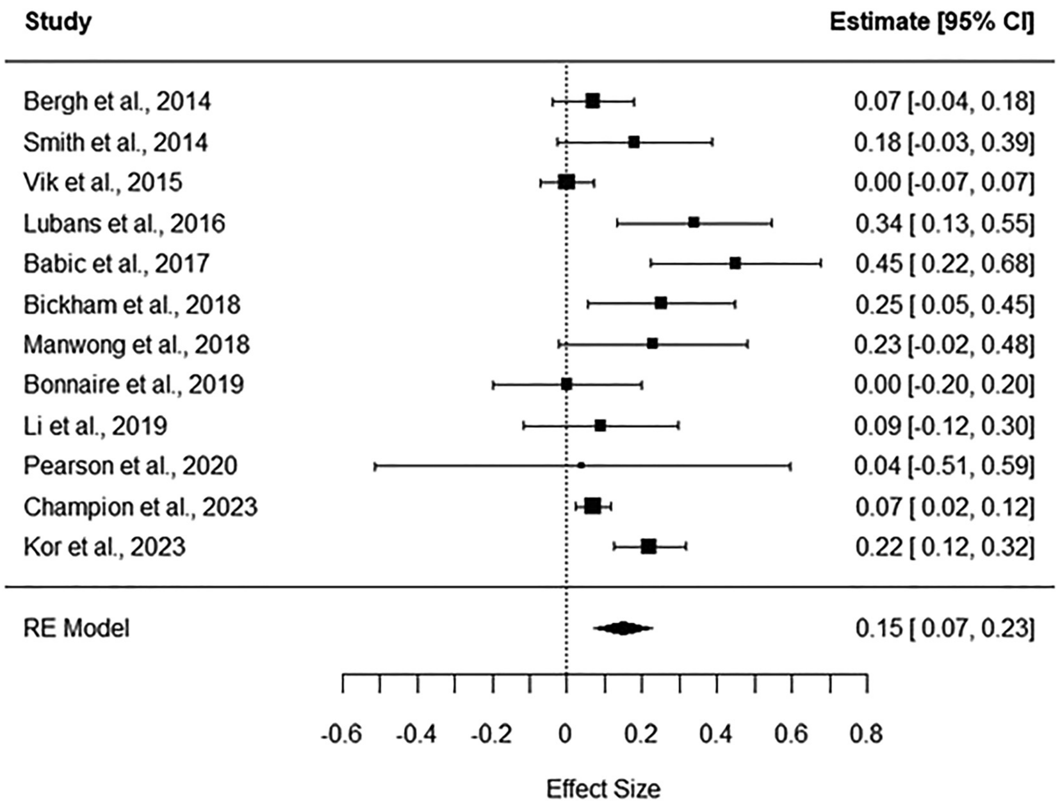

Fig. 3. Forest plot of interventions aimed at decreasing screen time

studies, the overall effect sizes remained stable, indicating the robustness of the results. The study by Akgül-Gündoğdu and Selçuk-Tosun (2023) emerged as a potentially influential study with very high effect size (d = 4.67), showing some impact on the overall effect size. Since its outlier statistics were not extreme ($R_{student}$ = 3.059, *Dffits* = 0.690, *Cook's distance* = 0.348) and its statistical conclusion validity was high, we decided to retain the study in the analysis. In the second group of studies, however, the study by Yang and Kim (2018) clearly stood out, being the only one with very high effect size (d = 3.18). Figure 4 shows how excluding the study in question considerably lowers the overall effect estimate (from d = 0.360 to d = 0.149) and reduces variability among studies (from SE = 0.2035 to SE = 0.040). Due to its

