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"Using digital media or sleeping … that is the question". A meta-analysis on digital media use and unhealthy sleep in adolescence

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ABSTRACT

This systematic review with meta-analysis aims to examine the relation between different aspects of digital media use and sleep health patterns. Eligible studies had to be longitudinal and with adolescents' sample. Multiple search strategies were applied until January 28, 2023 in order to identify relevant research published in peer-reviewed journal articles or available grey literature. A final set of 23 studies ($N = 116{,}431$; 53.2% female; M_{age} at baseline = 13.4 years) were included. The quality of the studies, assessed with an adapted version of the Newcastle-Ottawa Scale, was high with a consequent low risk of bias. Meta–analytic results showed that traditional media use ($r = -0.33$ [-0.44; −0.22]), social media use ($r = -0.12$ [-0.22; −0.01]), prolonged use ($r = -0.06$ [-0.11; −0.01]), and dysfunctional use ($r = -0.19$ [-0.29; −0.09]) are negatively related to adolescents' sleep health at a later time point. Conversely, sleep patterns were not related to social media use ($r = -.05$ [-0.10; 0.00]) and utilization time ($r = -0.13$ [-0.30; 0.04]), but they were related to dysfunctional use of media ($r = -0.22$ [-0.33; −0.10]). Overall, this review highlights the presence of a vicious cycle between digital media use and sleep health in adolescence.

1. Introduction

Nowadays, digital media are an integral part of daily lives, thanks to the continuous evolution of technology. Globally, 67.1% of the world's population has a smartphone, 62.5% use the Internet, and 58.4% are active on social networks (Starri, 2022). In this evolving context, adolescents use digital media the most (Gunnel et al., 2016). They live immersed in a technological world, using media seven days a week for many hours per day, so understanding how this impacts their well-being is of utmost importance (Rideout et al., 2010).

Technological devices accompany adolescents every moment of the day, even during hours usually devoted to sleep activity. For instance, it is widespread that adolescents use their electronic devices while in bed before falling asleep, and they even wake up to check messages (Franchina et al., 2018). This phenomenon has been defined as *sleep disturbed by digital media* (Akungu et al., 2021) and represents a primary source of concern. For these reasons, digital media has been identified as one of the risk factors in adolescents (Owens, 2014) for sleep health (a concept that includes both *quantitative*, such as sleep duration and sleep schedule, and *qualitative aspects*, such as sleep efficiency).

Along these lines, the current systematic review with meta-analysis aimed to provide a comprehensive overview of the longitudinal research on adolescents' digital media and sleep. Doing so, it sought to answer two main research questions: (a) how the amount of time and the different ways of digital media use, as well as the type of activity performed and the dysfunctional use of digital media are related to sleep health (i.e., sleep duration and schedule, sleep quality and presence of sleep disturbances) over time; (b) how sleep patterns are associated with digital media use in adolescence over time.

2. Digital media use in adolescence: between risks and benefits

Adolescents can access different tools for multiple purposes during everyday life (Smahel et al., 2020). For instance, they can use the Internet for school activities and watch television or play video games for recreational goals, or even use smartphones and social media as support for social relationships. This pervasiveness of digital tools might positively or negatively impact adolescents' development and well-being, depending on how these tools are used (Ferreira et al., 2020).

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2.1. Type of activities

Considering the relation between technology use and well-being in youth, it is crucial to distinguish the specific type of activity that is carried out. A primary distinction can be made according to adolescents' (passive or active) engagement (Dienline & Johannes, 2020). Passive activities, such as watching TV or scrolling through content on social networks, have been related to lower well-being (e.g., Thorisdottir et al., 2019). In contrast, activities that involve a stronger engagement, such as chatting or playing videogames, are correlated with positive well-being (e.g., Domahidi, 2018). However, this distinction does not consider the different ways the same activity can be carried out.

In addition to distinguishing between active and passive activities, it is also worth considering that adolescents differ in the way they engage in various activities, both according to the purpose for which they do them and according to specific personal characteristics, such as aspects of their identity (Raiziene et al., 2022). For example, among the different ways adolescents use the *Internet* (Valkenburg & Peter, 2009), the use of instant messaging chats, when compared with the use of chat rooms, online gaming, and entertainment of various kinds, emerges as the one that fosters the most social relationships in adolescence by increasing intimacy with friends over time (Blais et al., 2008).

A further distinction is between *traditional media* and *social media* or *social networks*. Social media are perceived as real relational contexts that overlap with offline life and are not simply vehicles of communication (Riva, 2016). Thus, well-being may relate differently to social media and to traditional media (e.g., Cohen & Blaszczynski, 2015; Fardouly et al., 2017), in light of the strong psychological value attributed to social media. On the one hand, the use of social media is negatively related to mental health (Kelly et al., 2018; O'Reilly et al., 2018) and specific aspects of self, such as low self-esteem about one's body image (for a review, see Huang et al., 2021; cf. also Markey & Daniels, 2022). On the other hand, social media, fostering social relationships (Rodgers et al., 2021), can be a protective factor against loneliness, especially for adolescents who lack social skills (Cauberghe et al., 2021; Rajamohan et al., 2019). However, both the positive and negative sides of the associations between these virtual environments and well-being need to be interpreted carefully. First, the detected effects are typically small. Second, there is heterogeneity in the available evidence that may depend on the different operationalizations of both well-being (Meier & Reinecke, 2021) and digital media use (e.g., differences between active or passive use; Valkenburg, 2022).

Beyond the distinction between different types of activities and media, it is worth noting that distinguishing which activity is being performed becomes increasingly complex since adolescents may also use multiple devices simultaneously. This behavior is known as *media multitasking* and refers to "the act of consuming multiple media simultaneously—for example, having a television on in the background while using a smartphone" (Cain et al., 2016, p. 1932). Adolescents who are media multitaskers more frequently show more problems in executive functions (Baumgartner et al., 2014), as well as in emotional regulation and academic performance (e.g., Van der Schuur et al., 2015). Thus, this tendency to use multiple devices simultaneously is related to some negative effects on psychophysiological health, and it is unclear whether it can also have positive effects.

In conclusion, adolescents engage in various activities through the use of media. Depending on the activity engaged in, both positive and negative effects are noted in terms of psychological and physical well-being. However, the differential impact of these activities on adolescents' adjustment is still unclear and might depend on the utilization time.

2.2. Utilization time

Beyond the type of activity performed, a fundamental aspect of digital media that impacts adolescents' well-being is how much time they spend using them (Dienline & Johannes, 2020). *Screen time* refers to the hours spent in front of a screen, so various technological devices, such as smartphones, computers, televisions, or video game consoles, are included in the definition (Gunnel et al., 2016). Exceeding hours of screen time in adolescence is associated with lower psychological well-being (Babic et al., 2017) and higher anxiety (e.g., Twenge & Campbell, 2018).

In addition to the time spent in front of different devices, specific activities involve adolescents for many hours a day, namely surfing the Internet and playing video games. Video games are often used for recreational purposes, such as to relax after experiencing a frustrating event during the day (Tyack et al., 2020). Nevertheless, spending many hours is related to a sedentary lifestyle (Hygen et al., 2022). In addition, if spending much time on the Internet is correlated with harmful health outcomes (for a review, see Ferreira et al., 2020), most of the evidence is based on cross-sectional research; thus, further longitudinal studies are needed to establish to what extent the effects are harmful (Schemer et al., 2021).

Overall, adolescents spend much time in activities involving new technologies. Generally, excessive time spent on media use has been identified as a source of concern. However, it is unclear whether these activities may also have positive effects and whether the association with well-being changes according to the amount of time spent using them.

2.3. Dysfunctional use

A final aspect to consider among the factors that can impact adolescents' well-being is the dysfunctional use of technology. Two main factors can fall within this macro-category. The first aspect is *digital stress*, which is the stress reaction resulting from the continuous use of technological tools that causes cognitive, affective, and physiological arousal in response to the stimuli coming from the devices being used (Thomee et al., 2010). Digital stress has been found to mediate the relation between technology use in adolescence and the adverse psychological outcomes experienced (Steele et al., 2020). A second aspect is the problematic use of technologies, which can result, in more severe cases, in addiction. In the Diagnostic and Statistical Manual of Mental Disorders, Internet and Gaming Disorders have been introduced for the first time in the fifth edition (DSM–5; American Psychiatric Association, 2013). Their diagnosis is based on symptomatology similar to the one characterizing substance addiction. However, this classification has given rise to a heated debate about what can be considered an addiction and what is simply a consequence of the pervasiveness of media use (Király et al., 2015; Ryding & Kaye, 2018), especially for digital natives like adolescents (Cerniglia et al., 2017).

