

## Digital media use and sleep in late adolescence and young adulthood: A systematic review

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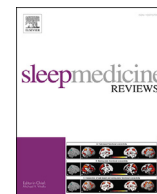
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# Digital media use and sleep in late adolescence and young adulthood: A systematic review



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## ABSTRACT

Despite much attention on digital media use and young peoples' sleep, the literature on digital media and its impact on sleep in older adolescents and young adults remains to be synthesized. We conducted a systematic review of studies including young people aged 16–25 years. We searched Medline, Web of Science, and CINAHL for observational studies, identifying 60 studies. These studies were assessed for methodological quality. Only studies rated as moderate or high-quality studies were included ( $n = 42$ ). A narrative synthesis summarized the impact of digital media use on eight sleep outcomes: Bedtime; Sleep onset latency or problems falling asleep; Sleep duration; Early awakening; Sleep disturbance; Daytime tiredness and function; Sleep deficits; Sleep quality. In summary, digital media use was associated to shorter sleep duration and poorer sleep quality. These associations were found for general screen use and use of mobile phone, computer, internet, and social media, but not for television, game console, and tablet use. Most studies investigating bedtime or nighttime use found associations to poor sleep outcomes. Later bedtime and daytime tiredness were associated with mobile phone use at night. Additional research is warranted to draw solid conclusions about the causal direction and to understand the underlying mechanisms.

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## 1. Introduction

Sleep is essential to development, mental and physical health, especially in young people to whom adequate sleep is crucial for health, learning and well-being [1,2]. Inadequate sleep and poor sleep quality are associated with several adverse outcomes both in the short and long term, including poor diet, obesity, increased morbidity, mental health problems such as depression and suicidal behavior, and substance abuse [2–4]. In the United States, the recommendation on nighttime sleep is 8–10 h of sleep for adolescents and 7–9 h of sleep for young adults [5]. Nonetheless,

reports from many countries show that adolescents sleep less than these recommendations [6,7] and sleep duration has declined over the last decades [8], although existing data is limited among young adults. A systematic review on data from the Netherlands, United Kingdom and United States reported that one in four slept less than the age-specific recommendation [7] with more pronounced short sleep prevalence for young people; for example, more than half of teenagers aged 14–17 years old did not get the recommended 8 h of sleep. Another study among 8th to 12th graders in the United States reported that more than 40% did not get at least 7 h of sleep per night [9]. Moreover, insomnia symptoms were prevalent with 16.5% of 14-17-year-olds and 22.6% of 18-25-year-olds experiencing difficulties initiating sleep [7]. A meta-analysis of international data among 11-18-year-olds from 1999 to 2010 reported that sleep duration tended to decrease with increasing age and bedtimes tended to become delayed with increasing age [6].

The advent of internet enable portable small screen devices (e.g., smartphones) provided the world with instant access to the internet and has arguably had a dramatic impact on young people's excessive use of digital media and possible their sleep [10,11]. A

*Abbreviations:* CI, Confidence Interval; CS, Cross-sectional design; DMLO, Dim light melatonin onset; EPHPP, Effective public health practice project; LD, Longitudinal design; MeSH, Medical subject headings; PECO, population (P), exposure (E), comparison (C) and Outcome (O); PRISMA, Preferred reporting items for systematic reviews and meta-analyses; PROSPERO, Prospective register of systematic reviews; OR, Odds Ratio.

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recent survey on 1125 people in Denmark shows that more than six out of ten 16–24-year-olds state that entertainment from mobile phones, tablets, computers, video games, or television are the reason to late bedtime and consequently insufficient sleep to feel rested [12]. Among young people, smartphones, and other devices with access to the internet and social media are more prevalent than the more conventional digital media such as television [13]. Nationally representative data from 8th, 10th and 12th grade in the United States reported that time spent online, gaming, and on social media sites has steadily increased from 2010 to 2016 whereas spending time with media such as television has decreased [13]. Still, 12th graders were spending 1.9 h/day on watching television during weekdays. Although time spent on a digital media such as television is decreasing, it is still used and, for example, young adults may have a television screen in the bedroom, and background television can negatively affect sleep through blue light.