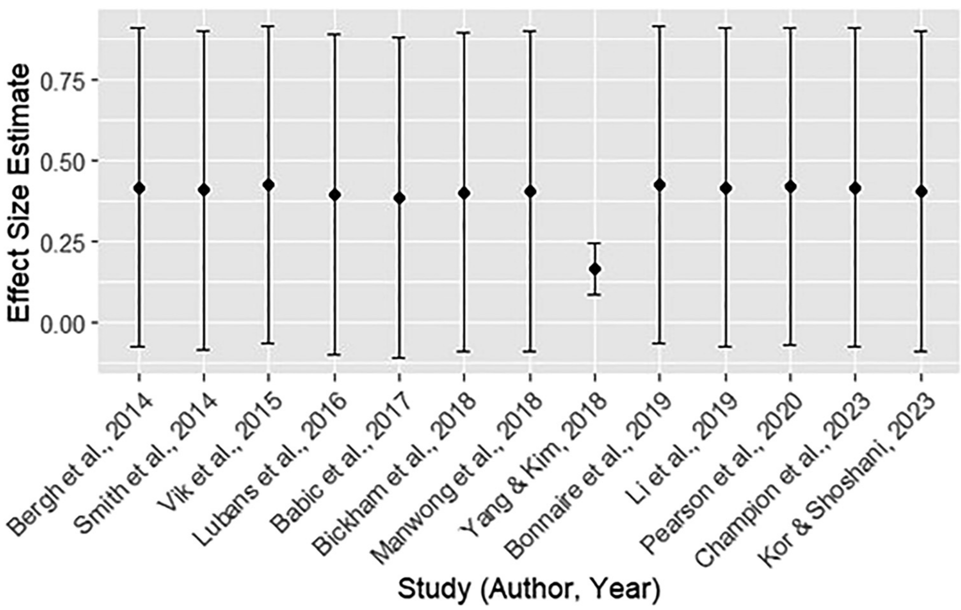

Fig. 4. Impact of study exclusion on the overall effect size estimate for the second group of studies

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large impact on the overall results and the extreme values of outlier statistics ($R_{student}$ = 8.495, *Dffits* = 2.322, *Cook's distance* = 1.071), we decided to exclude the study from further analysis (Note: Since the Yang & Kim, 2018 study reported on problematic use measures as well, it is still included in the first group of studies).

Publication bias assessment

The funnel plot for the first group of studies, showing the relationship between study size and effect size, is depicted in Fig. 5. There is noticeable asymmetry in the plot, specifically the gap indicating a lack of studies reporting below-average effect sizes on small samples, which could be due to publication bias. Confirming this visual assessment, Egger's test for funnel plot asymmetry returns a significant value (t = 4.510, df = 22, p < 0.001), suggesting that smaller studies more likely report larger effect sizes.

In addition, PET analysis showed a significant relationship between the effect size and the standard error (p < 0.001). The PEESE model provides an adjusted estimate of the true effect size, accounting for publication bias (Stanley & Doucouliagos, 2014). The estimated adjusted effect size is substantially lower; 0.694 (*95% CI*: 0.128–1.260), though still significant.

Conversely, the funnel plot for the second group of studies (Fig. 6) does not seem to show major asymmetry. Egger's regression test does not show statistically significant asymmetry (t = 1.978, df = 10, p = 0.076). Similarly, PET analysis fails to show a significant correlation between effect size and standard error. The adjusted estimate of the true effect size, accounting for publication bias, is only slightly lower than originally, (d = 0.131, *95% CI*: 0.037–0.225), according to the PEESE model.

Risk of bias

We used the JBI appraisal tools to evaluate a total of 17 randomized controlled trials and 17 quasi-experimental studies. For the randomized controlled trials, we found that 71% exhibited moderate internal validity, while 29% demonstrated low internal validity. Additionally, 59% achieved high (statistical) conclusion validity, 24% exhibited moderate conclusion validity, and 18% had low conclusion validity. Regarding the quasi-experimental studies, 65% displayed moderate internal validity, 24% exhibited low internal validity, while 12% demonstrated high internal validity. In terms of (statistical) conclusion validity among the quasi-experimental studies, 53% achieved high