The most common behavior that is considered as an addiction in adolescence involves smartphone use, which has now become a tool from which individuals, especially young people, hardly separate (Xie et al., 2019). Mobile phone addiction or smartphone addiction is commonly defined as "a form of uncontrollable and excessive mobile phone use and includes the main features of addictive behaviors, such as cognitive salience, mood modification, and relapse" (Gao et al., 2022, p. 2). This phenomenon is negatively related to adolescents' psychological health (e.g., Lo Coco et al., 2022). Furthermore, other aspects that should be considered are internet addiction and social network addiction. Internet addiction in adolescence is correlated with the enactment of aggressive behaviors (e.g., Ko et al., 2009). Social network addiction is associated with high stress levels, greater difficulty in impulse control and in goal-directed behaviors (e.g., Wartberg et al., 2021).

In conclusion, dysfunctional media use is a problematic phenomenon that increasingly regard adolescents. It is crucial to consider all behaviors classified as dysfunctional use comprehensively and to delve further into their implications on well-being. Furthermore, it is necessary to understand how well-being can be associated with the use of technologies in a vicious circle.

3. The vicious circle between use of digital media and sleep disruption in adolescence

The sharp rise in the use of digital media in the life of adolescents occurred contemporaneously with an alarming increase in sleep difficulties among youth. Unhealthy sleep during adolescence is multifaceted and includes quantitative (short *sleep duration*, irregular *sleep schedule*) and qualitative aspects (low *sleep efficiency*, namely as the amount of time a person is asleep during bedtime, *night awakenings* and *difficulties falling asleep*, *satisfaction with sleep*). These aspects typically manifest themselves in increased feelings of sleepiness during the day, which may hinder adolescents' everyday functioning in multiple ways (Cain & Gradisar, 2010). Also, these aspects lead to the development of sleep disturbances such as insomnia symptoms (i.e., difficulties initiating and maintaining sleep at night; Blake et al., 2018). Adolescents' unhealthy sleep patterns interfere with their psychosocial development (e.g., Owens, 2014) and represent a crucial transdiagnostic factor for physical and mental health (Harvey, 2016).

Digital media use has been identified as a potential risk factor that may influence adolescents' sleep (Akçay & Akçay, 2018; Bartel et al., 2015). So far, most attention has been devoted to how using portable devices such as smartphones (Carter et al., 2016), screen time (Lemola et al., 2015), and smartphone addiction (Randler et al., 2020) can be associated with adolescents' sleep health. It has been found that the use of electronic devices and smartphone addiction were linked to insufficient sleep quantity and quality, and a higher likelihood of onset of sleep disturbances in adolescence.

Several explanations have been formulated about the process by which digital media interfere with sleep. First, light from digital devices may affect sleep quality by acting on the secretion of melatonin, which activates the body system when our bodies should be relaxing to sleep (Chinoy et al., 2018). Second, adolescents typically use media before bedtime. This behavior delays the time one falls asleep, thus reducing the time spent sleeping (Custers & Van den Bulck, 2012). Finally, the content accessed through digital media can create cognitive arousal that makes it difficult to fall asleep and consequently impacts sleep quality (Harbard et al., 2016). In addition, high arousal levels and poor sleep might create a self-reinforcing vicious circle that negatively affects adolescents' well-being (Garde et al., 2012).

Recent systematic reviews provided an overview of the increasing research on the relation between various aspects of media use and sleep health in different age groups (Mac Cárthaigh et al., 2020; Zhang et al., 2022). Specifically, Mac Cárthaigh et al. (2020) examined the relation between a specific aspect of digital media use (i.e. problematic smartphone use) and sleep health in studies in which the majority of participants were between the ages of 15 and 24. Their systematic review included nine cross-sectional studies and found a weak-to-moderate correlation between problematic smartphone use and sleep. Zhang et al. (2022) tackled the association between mobile phone addiction and a specific aspect of unhealthy sleep (i.e., sleep disorders) in different age groups (school students, college students, and adults) by conducting a meta-analysis. They included 29 studies (mainly cross-sectional with the exception of two longitudinal studies) and found that mobile addiction was also weakly-to-moderately correlated with sleep disorders.

Taken together, extant systematic review (Mac Cárthaigh et al., 2020) and meta-analysis (Zhang et al., 2022) highlight an association between digital media use and sleep. However, they included only (Mac Cárthaigh et al., 2020) or predominantly (Zhang et al., 2022) cross-sectional studies. Thus, they could not disentangle the main direction of effects. Does digital media use erode sleep quality, or do adolescents with sleep difficulties turn to digital media as a compensatory behaviour? Although most attention has been paid to the negative effect of digital media (Cain & Gradisar, 2010), both mechanisms are plausible. For instance, adolescents with sleep difficulties may turn to digital media and use television or computer games as sleep aid (Eggermont & Van den Bulck, 2006; Tavernier & Willoughby, 2014). In addition, since digital media plays a fundamental role in adolescents' lives (Gunnel et al., 2016), media use can also be a way to fill free time (Hisler et al., 2020). Youth who have sleep problems (unrelated to media use) may need to fill their extra waking time with different activities, and they often turn to media use for this purpose. It is possible to hypothesize that the hours spent not sleeping will be occupied by other activities, such as spending more time using digital devices. Therefore, digital media can represent compensatory behaviors for adolescents (Magis-Weinberg et al., 2021; Puukko et al., 2020).

Thus, extant research points to digital media use as a potential risk factor for sleep health in different age groups, including adolescents. However, it suffers from a main limitation, as most available studies employed a cross-sectional design. Thus, it still needs to be determined how the association between sleep health and digital media use unfolds over time and which is the main direction of effects. To address this gap, the current study systematically reviews longitudinal research to comprehensively understand the transactions between adolescents' sleep and their use of digital media.

4. The present study

This systematic review with meta-analysis aims to advance the understanding of the interplay between digital media use and sleep health (for an overview of the main dimensions, see Fig. 1). In particular, this review focused on longitudinal studies that tackle possible vicious circles over time. Thus, the main aim is to address how digital media use (type of activities, utilization time, and dysfunctional use) and sleep health (sleep duration and schedule, sleep quality, and presence of sleep disturbances) are reciprocally related in adolescence.

5. Method

The present study was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021) (see the PRISMA checklist reported in supplemental material S1). This systematic review is part of a larger project which aimed to synthesize the evidence comprehensively yielded in longitudinal studies on the interplay between sleep quality and adolescents' psychosocial development (e.g., Bobba et al., 2023). The review protocol was registered on the PROSPERO database (ID: CRD42021281002).

5.1. Eligibility criteria

Several eligibility criteria concerning the study's characteristics and publications were set. Regarding the study characteristics, studies were eligible if (a) they evaluated a sample of adolescents from the general population attending junior or secondary high schools (aged between 10 and 19 years old); (b) employed a longitudinal study design (with at least two assessments, such as two-wave longitudinal studies or daily diaries); (c) assessed at least one aspect of digital media use and one of sleep; d) evaluated sleep with either objective (e.g., actigraphy, polysomnography) or subjective standardized measures (e.g., sleep diaries; questionnaires). Moreover, for what concern the characteristics of the publications, both journal articles and grey literature (accessible through database searches) were included to avoid selection biases. There were not limits on the publication date or language (when articles/dissertations were published in a language other than English, professional translators were contacted).