Digital media has become an integral part of young peoples' life and it should be a point of attention that newer, interactive media may affect young people in different ways than the more conventional, one-way communicational digital media. Compared with older adults, young adults are more inclined to like trying new digital media and is the group in Denmark spending the most time on digital media. A recent nationally representative study in Denmark showed that 15–24-year-olds use the internet on their mobile phone on average 316 min per week [14].

Despite much attention on digital media's impact on sleep [15–17], no study has so far systematically reviewed the literature on the entire body of electronic devices and media, both the conventional ones and the modern forms, and their associations with sleep in adolescents and young adults. Existing systematic reviews have mainly focused on school-aged children and young adolescents [18–22] and have found an association between digital media usage and sleep outcomes: inadequate sleep quantity, poor sleep quality, excessive daytime sleepiness, and insomnia symptoms. Another systematic review explored the relationship between mobile phone use and mental health targeting all age groups and found that mobile phone use at bedtime was associated with shorter sleep duration and lower sleep quality [23]. Few systematic reviews have targeted older adolescents and young adults [15,24], but only for specific uses of media, for example, social media [15] or problematic smartphone usage [24]. Both of these reviews found an association with sleep. To our knowledge, no previous review has examined the evidence of the associations between any digital media and any sleep or circadian outcome among adolescents and young adults in the age of 16–25 years. We are interested in any type of digital media device and engagement to fully examine how use digital media impact on sleep, especially today where many new forms of digital media are emerging. It is assumed but untested whether the same sleep deficits reported in children who use digital technologies are also evident in young people. Accordingly, the aim of this study was to fill this gap in the literature by means of a rapid review [25].

## 2. Methods

This systematic review was based on recommendations from the Cochrane rapid reviews method group [25,26] and The Preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines for systematic reviews [27]. This review was registered with the international Prospective register of systematic reviews (PROSPERO; CRD42021247592) on April 23, 2021.

### 2.1. Search strategy

A search strategy was developed based on the PECO (Population, Exposure, Comparison (if any) and Outcome) model [28]. The population was people aged 16–25 years, the exposure was digital media, and the outcome was any sleep outcomes. Literature was searched using the electronic databases Medline, Web of Science, and CINAHL on April 22, 2020. We used subject headings and Medical subject headings (MeSH) terms as well as free text searches in title, abstract, and keywords. The search was limited to articles published in the period January 1, 2010 to April 31, 2021, and only studies written in English, Danish, Swedish, or Norwegian were included in the search. The search strategy included relevant synonyms for the search terms adolescent/young adult (e.g., teenager, college student), digital media (e.g., smartphone, social media), and sleep (e.g., sleep latency, sleep hygiene). Search terms were identified in collaboration with a research librarian with expertise in systematic reviews to ensure the quality of the search strategy. See Table S1 in the supplemental appendix for the full search in each database. In addition, reference lists from previous systematic reviews were reviewed to identify other relevant studies.

### 2.2. Inclusion and exclusion criteria

Inclusion criteria were as follows.

- 1) Observational studies examining the association between digital media and sleep.
- 2) Studies with sample participants aged 16–25 years. Studies where the population overlapped with this age range were included if more than 50% of the study population or the average age were within 16–25 years. If age was not described, school level was used as an indicator of age.
- 3) Measure of digital media. We included studies that examined any digital media device (computer, smartphone, tablet, television, computers, etc.) or reported on a digital media platform (social media, internet, gaming, blogging, e-mail, etc.). That is, time spent on any type of device or any type of digital media platform.
- 4) Measure of outcomes. Studies that examined outcomes related to going to sleep (e.g., delayed bedtime), during sleep (e.g., sleep disturbance), or indicators of sleep deprivation (e.g., daytime tiredness).
- 5) Western countries, i.e., all EU countries as well as Andorra, Iceland, Liechtenstein, Monaco, Norway, San Marino, Switzerland, Vatican City, Canada, U.S, Australia, and New Zealand.
- 6) Peer-reviewed literature published in English, Danish, Swedish, or Norwegian. Studies were excluded if they focused only on specific study populations, for example, young adults with psychiatric diagnoses, overweight, or sleep disorders; were conference literature, books, or opinion papers; or only were available as abstracts.