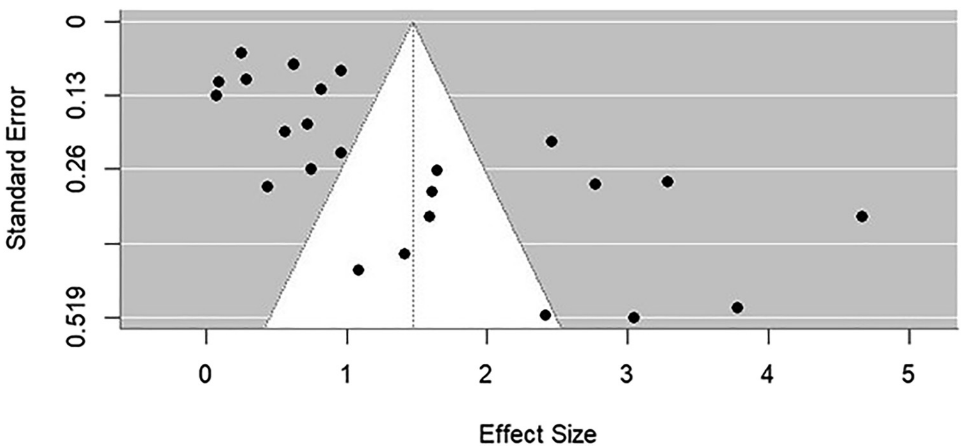

Fig. 5. Funnel plot showing the effects of the first group of studies (n = 24) in relation to study size (or standard error)

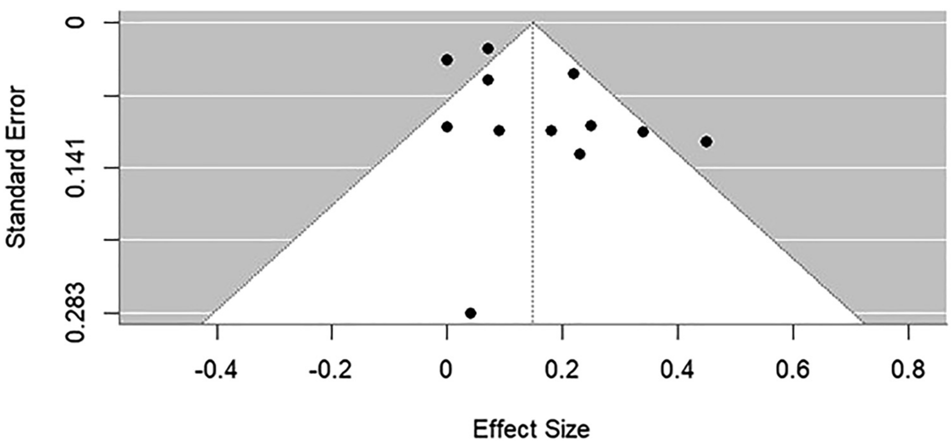

Fig. 6. Funnel plot showing the effects of the second group of studies (n = 12) in relation to study size (or standard error)

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conclusion validity, and 47% exhibited moderate conclusion validity. Detailed information regarding the assessment of risk of bias is available in Appendix (risk of bias of randomized control trials is presented in Table A1 and Fig. A1 and of quasi-experiments in Table A2 and Fig. A2).

To determine whether study quality played any part in effect size estimates, internal validity and conclusion validity were included as predictors of effect sizes as part of the subgroup analyses (see below; Tables 4 and 5). According to statistics provided, only the effect of internal validity of second-group studies on effect size could be argued for (had statistical power improved). In this case however, studies of lower quality reported smaller (rather than larger) effects. Thus, the observed intervention effects (on both problematic use and screen time) are likely not due to low study quality.

Subgroup analysis

Table 4 shows the results of subgroup analysis for interventions targeting problematic use outcomes. Judging by effect size differences and the Q statistic, variables Leader, Parents, Population and Approach display substantial subgroup differences, while Duration does not. Although the

Table 4. Subgroup analysis for the first group of interventions (outcome = problematic use)