5.2. Literature search

The literature search was conducted through several strategies in order to systematically identify eligible relevant research published in peer-reviewed journal articles or available as grey literature. The

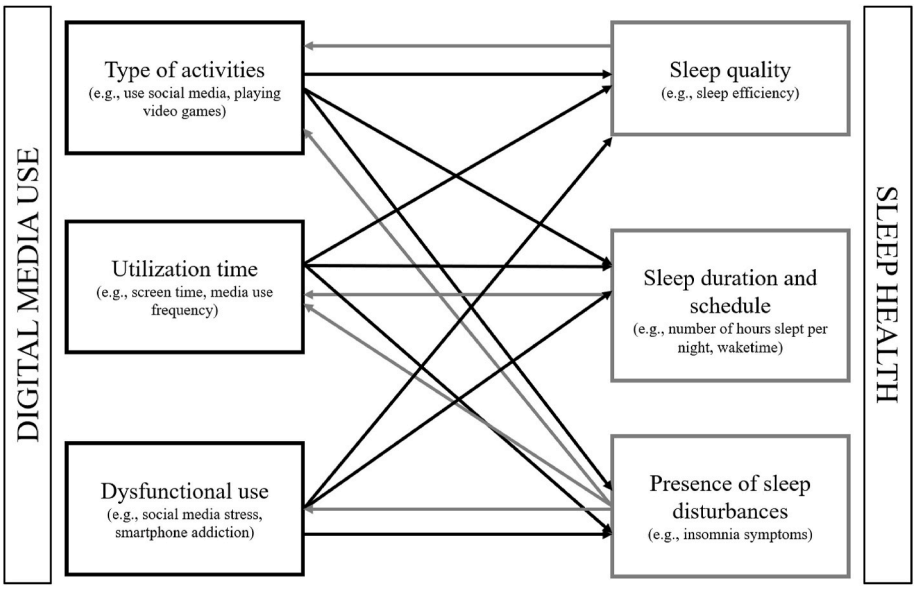

Fig. 1. Overview of the main dimensions of digital media use and sleep health variables included in this systematic review.

literature search was conducted on September 23, 2021 and updated on January 28, 2023. Several databases were searched (i.e., Web of Science, Scopus, PsycINFO, PsycArticles, PubMed, MEDLINE, ERIC, ProQuest Dissertations and Theses, and GreyNet). Full query strings used in each database are reported in the supplemental materials (S2).

Additionally, the websites of journals deemed most likely to publish studies on the topic were searched. The list of the screened journals is available in the supplemental materials S3 and was generated through the statistics of the previous search in Web of Science. Furthermore, conference proceedings included in sleep-related journals were screened (*Journal of Sleep Research,* in which *European Sleep Research Society Congress* proceedings were published, and *Sleep Medicine,* in which the *World Sleep Congress* proceedings were published). Finally, the reference list of the screened full-texts and relevant previous systematic reviews and meta-analyses (e.g., Scherrer & Preckel, 2021; the complete list is provided in the supplemental materials S4) were hand searched. The searches and the screening were run and managed on Citavi 6 software.

5.3. Selection of studies

The PRISMA diagram (Fig. 2) reports the results of the search strategies. The literature search resulted in 43,538 abstracts, and 19,393 duplicates were removed. The remaining abstracts (N = 24,145) were screened independently by two evaluators against the eligibility criteria (the percentage of agreement was substantial, Cohen's Kappa = .77). Next, following the same procedure used for abstract screening, the full-texts were screened (the agreement was moderate, Cohen's Kappa = .58). In both steps, discrepancies were discussed with a third rater, and the final decisions were taken through a discussion among the three evaluators. In total, 23 studies were included in this systematic review.

5.4. Coding of primary studies

In order to extract relevant information from each selected primary study, a coding protocol was prepared. Two evaluators independently coded included studies (the percentage of agreement was 91%) and discrepancies were discussed with a third rater. Next, the final decisions were discussed among the three evaluators.

In the first section of the protocol, the following characteristics of the publication were coded: type of publication (i.e., journal article or grey literature), year of publication, and language of publication. The next section was related to the studies' characteristics and included: funding sources (i.e., international, national funding, local funding, multiple funding sources); the number of waves of the longitudinal design; the time lag between waves; the dimensions of each study (coded according to the variables presented in Fig. 1); and the source of information used to evaluate them (i.e., self-reports, objective assessment). In the third part, the following participants' characteristics were extracted: sample size, gender composition of the sample (% females), mean age, geographical location, and ethnic composition of the sample.[1]

Finally, due to the high heterogeneity of the studies included, different effect sizes were coded (i.e., odds ratio, cross-lagged Pearson's correlations, Spearman's Rho correlations) to address how digital media use (type of activities, utilization time, and dysfunctional use) and sleep health (sleep duration and schedule, sleep quality, and presence of sleep disturbances) were longitudinally related (see Strategy of analysis section). If only standardized beta regression coefficients were reported, the correlation coefficients were estimated based on Peterson and Brown, 2005. When data for effect size computations were not reported in primary studies, the authors were contacted by email to request missing data. In order to retrieve the needed data for effect size computation, 13 authors were contacted. Three authors replied by providing the requested data; three replied that they could not provide the required data (e.g., they could no longer access the dataset); and seven did not respond. The total number of 23 studies included in the review accounts for eight that were excluded because of insufficient data, as indicated in the PRISMA diagram (Fig. 2). The excel file with all coded data is available in OSF (https://osf.io/hmf3b/?view_only=8f2cbb0a138847578eaa706e819b44ca).

5.5. Methodological quality assessment and risk of bias

In line with the PRISMA guidelines (Page et al., 2021), each study's methodology quality and risk of bias were evaluated (Gough, 2007; Valentine, 2009; Valentine & Mc Hugh, 2007). The first two authors independently performed the quality assessment (the percentage of agreement was 82%) by using an adapted version of the Newcastle-Ottawa Scale (NOS) for cohort studies (Wells et al., 2022).

[1] Information about family structure, living arrangements, parental socio-economic status, and parental educational background was missing from several studies and, when available, was reported heterogeneously. Thus, it could not be further coded and examined.

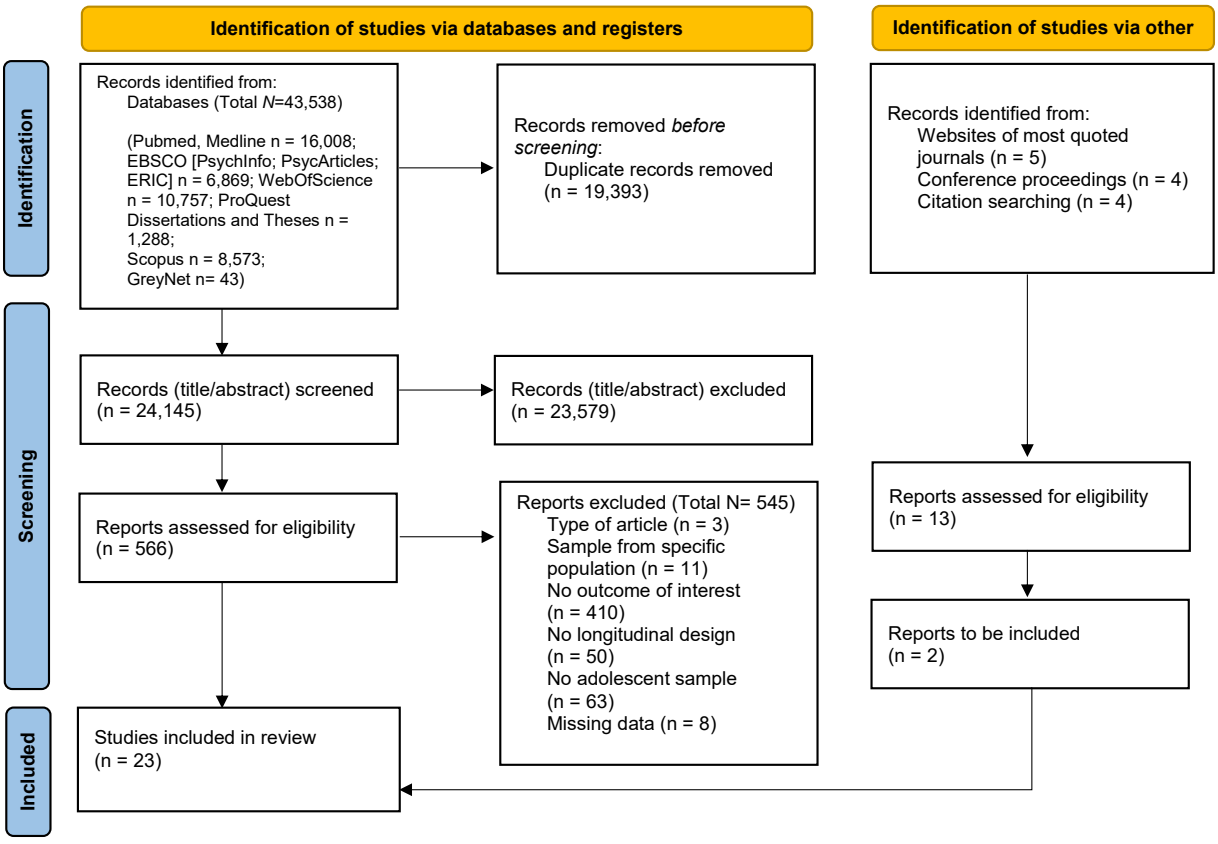

Fig. 2. PRISMA diagram search flow.