			Effect size estimate			Heterogeneity	Subgroup differences	
Moderator	Subgroup	*k*	*d*	Lower *95% CI*	Upper*95% CI*	I^2 (%)	*Q*	*p*
Leader	Internal leader	5	0.966	0.735	1.198	59.2	3.56	0.059
	External leader	17	1.646	0.979	2.314	96.8		
Parents	Parents included	10	2.104	1.153	3.055	97.2	4.02	0.045
	Parents not included	14	1.035	0.601	1.470	94.7		
Population	General	13	0.987	0.505	1.469	94.1	4.72	0.030
	At risk	11	2.043	1.221	2.865	96.8		
Approach	Therapy based	10	1.965	1.108	2.821	96.8	2.59	0.108
	Non-therapy based	14	1.129	0.579	1.679	95.6		
Duration	<1 month	5	1.458	0.186	2.729	98.0	0.23	0.890
	1–3 months	10	1.553	0.762	2.344	96.2		
	>3 months	5	1.199	0.002	2.396	93.8		
Internal validity	Low	6	1.265	0.32	2.209	97.3	0.60	0.742
	Moderate	16	1.587	0.919	2.254	96.3		
	High	2	1.256	0.672	1.841	0.0		
Conclusion validity	Low	3	2.003	0.271	3.735	93.1	0.51	0.774
	Moderate	9	1.340	0.761	1.919	93.5		
	High	12	1.446	0.615	2.277	97.4		

Note: k = number of studies, d = effect size estimate, calculated as Cohen's d (i.e., 0.2 = small, 0.5 = medium, 0.8 = large effect; Cohen, 1988).

Table 5. Subgroup analysis for the second group of interventions (outcome = screen time)

			Effect size estimate			Heterogeneity	Subgroup differences	
Moderator	Subgroup	*k*	*d*	Lower *95% CI*	Upper *95% CI*	I^2 (%)	*Q*	*p*
Leader	Internal leader	5	0.105	0.018	0.193	75.4	1.53	0.216
	External leader	7	0.203	0.076	0.330	49.0		
Parents	Parents included	2	0.084	−0.110	0.278	0.0	0.47	0.491
	Parents not included	10	0.159	0.072	0.245	74.0		
Population	General	8	0.109	0.026	0.192	61.2	1.72	0.190
	At risk	4	0.238	0.064	0.412	81.7		
Approach	Therapy based	1	0.070	0.022	0.118	–	3.32	0.068
	Non-therapy based	11	0.160	0.075	0.250	69.7		
Duration	<1 month	2	0.043	−0.101	0.187	0.0	4.42	0.110
	1–3 months	5	0.092	−0.008	0.193	52.1		
	>3 months	5	0.231	0.107	0.355	67.0		
Internal validity	Low	5	0.087	0.003	0.172	52.6	2.04	0.154
	Moderate	7	0.192	0.076	0.308	61.8		
	High	–	–	–	–	–		
Conclusion validity	Low	–	–	–	–	–	0.22	0.640
	Moderate	4	0.117	−0.059	0.292	68.4		
	High	8	0.163	0.077	0.250	67.1		

Note: k = number of studies, d = effect size estimate, calculated as Cohen's d (i.e., 0.2 = small, 0.5 = medium, 0.8 = large effect).

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associated p-values may indicate these effects are hardly significant, Cuijpers, Griffin, and Furukawa (2021) note that subgroup analyses often suffer from lack of statistical power, and thus should not rely on p-values for evaluating intergroup variability. Lastly, high proportions of heterogeneity indicate that even within subgroups the effectiveness of interventions varies significantly.

Table 5 shows the results of subgroup analysis for the second group of interventions, which aimed to reduce screen time outcomes. Due to fewer studies (and even lesser statistical power) and generally smaller effect sizes among these interventions, we resort to judging the relative differences between effect sizes of subgroups. For variables Leader, Parents, Population, and Duration, effect size estimates of one subgroup outperform the other subgroup(s) by a factor of two. The heterogeneity within subgroups of these interventions is moderate to high.

Intervention leader. Interventions aimed at decreasing adolescents' problematic DT use were led more commonly by external intervention leaders (e.g. research team, psychologists; 77%) and sometimes by internal leaders (e.g. teachers, school nurses; 23%). In terms of their effectiveness, interventions led by external leaders were more effective in reducing problematic use ($d = 1.646$) compared to interventions led by internal providers ($d = 0.966$). The second group of interventions were more evenly distributed in terms of leaders (58% external, 42% internal). Again, interventions led by external leaders displayed slightly higher effects on screen time, on average.