Discrepancies were discussed with a third rater and resolved among the three evaluators. Following the procedure of previous systematic reviews of longitudinal studies (e.g., Bobba et al., 2023; Buizza et al., 2022; Scott et al., 2020), the assessment areas of the scale were adapted to the relevant characteristics of the specific study design. Specifically, the adapted version of the NOS included six items categorized into three dimensions: Selection, Comparability, and Outcome. A series of response options is provided for each item. A star system is used, assigning a maximum of one star for each Selection and Outcome item and a maximum of two stars for the Comparability item to high-quality studies. The selection dimension evaluated the representativeness (Item 1) and the description of the missing data patterns (Item 2). The comparability dimension assessed the control of stability and covariates (Item 3). Finally, the Outcome section included the evaluation of the method used for the assessment of the outcome (Item 4), the adequacy of the follow-up (Item 5), and the attrition rate description (Item 6). Document S5 of the Supplemental Materials shows the full list of items.

5.6. Strategy of analysis

Data related to digital media use measured at one time point (e.g., type of activities at T1) and sleep health variables at the last time point considered in the study (T2), or sleep health variables at one time point (T1) and digital media use variables at the last time point considered in the study (e.g., dysfunctional use at T2) were coded. In order to compute overall meta-analytic statistics, the effect sizes of primary studies were converted into Pearson's correlation (converted into Fisher's Z-scores for computational purposes and converted back into correlations for presentation; Lipsey & Wilson, 2000). Correlations of |0.10| are considered small, |0.30| moderate, and |0.50| large effect sizes (Cohen, 1988; Ellis, 2010). Variance, standard error, 95% confidence interval, and statistical significance for each effect size were computed.

When at least two studies (Deeks et al., 2022) were available on the same association, a meta-analysis was conducted using the software ProMeta3 to obtain an overall estimate with the random-effects model (Hedges & Vevea, 1998). In order to evaluate heterogeneity across studies, the *Q* statistic (testing the statistical significance) and the I^2 (to estimate it, with values of 25%, indicating low, 50% moderate, and 75% high levels of heterogeneity) were used (Higgins et al., 2003). Moderator analyses were applied to test which factors can account for the heterogeneity (Crocetti, 2016; Viechtbauer, 2007). Different moderators were tested using subgroup analysis (for categorical moderators, such as the method used to assess sleep) and meta-regression (for numerical moderators, such as the age of participants and time-lag between waves) (Borenstein et al., 2010). Finally, publication bias (Rothstein et al., 2005) was examined through the visualization of the funnel plot (i.e., a scatter plot of the effect sizes estimated from individual studies against a measure of their precision, such as their standard errors). Without bias, the plot would be shaped as a symmetrical inverted funnel. However, since smaller or non-significant studies are less likely to be published, studies in the bottom left-hand corner of the plot are often omitted. To evaluate the funnel plot, the Egger's regression method (Egger et al., 1997), which statistically tests the asymmetry of the funnel plot, with non-significant results indicative of the absence of publication bias, was used.

6. Results

6.1. Study characteristics

Twenty-three studies were included in the systematic review. A summary of the characteristics of the included studies is reported in Table 1. Concerning the characteristics of the publication, all the studies were articles published in peer-reviewed journals. Only one study (Klar et al., 2019) was published in German, while all the remaining studies were published in English. In terms of year of publication, most of them

Table 1
Study characteristics.

Study	Characteristics of the studies							Characteristics of the participants					
Authors and year	Funding	Number of waves	Interval between waves	Media use variable	Media use assessment	Sleep duration (daily sleep hours)	Sleep variable assessment	Sample size baseline	Sample size follow-up	% Female	Mean age (Years)	Country	Ethnic background
Alqaderi et al. (2016)	National funding	2	4 years	Dysfunctional use	Subjective	Sleep duration and sleep schedule	Subjective	8317	6316	61.40%	10	Kuwait	n/a
Barlett et al. (2012)	n/a	3	7 months	Utilization time	Subjective	Sleep duration and sleep schedule	Subjective	1196	1110	53%	9.60	USA	90% White
Burnell et al. (2022)	National funding	Daily	14 days	Utilization time	Subjective	Sleep duration and sleep schedule	Subjective	388	388	50%	13.37	USA	White 59%; Black 21%; Hispanic 13%; Multiracial/ other 6%
Chen and Wu (2021)	n/a	2	6 months	Dysfunctional use	Subjective	Sleep disturbances	Subjective	n/a	1039	52.60%	n/a	Taiwan	n/a
Foerster et al. (2019)	Multiple funding	2	1 year	Dysfunctional use; Utilization time	Subjective	Sleep quality	Subjective	n/a	843	56.40%	n/a	Switzerland	Swiss: 646 (67.6%); Swiss and other: 120 (14.2%); Other: 77 (9.2%)
Hamilton et al. (2020)	National funding	Daily	Day-to-day	Utilization time	Subjective	Sleep duration and sleep schedule	Objective	n/a	76	46%	11.20	USA	53% African American
Hrafnkelsdottir et al. (2020)	Multiple funding	Daily	Day-to-day	Utilization time	Objective	Sleep quality	Objective	n/a	247	58%	15.80	Iceland	n/a
Kim et al. (2020)	Local funding	Daily	Day-to-day	Utilization time	Subjective; Objective	Sleep quality; Sleep disturbances	Subjective	n/a	263	49%	12.20	USA	Non-Hispanic: 36.12%; white Hispanic:47.15%; white Others: 16.73
Klar et al. (2019)	European funding	2	1 year	Utilization time	Subjective	Sleep disturbances	Subjective	1440	1060	55.32%	14.50	Germany	n/a
Kracht et al. (2022)	Multiple fundings	2	2 years	Utilization time	Subjective	Sleep duration	Objective	273	151	54.2%	12.50	USA	White: 59.7%; African American: 34.8%; Another or multiple ethnicity: 5.5%.
Li et al. (2022)	Multiple fundings	2	5 months	Dysfunctional use	Subjective	Sleep disturbances	Subjective	2399	1609	63.5%	16.53	China	n/a
Lin et al. (2021)	No	4	1 months	Dysfunctional use	Subjective	Sleep disturbances	Subjective	1098	812	54.6%	15.55	Iran	n/a
Liu et al. (2023)	Multiple fundings	3	1 year	Dysfunctional use	Subjective	Sleep disturbances	Subjective	1053	773	47.2%	13.18	China	n/a
Maksniemi et al. (2022)	Multiple fundings	5	1 year	Utilization time	Subjective	Sleep quality	Subjective	426	n/a	65.7%	n/a	Finland	n/a
Marciano et al. (2022)	National funding	2	1 year	Utilization time	Subjective	Sleep disturbances	Subjective	674	674	56.7%	14.45	Switzerland	n/a
Poulain et al. (2018)	Multiple funding	2	12.4 months	Utilization time	Subjective	Sleep duration and sleep schedule	Subjective	467	221	52%	13	Germany	n/a
Saelee et al. (2020)	National funding	2	2 years	Utilization time	Subjective	Sleep duration and sleep schedule	Subjective	90,118	12,692	49.60%	15	USA	White: 66% African American Asian: 14.8 Hispanic: 3.9 Other: 3.1
Schweizer et al. (2017)	Multiple funding	2	2 years	Type of activities	Subjective	Sleep disturbances; Sleep quality	Subjective; Objective	3367	591	49.10%	14.20	Switzerland	83,5% Swiss
Tavernier et al. (2017)	National funding	Daily	Day-to-day	Type of activities	Objective	Sleep quality; Sleep duration	Subjective	n/a	71	43.70%	14.50	USA	Non-Hispanic white (14, 19.7%), Black or African-

(*continued on next page*)

Table 1 (*continued*)

Study	Characteristics of the studies							Characteristics of the participants					
Authors and year	Funding	Number of waves	Interval between waves	Media use variable	Media use assessment	Sleep duration (daily sleep hours)	Sleep variable assessment	Sample size baseline	Sample size follow-up	% Female	Mean age (Years)	Country	Ethnic background
						and sleep schedule							American (14, 19.7%), Hispanic or Latino (16, 22.5%), Mixed (14, 19.7%), and Other (13, 18.3%)
van den Eijnden et al. (2021)	Local funding	2	2 years	Utilization time; Dysfunctional use	Subjective	Sleep quality; Sleep schedule	Subjective	2708	2021	45%	13.86	Netherlands	95.4% had a Dutch background
van der Schuur et al. (2019)	n/a	3	4 months	Utilization time	Subjective	Sleep disturbances	Subjective	1241	1103	49%	12.61	Netherlands	n/a
van der Schuur et al. (2018)	n/a	3	4 months	Type of activities	Subjective	Sleep duration and sleep schedule	Subjective	1262	1174	49%	12.61	Netherlands	n/a
Yoo (2020)	Multiple funding	4	Approximately 3 years	Utilization time; Dysfunctional use	Subjective	Sleep duration and sleep schedule	Subjective	n/a	2254	n/a	12.90	Korea	n/a

Notes. All the included studies were articles published in peer-reviewed journals.

(69.4%) were published recently between 2019 and 2023, and the remaining (30.6%) were published before 2019. Concerning the study design, five studies used a daily study design. Of the remaining, half of the studies (50%) included two time points, three (18%), or more than three (14%) time points. The average time lag between adjacent waves was about 1 year ($M = 14.3$ months, $SD = 11.5$ months), ranging from 1 months to 4 years. Only three studies (14%) assessed the sleep duration variable using an objective measure (i.e., actigraphy), the remaining studies used self-report measures, and one used a combination of subjective and objective measures. Most studies (78.3%) reported one or multiple funding sources.

The total number of participants was 116,431 ($M = 7276.9$, $SD = 22{,}177.5$, range 273–90,118). Most samples were gender-balanced (the average percentage of females across samples was 53.2%; range 44–66%), and the average age of sample participants at baseline was 13.4 years ($SD = 1.8$, Range: 9.6–16.5 years). With regards to the geographic context of the studies, most of them were conducted in Europe (43.3%), and the remaining studies were conducted in the USA (30.4%), Korea (4.4%), Kuwait (4.4%), Iran (4.4%), Taiwan (4.4%) and China (8.7%).

6.2. Methodological quality and risk of bias of the studies

Results of the methodological quality and risk of bias assessment are reported in Table S6 of the Supplemental Materials. Specifically, all included studies displayed at least one star in all the evaluated domains. Moreover, 14 out of 23 studies reported the maximum of stars in the selection domain, 13 out of 23 in the comparability domain, and five in the outcome domain. Thus, the overall quality of the studies was high, with a consequent low risk of bias.

6.3. Meta-analyses of the longitudinal interplay between digital media and sleep health

All the effect sizes of the included studies are reported in Table 2. Results of all the meta-analyses for the longitudinal interplay between digital media use (i.e., type of activities, social media use, utilization time, and dysfunctional digital media use) and sleep health are reported below. All forest plots, funnel plots, and scatter plots for tested moderators (i.e., time-lag between waves and mean age of participants) are reported in the supplemental materials. It was not possible to conduct subgroup analyses for the categorical moderator (i.e., the method used to assess sleep) since insufficient studies used objective measures to assess sleep health.

6.3.1. The interplay between type of activities and sleep health

Regarding the interplay between different types of activities and sleep health (i.e., having a smartphone, media multi-tasking), three studies examined this link (Schweizer et al., 2017; Tavernier et al., 2017; Van der Schuur et al., 2018). Of these, only one (Van der Schuur et al., 2018) evaluated this connection bidirectionally. Therefore, a meta-analytic calculation could be applied to obtain overall estimates only for one direction, that is the longitudinal association between the type of activities at one time point (T1) and sleep health variables at a later time (T2). Results, summarized in Table 3 showed a significant effect ($r = -0.33$, $p < .001$). Heterogeneity statistics were high and significant. Despite that, moderator analyses highlighted that results were not moderated by the characteristics of the participants (i.e., mean age at T1, $B = -0.06$, $p = .51$) or by characteristics of the studies (i.e., time-lag between waves, $B = -0.01$, $p = .43$). Furthermore, the visual investigation of the funnel plot suggested a low risk of publication bias that was statistically confirmed by a non-significant Egger's test.

Furthermore, five studies (Hamilton et al., 2020; Maksniemi et al., 2022; Tavernier et al., 2017; Van den Eijnden et al., 2021; Van der Schuur et al., 2019) evaluated the specific effect of social media use on sleep health. Moreover, two studies (Maksniemi et al., 2022; Van der

Table 2
Effect sizes of the included studies.

Study	Sleep variable (Method of assessment)	Digital media use variable	Digital media use category for meta-analytic calculation	Time-lag	Digital media use variables T1 → Sleep variables T2[1] (Effect size reported)	Digital media use variables T1 → Sleep variables T2[1] (Effect size expressed as Pearson's correlations)	Sleep variables T1 → Digital media use variables T2[2] (Effect size reported)	Sleep variables T1 → Digital media use variables T2[2] (Effect size expressed as Pearson's correlations)	Main findings
*Alqaderi et al., 2016	Sleep duration (S)	Watch TV/use video games before bedtime	Digital media dysfunctional use	4 years	$\beta = -0.04$* [−0.05; −0.12]	$r = -.04$*[-.06; −.01]			Different types of problematic use of digital media during bedtime are associated with shorter sleep duration over time. These associations are small.
		Use bed for watching TV/ playing video games			$\beta = -0.06$* [−0.01; −0.08]	$r = -.06$***[-.08; −.03]			
		Watching TV/ using video games			$\beta = -0.03$* [−0.05; −0.09]	r = −.03* [-.05; −.00]			
*Barlett et al., 2012	Sleep duration (S)	Screen time	Utilization time	7 months	$r = -.19$***	$r = -.19$*** [-.25; −.13]	$r = -.21$***	$r = -.21$*** [-.28; −.15]	Screen time is bidirectionally associated with shorter sleep duration over time. These associations are moderate.
*Burnell et al., 2022	Sleep duration (S)	Utilization time (total messages sent)	Utilization time	Daily	r = .05	$r = .05$ [-.05; .15]	r = −.15*	$r = -.15$* [-.25; −.05]	Utilization time is not bidirectionally associated with sleep duration, bedtime and waketime over time. Longer sleep duration is associated with less utilization time over time. The association is small.
	Bedtime (S)				r = .07	$r = -.07$ [-.17; .03]	r = .05	$r = -.05$ [-.15; .05]	
	Waketime (S)				r = .12	$r = .12$ [.02; .22]	r = .09	$r = .09$ [-.01; .19]	
*Chen & Wu, 2021	Insomnia symptoms (S)	Smartphone addiction	Digital media dysfunctional use	6 months	$r = .21$**	$r = -.21$*** [-.27; −.15]	$r = .22$**	$r = -.22$*** [-.28; −.16]	Smartphone addiction and insomnia symptoms are bidirectionally associated over time. The associations are small.
Foerster et al. (2019)	Sleep quality (S)	Screen time	Utilization time	1 year	$OR = 1.82$ [0.67; 4.96]				Greater screen time is not associated with sleep quality over time.
*Hamilton et al., 2020	Sleep duration (S)	Utilization time (TV)		Daily	$r = .06$	$r = .06$ [-.17; .29]			Playing videogames or television use, is not associated with sleep duration over time.
		Utilization time (Videogames)			$r = .02$	$r = .02$ [-.21 – .25]			
		Social media use	Social media use		$r = -.13$	$r = -.13$ [-.36; .10]			Social media use is negative associated with sleep duration over time. The association is small.
Hrafnkelsdottir et al. (2020)	Sleep duration (S)	Screen time	Utilization time	Daily	$b = 3.81$*** (1.01)				Greater screen time is associated with later bedtime, later waketime and more sleep duration over time. These associations are moderate.
	Bedtime (S)				$b = 4.02$*** (1.07)				
	Waketime (S)				$b = 3.27$** (1.11)				
Kim et al. (2020)	Sleep duration (O)	Screen time	Utilization time	Daily	$b = -1.16$ [-4.31; 2.00]				Greater screen time during the day is associated with lower sleep quality, but not with sleep duration and sleep
	Sleep efficiency (O)				$b = -0.19$ [-0.10; 0.83]				

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Table 2 (*continued*)