Parent inclusion. Less than half of all interventions in the first group planned to actively include parents in the implementation of interventions. Those which did, however, yielded a bigger reduction in adolescents' problematic DT use ($d = 2.104$) than those which did not ($d = 1.035$). Conversely, the two out of twelve interventions aimed at reducing screen time that actively included parents, yielded a smaller reduction in screen time ($d = 0.084$) compared to other ten ($d = 0.159$).

Target population. Interventions could also be categorized according to their target population. In the first group, 13 interventions were targeting the general population of children and adolescents (i.e. universal prevention) while 11 interventions targeted populations at risk (i.e. indicated or selective prevention). The latter were more successful in reducing problematic DT use ($d = 2.043$) than the former ($d = 0.987$). In the second group, interventions aimed at reducing screen time were more commonly intended for the general population (67%), although interventions intended for at-risk groups were still more effective ($d = 0.238$ versus $d = 0.109$).

Intervention approach. A common distinction between interventions was whether their methods to reducing negative outcomes were based on psychotherapy-related paradigms and theories (e.g. cognitive-behavioral therapy), or instead, on theories and concepts not explicitly associated with psychotherapy (e.g., social cognitive theory, self-determination theory). Ten out of 24 interventions aimed at reducing problematic DT use could be classified as therapy-based – these interventions were more successful ($d = 1.965$) than their counterparts from various theoretical backgrounds ($d = 1.129$). Within interventions aimed at reducing screen time, only one out of twelve employed a therapy-based approach.

Intervention duration. Most interventions consisted of activities and sessions over multiple days, weeks or months. For the first group of interventions, longer duration did not seem to be related to effect size, since interventions shorter than one month yielded similar results ($d = 1.453$) to those lasting up to 3 months ($d = 1.553$), while interventions lasting beyond 3 months displayed a slightly lesser effect ($d = 1.199$). On the other hand, the duration of screen time interventions seemed to contribute to their effectiveness, since the subgroup of interventions lasting beyond 3 months clearly outperformed the other two ($d = 0.231$).

DISCUSSION

Overall, school-based interventions were shown to be highly effective in reducing problematic DT use among children and adolescents. The substantial effect size observed in our meta-analysis emphasizes the potential of interventions to address and mitigate issues related to excessive or harmful use of DTs within the school environment. Importantly, the positive effects of these interventions appear to persist to a large degree in follow-up measurements, according to the available data. Some caution should be taken before interpreting these optimistic results, as our analysis indicated that small-sample studies in our review reported significantly higher effect sizes on average – a potential indicator of publication bias. An alternative reason may have been that researchers implementing interventions on a smaller scale could afford more attention to detail, more resources or a more personalized approach compared to larger studies, resulting in better intervention outcomes. While the effect size estimate corrected for potential publication bias was distinctly lower, it could still be interpreted as moderate to high. Encouragingly, risk of bias analysis showed an overall acceptable levels of statistical conclusion validity, while study quality did not exhibit a significant impact on intervention effectiveness.

Conversely, school-based interventions aimed at reducing screen time in the population of children and adolescents, showed a rather modest, yet significant effect. The limited data we obtained indicated a similar effect on follow-up measurements. We suggest several potential explanations for the diminished effectiveness of screen time interventions. Firstly, interventions specifically designed to address (digital) addiction symptoms may be more likely to employ evidence-based techniques, commonly used with success in addiction treatment, such as the cognitive-behavioral therapy approach. These techniques target underlying

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psychological and behavioral mechanisms driving addiction and address factors such as compulsive use, cravings and withdrawal symptoms, which are not typically the focus of interventions aimed at reducing screen time (Ding & Li, 2023). Secondly, reducing screen time represents a broader goal that involves changing habits, lifestyle and social norms. Interventions, which are primarily school-based may have a limited impact on external environmental and social factors, such as family dynamics and peer influence. Thirdly, both education and everyday life are becoming increasingly reliant on digital devices which can make a major reduction in screen time impractical for many individuals (Marciano, Camerini, & Morese, 2021). Since screen time is not inherently negative, is only one aspect of problematic DT use (besides content, motives, patterns of use etc.), and is likely quite resistant to change, we advise focusing on more comprehensive goals of school-based interventions.

During the reviewing process we observed that interventions considerably varied in terms of their design, content, approach, duration and other characteristics, which was reflected in a high degree of heterogeneity in their effectiveness. While some interventions indeed performed astonishingly well in reducing problematic DT use, a few showed little to no effect, indicating that much remains to be explored in regards to the role of various intervention characteristics. To address this question, subgroup analysis was conducted, and revealed that interventions led by an external leader, interventions actively including parents, and interventions working specifically with at-risk children, were associated with a larger degree of problematic DT use reduction and screen time reduction. Even so, further research is recommended to confirm these subgroup trends, as the low statistical power prevented firm conclusions.

Practical implications

- Stakeholders interested in considerably reducing students screen time may struggle achieving this through school-based interventions alone. Fortunately, meaningfully preventing and reducing harmful use of digital devices is both the more desirable and the more realistic goal of school-based interventions. Taking the increasing prevalence of excessive DT use among youth into account, policy-makers should strongly consider the possibilities of systemic inclusion of digital addiction interventions in the school curriculum.
- The preference for externally led school-based interventions emphasizes the importance of in-depth familiarity with the topic of digital addiction or problematic use, which may be more important than familiarity with students and school in this context. In cases of internally led interventions, extra time and effort should be devoted to educating leaders.
- Increased effectiveness of interventions including parents in their activities confirms their key role in supporting and encouraging positive behaviors of their children. The extra resources devoted to ensuring parents' active inclusion (beyond receiving educational flyers and e-mails) in digital addiction interventions may be well spent.
- Interventions working specifically with children at-risk, either predisposed to problematic DT use or already showing signs of problematic use, turned out to be highly effective. Forming groups of students based on their risk for problematic use (e.g. after filling out a questionnaire) and administering the interventions only for high-risk students may be a sensible solution, if resources are limited. Nevertheless, if feasible, the general population of students will also substantially benefit from digital addiction interventions.
- Interventions conceptualized around an established psychotherapy paradigm (e.g. cognitive-behavioral therapy) which may incorporate therapeutic techniques could be better suited for addressing the underlying issues associated with problematic DT use than those based on other paradigms. On the other hand, their effectiveness at reducing screen time is yet to be proven.

Limitations

When examining the conclusions of our review, some limitations need to be considered. The trends described above are based on the comparisons between mean effect sizes among subgroups, which are sensitive to outliers at small sample sizes. A related issue is the low statistical power for subgroup analysis, preventing firm conclusion. Secondly, since screen time measures consistently display high levels of interpersonal variability (i.e. high standard deviation), effect size estimates naturally favor measures of problematic use which vary less – for example, decreasing one's screen time by 20% would yield a smaller effect size than decreasing one's problematic DT use score by 20%. This may have led to an underestimation of screen time effect sizes. Thirdly, due to the observed indices of publication bias, as well as substantial heterogeneity between interventions, it is difficult to accurately predict how much effect we can expect from a typical school-based intervention. Lastly, the review was not preregistered and no formal protocol was prepared, which may limit the transparency and reproducibility of the review process.

Conclusions

Given the early age at which children become regular users of digital devices, excessive and otherwise problematic DT use and even digital addiction have become pressing concerns for many school-aged children and adolescents. To this end, school-based interventions aimed at preventing digital addictions can be used with success. According to the present literature review and meta-analysis, school-based interventions can be particularly effective at preventing problematic DT use, while they are evidently less successful at reducing students' screen time. Judging by the available data from peer-reviewed studies, interventions led by external providers (i.e. researchers, psychologists,

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therapists), actively involving parents, targeting at-risk populations, and utilizing a therapy-based approach are more likely to effectively prevent problematic DT use and digital addictions. Considering the potential implied by the data in the present meta-analysis, policy makers should give serious consideration to the systemic inclusion of digital addiction interventions within the school curriculum. Meanwhile, research and practice should continue to examine which characteristics and factors enhance or reduce the effectiveness of interventions aiming to prevent digital addictions.