Study	Sleep variable (Method of assessment)	Digital media use variable	Digital media use category for meta-analytic calculation	Time-lag	Digital media use variables T1 → Sleep variables T2[1] (Effect size reported)	Digital media use variables T1 → Sleep variables T2[1] (Effect size expressed as Pearson's correlations)	Sleep variables T1 → Digital media use variables T2[2] (Effect size reported)	Sleep variables T1 → Digital media use variables T2[2] (Effect size expressed as Pearson's correlations)	Main findings
	General sleep quality (S)				$b = -0.01$* [-0.02; −0.00]				efficiency. The association is small.
Klar et al. (2019)	Insomnia symptoms (S)	Use of internet Pathological Internet use	Utilization time Digital media dysfunctional use	1 year	$OR = 0.08$* [0.00; 0.17] OR = 1.29***		$\beta = .06$*	r = −.11*** [-.17; −.05]	Excessive time spent on Internet is associated with more insomnia symptoms over time. The association is small. Pathological Internet and sleep problems are bidirectionally associated over time. The associations are small.
Kracht et al., 2022	Sleep duration (O)	Nigh-time screen time (TV and portable devices)	Utilization time	2 years	$b = -0.51$** (0.27)				Night-time screen time (based on TV and portable devices) is associated with shorter sleep duration over time. The association is medium.
*Li et al., 2022	Daytime sleepiness (S)	Smartphone addiction	Digital media dysfunctional use	5 months	$r = .32$***	r = -.32*** [-.36; −.28]			Smartphone addiction is associated with daytime sleepiness over time. This association is moderate.
*Lin et al., 2021	Insomnia symptoms (S)	Social media addiction	Digital media dysfunctional use	3 months	$r = .37$***	$r = -.37$*** [-.43; −.31]	$r = .32$***	$r = -.32$*** [-.38; −.26]	Social media addiction and insomnia symptoms are bidirectionally associated over time. The associations are moderate.
Liu et al. (2023)	Insomnia symptoms (S)	Internet Gaming Disorder	Digital media dysfunctional use	2 years	$OR = 2.20$* (1.26–3.86)				Internet Gaming Disorder is associated with daytime insomnia symptoms over time. This association is moderate.
*Maksniemi et al., 2022	Bedtime (S)	Social media use	Social media use	6 years	$r = .03$	$r = -.03$ [-.13; .07]	$r = .02$	$r = -.02$ [-.12; .08]	Social media use and bedtime are not associated over time.
*Marciano et al., 2022	Sleep problems (S)	Increased screen time	Utilization time	1 year	$\beta = .07$	$r = -.07$ [-.14; .01]			Increased screen time from T1 to T2 was not associated with sleep problems over time.
Poulain et al. (2018)	Insomnia symptoms (S)	Utilization time (watching TV/ video)	Utilization time	12.4 months	$b = -0.22$ [-1.15; 0.70]		$OR = 1.01$ [0.90; 1.13]		Excessive time spent on Internet or with Computer, but not watching TV or video and use of mobile phone, is associated with more insomnia symptoms over

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Table 2 (*continued*)

Study	Sleep variable (Method of assessment)	Digital media use variable	Digital media use category for meta-analytic calculation	Time-lag	Digital media use variables T1 → Sleep variables T2[1] (Effect size reported)	Digital media use variables T1 → Sleep variables T2[1] (Effect size expressed as Pearson's correlations)	Sleep variables T1 → Digital media use variables T2[2] (Effect size reported)	Sleep variables T1 → Digital media use variables T2[2] (Effect size expressed as Pearson's correlations)	Main findings
									time. The association is small. Utilization time and insomnia symptoms are not bidirectionally associated over time.
*Saelee et al., 2020	Short sleep duration (S)	Screen time	Utilization time	2 years	$r = -.06$**	$r = -.06$*** [-.08; −.04]			Greater screen time is associated with shorter sleep duration. The association is small.
*Schweizer et al., 2017	Sleep duration on school days (S)	Owners of smartphone vs non-owners	Type of activities	2 years	$M_{T0} = 7.81$ (0.10), $M_{T1} = 7.28$ (0.12)/$M_{T0} = 8.61$(0.12), $M_{T1} = 8.00$ (0.20)	$r = -.20$*** [-.28; −.11]			Owning a smartphone is related to shorter sleep duration both on school days and on weekends/ vacation. These associations are moderate and large respectively.
	Sleep duration on weekends/ vacation (S)	Owners of smartphone vs non-owners			$M_{T0} = 9.48$ (0.16), $M_{T1} = 9.28$ (0.12)/$M_{T0} = 10.2$(0.24), $M_{T1} = 9.44$ (0.30)	$r = -.77$*** [-.80; −.74]			
	Sleep disturbances incidenc e (S)	Owners of smartphone vs non-owners			33.7% ($n = 383$)/23.4% ($n = 55$)	$r = -.09$ [-.21; .03]			Owning a smartphone is positive related to more sleep disturbances. This association is small.
*Tavernier et al., 2017	Sleep duration (O)	Social media use (Facebook)	Social media use	Daily	$r = -.33$**	$r = -.33$** [-.54; −.12]			Facebook use, but not Twitter use, is associated with shorter sleep duration over time. The association with Facebook is moderate. Using a computer and watching television is associated with shorter sleep duration and lower sleep quality over time. The associations are moderate.
		Social media use (Twitter)			$r = -.04$	$r = -.04$ [-.28; .20]			
		Use of computer	Type of activities		$r = -.33$**	$r = -.33$** [-.54; −.12]			
	Sleep efficiency (O)	Use of TV			$r = -.27$*	$r = -.27$* [-.49; −.05]			
					$r = -.04$ [-.28; .20]				
*Van den Eijnden et al., 2021	Bedtime (S)	Social media use	Social media use	2 years	$r = .29$***	$r = -.29$*** [-.34; −.24]			Social media use is positively associated with later bedtime over time, but not with perceived quality of sleep. The association is moderate.
	Sleep quality (S)				$r = -.14$***	$r = -.14$*** [-.18; −.10]			
	Bedtime (S)	Problematic social media use	Digital media dysfunctional use		$rs = .14$***	$r = -.15$*** [-.19; −.10]			More problematic social media use is associated with later bedtime and lower sleep quality over time. The
	Sleep quality (S)				$rs = -.17$***	$r = -.18$*** [-.22; −.14]			

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Table 2 (*continued*)

Study	Sleep variable (Method of assessment)	Digital media use variable	Digital media use category for meta-analytic calculation	Time-lag	Digital media use variables T1 → Sleep variables T2[1] (Effect size reported)	Digital media use variables T1 → Sleep variables T2[1] (Effect size expressed as Pearson's correlations)	Sleep variables T1 → Digital media use variables T2[2] (Effect size reported)	Sleep variables T1 → Digital media use variables T2[2] (Effect size expressed as Pearson's correlations)	Main findings
									associations are small.
*Van der Schuur et al., 2018	Sleep disturbances (S)	Media multi-tasking	Type of activities	4 months	$r = .27$***	$r = -.27$*** [-.32; −.22]	$r = .24$***	$r = -.24$*** [-.29; −.19]	Media multi-tasking and sleep disturbances are bidirectionally associated over time. The associations are moderate.
*Van der Schuur et al., 2019	Sleep onset latency (S)	Social media use	Social media use	4 months	$r = .05$	$r = -.05$ [-.11; .01]	$r = .06$	$r = -.06$ [-.12; −.00]	Social Media use was not significant associated with sleep quality.
*Yoo, 2020	Sleep duration (S)	Using computer	Utilization time	3 years	$\beta_{1997} = -0.03$ (0.02) $\beta_{2000} = -0.21$*** (0.031)	$r = -.03$ [-.07; .01] $r = -.21$*** [-.25; −.17]			Time spent on Computer and watching video/TV is associated with shorter sleep duration in recent generations than in past generations. The associations are small. No differences between generations emerged about time spent playing video games. Smartphone overuse is associated with shorter sleep duration in recent generations than in past generations. These associations are small.
		Watching video/TV			$\beta_{1997} = -0.03$ (0.02) $\beta_{2000} = -0.09$** (0.02)	$r = -.03$ [-.07; .01] $r = -.10$** [-.14; −.05]			
		Playing video games			$\beta_{1997} = -0.06$ (0.03) $\beta_{2000} = 0.04$ (0.03)	$r = -.06$** [-.11; .02]			
		Smartphone overuse			$\beta_{1997} = 0.02$ (.00)	$r = .07$** [-.21; −.13]			
			Digital media dysfunctional use		$\beta_{2000} = -0.12$** (.00)	$r = -.12$*** [-.16; −.07]			

Notes. [1]Cross-lagged effects between digital media use measured at one time point and sleep measured at the last time point considered in the study. [2]Cross-lagged effects between sleep measured at one time point and digital media use measured the last time point considered in the study. (S) = subjective assessment of sleep health parameters; (O) = objective assessment of sleep health parameters. T = Time; *M* = Mean and Standard Deviation in parenthesis; *n* = sample; β = Standardized regression coefficient and Standard Error estimate in parenthesis; β1997 = Standardized regression coefficient and Standard Error estimate in parenthesis of 1997 Birth-cohort; β2000 = Standardized regression coefficient and Standard Error estimate in parenthesis of 2000 Birth-cohort; *r* = Pearson's correlation (confidence intervals are reported between square brackets); OR= Odds ratio and confidence interval in parenthesis. ***$p < .001$, **$p < .01$, *$p < .05$. Studies marked with an asterisk (*) are those included in the meta-analyses reported in Table 3 (when the effect sizes could not be converted into Pearson's correlations, it was not possible to include them in the meta-analytic computations).