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Authors' contribution: SŠ and MarŽ prepared the study concept and design, analysis and interpretation of data was done by JH and MajŽ, statistical analysis was performed by MarŽ, all authors had access to the data collected and all contributed to writing the manuscript.

Registration information: This review was not registered and a protocol was not prepared.

Data availability: All data extracted from the included studies can be obtained from the authors upon request.

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Appendix

Table A1. Risk of Bias for randomized controlled trials

Study	Bias related to selection and allocation	Bias related to administration of intervention/ exposure	Bias related to assessment, detection, and measurement of the outcome	Bias related to participant retention	Internal validity	Statistical conclusion validity
Agbaria (2023)	Low	High	High	Low	Low	High
Akgül-Gündoğdu and Selçuk-Tosun (2023)	Low	Low	Moderate	Low	Moderate	High
Babic et al. (2017)	High	High	Moderate	Low	Moderate	High
Champion et al. (2023)	High	Critical	Moderate	Low	Low	High
Haug, Boumparis, Wenger, Schaub, and Paz Castro (2022)	Low	Moderate	Low	Low	Moderate	High
Kor in Shoshani (2023)	Low	High	Low	Low	Moderate	High
Li et al. (2019)	High	Critical	Moderate	Low	Low	Moderate
Lindenberg, Kindt, and Szász-Janocha (2022)	High	High	Moderate	High	Moderate	High
Lubans et al., (2016)	Critical	Moderate	Moderate	Low	Moderate	Moderate
Manwong, Lohsoonthorn, Booranasuksakul, and Chaikoolvatana (2018)	High	Moderate	Moderate	High	Low	High
Mathew, Krishnan, and Bhaskar (2020)	High	Moderate	Moderate	Low	Moderate	Low
Pearson et al. (2020)	High	Moderate	Low	Low	Moderate	Moderate
Şermet Kaya, Seviğ, and Zincir (2023)	Moderate	Moderate	Moderate	Moderate	Moderate	Low
Smith et al. (2014)	High	Moderate	Moderate	Low	Moderate	High
Bergh et al. (2014)	Moderate	Moderate	Low	Low	Moderate	High
Vik et al. (2015)	Critical	Moderate	Moderate	High	Low	Moderate
Zamanian, Sharifzadeh, and Moodi (2020)	Low	Moderate	Moderate	High	Moderate	Low

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Table A2. Risk of bias for quasi-experiments

Study	Bias related to temporal precedence	Bias related to confounding factors	Bias related to administration of intervention/ exposure	Bias related to selection and allocation	Bias related to assessment, detection, and measurement of the outcome	Bias related to participant retention	Internal validity	Statistical conclusion validity
Apisitwasana, Perngparn, and Cottler (2018)	Low	Moderate	Low	Low	Low	Low	Moderate	High
Avci, Gündoğdu, Dönmez, and Avci (2023)	Low	Moderate	Low	Low	Low	High	Moderate	High
Bağatarhan in Siyez (2022)	Low	Moderate	Low	Low	Low	Low	Moderate	Moderate
Berber Çelik (2017)	Low	Low	Low	Low	Low	Low	High	Moderate
Bickham, Hswen, Slaby, and Rich (2018)	Low	Critical	Low	Low	Low	High	Low	High
Bonnaire, Serehen, and Phan (2019)	Low	Moderate	Low	Low	Low	High	Moderate	High
Boor Boor, Khodabakhshi-Koolaee, and Falsafinejad (2021)	Low	High	Low	Low	Low	High	Moderate	High
Choi, Chun, Lee, Yoo, and Kim (2020)	Low	High	Low	Low	Low	High	Moderate	Moderate
Fiseha and Razon-Estrada (2020)	Low	Critical	Low	Low	Low	Low	Low	Moderate
Gholamian, Shahnazi, and Hassanzadeh (2019)	Low	Low	Low	Low	Low	High	Moderate	High
Khoshgoftar, Amidi Mazaheri, and Tarahi (2019)	Low	Moderate	Low	Low	Low	High	Moderate	High
Kumkronglek, Sirisatayawong, and Chupradit (2023)	Low	High	High	Low	Low	High	Low	Moderate
Li et al. (2017)	Low	Low	Low	Low	Low	Moderate	Moderate	High
Ortega-Barón, González-Cabrera, Machimbarrena, and Montiel (2021)	Low	High	Low	Low	Low	High	Low	High
Tas in Ayas (2018)	Low	Low	Low	Low	Low	Low	High	Moderate
Uysal in Balci (2018)	Low	Moderate	Low	Low	Low	High	Moderate	Moderate
Yang in Kim (2018)	Low	Moderate	Low	Low	Low	Moderate	Moderate	Moderate