Schuur et al., 2018) evaluated this connection bidirectionally. Results of the meta-analysis estimating the longitudinal association between social media use at one time point and sleep health variables at a later time (Table 3) yielded a significant effect ($r = -0.12$, $p < .05$). Heterogeneity statistics were high and significant. Despite that, moderator analyses highlighted that results were not moderated by the characteristics of the participants (i.e., mean age at T1, $B = -0.04$, $p = .35$) or the characteristics of the study (i.e., time-lag between waves, $B = -0.01$, $p = .31$). Furthermore, the visual investigation of the funnel plot suggested a low risk of publication bias that was statistically confirmed by a non-significant Egger's test. Finally, results of the meta-analysis on the longitudinal association between sleep health at one time point and social media use variables at a later time (Table 3) indicated a non-significant effect ($r = -0.05$, $p = .06$). Heterogeneity statistics were moderate and non-significant.

6.3.2. *The interplay between utilization time and sleep health*

Twelve studies evaluated the interplay between sleep health and utilization time. Of these, three studies (Barlett et al., 2012; Burnell et al., 2022; Poulain et al., 2018) evaluated this connection bidirectionally. The remaining studies evaluated the unidirectional effect of the utilization time (i.e., screen time, use of TV, and video games time) on sleep. Results of the meta-analysis estimating the longitudinal association between utilization time at one time point (T1) and sleep health variables at a later time (T2) (Table 3) yielded a significant effect ($r = -0.06$, $p < .05$). Heterogeneity statistics were high and significant. Despite that, moderator analyses highlighted that results were not moderated by the characteristics of the participants (i.e., mean age at T1, $B = 0.02$, $p = .44$) or by characteristics of the studies (i.e., time-lag between waves, $B = 0.01$, $p = .44$). Egger's test was not significant, highlighting the lack of publication bias. Finally, results of the meta-analysis on the longitudinal association between sleep health at

Table 3
Overall meta-analytic calculations of the bidirectional relations between digital media and sleep health.

Overall effect Between Digital Media Use T1 → Sleep Health T2[1]	*k*	ES [95% CI]	*Q*	I^2	Egger's test	Overall effect Between Sleep Health T1 → Digital Media Use T2[2]	*k*	ES [95% CI]	*Q*	I^2	Egger's test
Type of activities T1 → Sleep Health T2	3	−.33*** [-.44; −.22]	10.15**	80.30	−0.27						
Social Media Use T1 → Sleep Health T2	5	−.12* [-.22; −.01]	28.13***	85.78	0.65	**Sleep Health T1 → Social Media Use T2**	2	−.05 [-.10; −.00]	0.49	0.00	
Utilization time T1 → Sleep Health T2	6	−.06* [-.11; −.01]	27.43***	81.77	0.12	**Sleep Health T1 → Utilization time T2**	2	−.13 [-.30; .04]	11.32**	91.16	
Digital Media Dysfunctional Use T1 → Sleep Health T2	6	−.19*** [-.29; −.09]	222.05***	97.75	−3.03*	**Sleep Health T1 → Digital Media Dysfunctional Use T2**	3	−.22*** [-.33; −.10]	22.84***	91.24	−1.79

Notes. [1]Cross-lagged effects between digital media use measured at one time point (T1) and sleep health measured at the last time point (T2) considered in the study. [2]Cross-lagged effects between sleep health measured at one time point (T1) and digital media use measured at the last time point (T2) considered in the study. *k* = number of studies; ES = Effect Size; *Q* = heterogeneity test; I^2 = heterogeneity estimate. ***$p < .001$, **$p < .01$, *$p < .05$. To compute the overall meta-analytic summary, the effect sizes of studies were recoded so that different type of activities at T1 were related to higher sleep health parameters (i.e., higher sleep quality) at T2.

one time point and utilization time at a later time (Table 3) showed a non-significant effect ($r = -0.13$, $p = .14$). Heterogeneity statistics were moderate and significant.

6.3.3. The interplay between digital media dysfunctional use and sleep health

Eight studies evaluated the interplay between digital media dysfunctional use and sleep health. Of these, three studies (Chen & Wu, 2021; Klar et al., 2019; Lin et al., 2021) evaluated this connection bidirectionally. The remaining studies evaluated the unidirectional effect of dysfunctional digital media use on sleep health indicators. Results of the meta-analysis estimating the longitudinal association between digital media dysfunctional use at one time point (T1) and sleep health variables at a later time (T2) (Table 3) yielded a significant effect ($r = -0.19$, $p < .001$). Heterogeneity statistics were high and significant. Nonetheless, moderator analyses highlighted that results were not moderated by the characteristics of the participants (i.e., mean age at T1, $B = -0.06$, $p = .06$) or by the characteristics of the studies (i.e., time-lag, $B = 0.01$, $p = .07$). Egger's test was significant, highlighting the presence of publication bias. Finally, results of the meta-analysis on the longitudinal association between sleep health at one time point and digital media dysfunctional use variables at a later time (Table 3) showed a significant effect ($r = -0.22$, $p < .001$). Heterogeneity statistics were high and significant. Furthermore, the visual investigation of the funnel plot suggested a low risk of publication bias that was statistically confirmed by a non-significant Egger's test.

7. Discussion

Recently, there has been an alarming increase in sleep difficulties in adolescence (Jakobsson et al., 2022). Digital media have been considered as one of the main risk factors, especially because of their massive utilization among adolescents (Gunnel et al., 2016). In order to understand the relation between these two aspects, it is essential to consider the use of digital media taking into account how long and in which ways these are used (i.e., type of activities, utilization time, and dysfunctional use) and studying sleep health as a multifaceted construct (i.e., sleep duration and schedule, sleep quality, and presence of sleep disturbances). Furthermore, while most attention has been given to the influence that digital media use has on sleep health, there is a lack of awareness of the bidirectionality of this relation. For these reasons, the present systematic review with meta-analysis aimed to extend prior knowledge on this topic, mainly based on cross-sectional research (for prior reviews see Mac Cárthaigh et al., 2020; Zhang et al., 2022), focusing on longitudinal studies which examined the interplay between adolescents' digital media use and sleep health. Overall, the present results highlight a bidirectional association between these two variables over time. The findings are discussed below considering the two directions of effects and. suggesting future lines of research emphasizing the importance of taking a multifaceted approach to gain a comprehensive understanding of the phenomenon.

7.1. Opening the box: the impact of digital media use on sleep health in adolescence

This systematic review with meta-analysis examined the longitudinal association between healthy sleep patterns and digital media use, considering the a) type of activities, b) utilization time, and c) dysfunctional use. Meta-analytic results showed a moderate and negative association between different types of digital media use (e.g., having a smartphone, using a computer, media-multitasking) and sleep health over time. Specifically, different activities are correlated with lower sleep quality, shorter sleep duration, and the onset of sleep difficulties assessed with subjective and objective measures. These results are in line with previous research that suggested that certain activities, such as media-multitasking (e.g., Baumgartner et al., 2014; Van der Schuur et al., 2015) and Internet use are negatively associated with well-being in adolescence and, in particular, sleep health (Carter et al., 2016).

Studies examining the use of social networks were considered as a separate subcategory within the types of activities. Meta-analytic results showed a small but significant effect of social media use on sleep health in adolescence. In particular, the use of social media, such as Facebook or Twitter, at one time point was related to shorter sleep duration, later bedtime, and lower sleep quality at a later time point. These findings extend data from previous research showing a negative association between social media and both mental health (Kelly et al., 2018; O'Reilly et al., 2018), and adolescents' sleep health. However, the link of social media use with sleep was weaker than the one with traditional media, probably because social media may be a protective factor in adolescents' lives (Cauberghe et al., 2021; Rajamohan et al., 2019). These results support the importance of distinguishing traditional media from social media in relation to the different impact they may have in terms of psychological well-being (e.g., Cohen & Blaszczynski, 2015; Fardouly et al., 2017).