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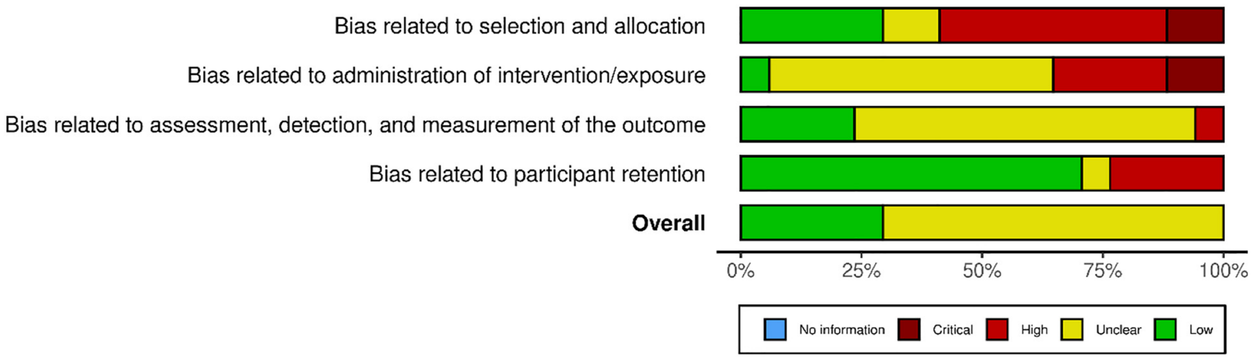

Fig. A1. Risk of Bias summary for randomized controlled trials

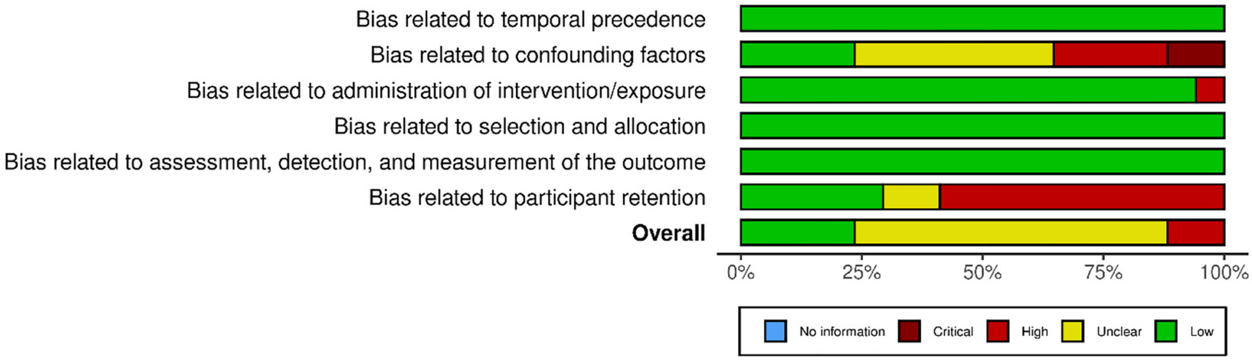

Fig. A2. Risk of Bias summary for quasi-experiments

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