Regarding utilization time, meta-analytic results showed that a large amount of digital media utilization time (i.e., screen time, use of TV and video games time) had a small but significant negative impact on sleep duration and sleep quality, mainly shortening sleep duration, delaying bedtimes, and increasing sleep onset latency. These results are in line with previous research suggesting that exceeding hours of screen time in adolescence is associated with lower psychological well-being (e.g., Babic et al., 2017; Twenge & Campbell, 2018). This negative effect can be explained according to the hypothesis (Custers & Van den Bulck, 2012) that spending much time using digital media delays the time at

which one goes to sleep and generally occupies the hours that would usually be devoted to sleep. In addition, it was found that using digital media for a long time is associated with the later onset of sleep problems and insomnia symptoms over time. In particular, the sleep disorders most commonly associated with overuse emerged to be excessive daytime sleepiness (Poulain et al., 2018) and difficulty falling asleep (Foerster et al., 2019; Klar et al., 2019; Marciano et al., 2022). This link can be explained according to the hypothesis that difficulty falling asleep and subsequent daytime sleepiness may result from excessive arousal created by digital media (Harbard et al., 2016). Thus, prolonged use of electronic devices during the night-time hours can cognitively stimulate adolescents by eliciting symptoms of insomnia.

Finally, meta-analytic results showed a small and negative association between the dysfunctional use of digital media and sleep health subjectively measured over time. These findings confirm those of previous research that reported how dysfunctional use of digital media was associated with negative outcomes in both social well-being (e.g., Ko et al., 2009) and psychological well-being (Lo Coco et al., 2022; Steele et al., 2020; Wartberg et al., 2021). In addition, the current findings extend previous works that had only examined smartphone addiction as a dysfunctional behavior that impacts sleep (Mac Cárthaigh et al., 2020; Randler et al., 2020; Zhang et al., 2022). Besides problematic use of smartphone, pathological use of the Internet and social media, as well as using digital media before going to sleep, are also associated with negative sleep health outcomes. Thus, this systematic review highlights the importance of considering how digital media are used, for what purpose, and for how long.

7.2. The other side of the coin: the effect of sleep health on digital media use

Although most studies focused on the effect that digital media use has on sleep health, the present review also investigated effects in the other direction, to understand whether unhealthy sleep is related to how digital media are used over time. In this respect, it is worth first noting that only a few studies addressed this phenomenon. As a result, although the size of the longitudinal correlations was similar to those found for the effects in the other direction (from digital media to sleep), they did not reach statistical significance due to the low number of studies. More specifically, a negative association was found between sleep health and social media use (Maksniemi et al., 2022; Van der Schuur et al., 2019) and utilization time (Barlett et al., 2012; Burnell et al., 2022). These findings underscore the bidirectionality of the relation between sleep health and type of activities, and utilization time. Since digital media plays a fundamental role in adolescents' lives (Gunnel et al., 2016), it is possible to suppose that the hours spent not sleeping will be occupied by other activities, such as spending more time using digital devices, even using multiple devices at the same time. However, more studies investigating the effect sleep health has on digital media use are needed to better understand this relation.

There is also a bidirectional relation between the dysfunctional use of digital media and sleep health. The presence of insomnia symptoms assessed through self-report measures was associated with pathological Internet use (Klar et al., 2019), social media addiction (Li et al., 2022), and smartphone addiction (Chen & Wu, 2021) over time. This relation could be explained in terms of compensatory behavior enacted by adolescents, that is, an attempt to use digital media as sleep aids (Eggermont & Van den Bulck, 2006). The presence of symptoms of insomnia, such as difficulty falling asleep, could promote the urge to use digital devices to relax. At the same time, however, excessive use of digital media may lead, as pointed out earlier, to worse sleep quality. At this point, a vicious cycle can take place, which drives excessive use of digital media and, at the same time, makes the symptoms of insomnia increasingly severe. Thus, this systematic review pointed out the importance of considering the bidirectionality of this relation, which is often neglected.

7.3. Limitations and suggestions for future research

The result of this systematic review should be considered in light of some limitations. The first limitation of the present review concerns the heterogeneity of the reviewed literature. The studies considered different variables, especially with regard to aspects of digital media use. In addition, most of the present studies examined the relation between the two variables in a unidirectional way. Only eight studies (Barlett et al., 2012; Chen & Wu, 2021; Klar et al., 2019; Lin et al., 2021; Maksniemi et al., 2022; Poulain et al., 2018; Van der Schuur et al., 2018, 2019) considered the bidirectionality of the relation. However, these studies focused only on certain aspects of the phenomenon. Therefore, future longitudinal research is needed to disentangle how quantity and quality of sleep are related to different activities performed with digital media, time of use, and dysfunctional behaviors. The same virtual environment may also be perceived differently by users and thus have a different impact on well-being. For example, future studies should consider all facets of social media use, adopting an approach that takes into account why and how individuals differ in their interaction with these platforms (e.g., the differences between passive/active users and for whom social media induce social comparison; Valkenburg, 2022).

Second, most studies included in the review relied on self-report measures. Only four studies measured sleep parameters objectively through the actigraphic method (Hamilton et al., 2020; Hrafnkelsdottir et al., 2020; Kracht et al., 2022; Schweizer et al., 2017), and only one study measured the time of digital media use objectively relying on data obtained from mobile phone operators (Foerster et al., 2019). Thus, self-report data should be considered with caution because may be affected by social desirability and shared variance issues. Future research should integrate objective and subjective assessments of both digital media use and sleep health. It might be helpful, for example, to obtain usage data recorded by electronic devices to get an objective estimate of actual time spent using digital media (Sewall et al., 2022), since self-report measures may not give a true estimate of the frequency and duration of digital media use (for a meta-analysis see Parry et al., 2021). Including objective measures makes it possible to jointly consider both the actual time spent in front of the screen and the user's subjective perception of use, which may change according to the type of activity performed and environmental factors (Hodes & Thomas, 2021; Kaye et al., 2020). In addition, it is important that future studies evaluate sleep parameters through actigraphy (Sadeh, 2011), because there may be discordance between perceived sleep quality measured through self-report instruments and objective sleep quality measured through actigraphy (Carvalho, Lauar, Drager, Moyses, & Elias, 2022).

Finally, to better understand how (i.e., underlying mechanisms) digital media use and sleep health are related over time and for whom (i.e., moderations) this association is stronger, it is required to design longitudinal studies with at least three assessments (while about half of the studies in the current review included only two time points). In this way, it would be possible to identify relevant mediators (e.g., chronotype; Hisler et al., 2020) and moderators (e.g., rules imposed by parents concerning digital media use; Van den Eijnden et al., 2021) playing a role in the interplay between digital media use and sleep health in adolescents. Therefore, future lines of research examining these issues will provide a better understanding of the mechanisms through which digital media use and adolescent sleep health are interconnected and clarify which factors make some adolescents more at risk than others. This knowledge is of utmost importance to develop evidence-based interventions.

8. Conclusions

This systematic review with meta-analysis provided a comprehensive synthesis of longitudinal research on the relation between digital media use and sleep health in adolescence. First, meta-analytic results showed that different activities through digital media, prolonged use,

and dysfunctional use are negatively related to adolescent sleep health over time. Second, the findings showed also that there is a longitudinal association between unhealthy sleep (i.e., lower sleep duration, greater daytime sleepiness, and insomnia symptoms) and some aspects of digital media use (i.e., multi-tasking behavior, utilization time, and dysfunctional) during adolescence. Thus, these results suggest the presence of a vicious cycle between sleep health and media use in adolescence.

From a theoretical perspective, this review highlights gaps in the existing literature. In order to address them, the main new element introduced by this review is to emphasize the importance of considering the bidirectionality of the relation between sleep health and digital media use. Secondly, it highlights the importance of conducting future longitudinal studies that aim to expand knowledge on the topic by examining quantitative and qualitative aspects of both sleep health and digital media use. Only by considering all the different facets of the phenomenon would be possible to have a comprehensive understanding of it.

Likewise, this study has important practical implications. Through the approach that considers the bidirectional nature of the phenomenon, it will be possible to design evidence-based interventions that can promote well-being in adolescence by working in two main directions. On the one hand, by educating on the informed use of digital media, it is possible to promote healthy sleep in adolescence; on the other hand, by improving sleep health, it is possible to address the dysfunctional and excessive use of digital media.

Authors' contributions

M.P. conceived the study, coded the papers included in the review, wrote the manuscript, and participated in the interpretation of the results; V.B. conceived the study, coded the papers included in the review, performed the statistical analyses, wrote the manuscript, and participated in the interpretation of the results; E.C. conceived the study, wrote the manuscript, and participated in the interpretation of the results. All authors read and approved the final manuscript.

Ethical approval

No ethical approval was needed because data from previously published studies in which informed consent was obtained by primary investigators were retrieved and analyzed.

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Declaration of competing interest

The authors report no conflicts of interest.

Data availability

The excel file with all coded data is available in OSF (https://osf.io/hmf3b/?view_only=8f2cbb0a138847578eaa706e819b44ca).

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.chb.2023.107813.

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