### 2.3. Screening

A random sample of titles and abstracts ( $n = 30$ ) were screened by three reviewers to test compliance, and 20% of titles and abstracts were screened for eligibility by two reviewers independently. One reviewer screened the rest of the identified titles/abstracts, while another reviewed the excluded titles/abstracts, and if necessary, disagreement regarding inclusion was resolved through discussion (Cohen's Kappa for agreement: 0.55). Abstracts relevant to the research questions were put forward for full-text

review against the inclusion and exclusion criteria. A random sample of full-text articles (n = 7) were assessed by three reviewers to test compliance. One reviewer assessed the rest of the full-text articles for potentially eligible articles, while another reviewed the excluded full-text articles. Discordance regarding inclusion was resolved through discussion.

### 2.4. Quality assessment

The included studies were assessed for methodological quality. The assessment was conducted by two reviewers independently (a total of three reviewers were involved), and meetings were held continuing focusing on inter-rater reliability. The methodological quality of the studies was assessed using the Effective Public Health Practice Project (EPHPP) assessment tool [29]. Based on recommendations from the Cochrane Rapid Reviews method group the quality assessment were limited to contain only the most essentials components [25] which are selection bias, confounders, and data collection methods. These components were chosen based on earlier experience gathered for a previous systematic review on the association between digital media use and sleep in a younger age group [22]. Studies were rated strong on *selection bias* if the study population is very likely to represent the target population and there is more than 80% participation. A strong rating for the component *confounding* was assigned to studies that controlled for at least 80% of relevant confounders, i.e., gender, age, socioeconomic status, and mental health. Confounders were selected based on discussion and consensus in the author group and existing epidemiological studies [30–34]. Finally, a strong *data collection method* was assigned if the data collection tools for the outcome have shown to be valid and reliable, for example, the validated sleep instrument Pittsburgh sleep quality index [35]. Each study received a global rating of high, moderate, or low quality; high quality if it was rated weak on none of the three components, moderate quality if it was rated weak on one of the three

components, and low quality if it was rated weak on at least two of the three components. Low-quality studies were excluded to ensure moderate and high evidence.

### 2.5. Data extraction and synthesis

We extracted data using a standardized data extraction form that included country of study, sample size, study design, data collection method, sleep outcomes, digital media exposure, and reported findings related to associations between digital media use and sleep. Narrative synthesis was done grouped by sleep outcomes in which we highlighted any similarities or differences in the findings and explored whether heterogeneity in results might be due to variability in study design, populations, measures employed, and outcomes studied.

## 3. Results

### 3.1. Study identification and study characteristics

A total of 13,311 articles were identified through our initial search, and 42 studies were included (see Fig. 1). Eight studies were longitudinal, and 35 were cross-sectional studies. The paper by Billari et al. was included as both a cross-sectional and longitudinal study [36]. The most common country where the studies were conducted were in the U.S. (n = 13). Sleep duration (n = 23) and sleep quality (n = 28) were most measured. The measurement of digital media use differentiated substantially with mobile phone use (n = 18) and total screen use (n = 14) were most commonly measured. We compiled variables measuring the general use of digital media into “total screen use”. The total screen use variables cut across the specific digital devices and online activities (e.g., some studies summarized total time spent on all types of screens). Study characteristics are described in Table 1.

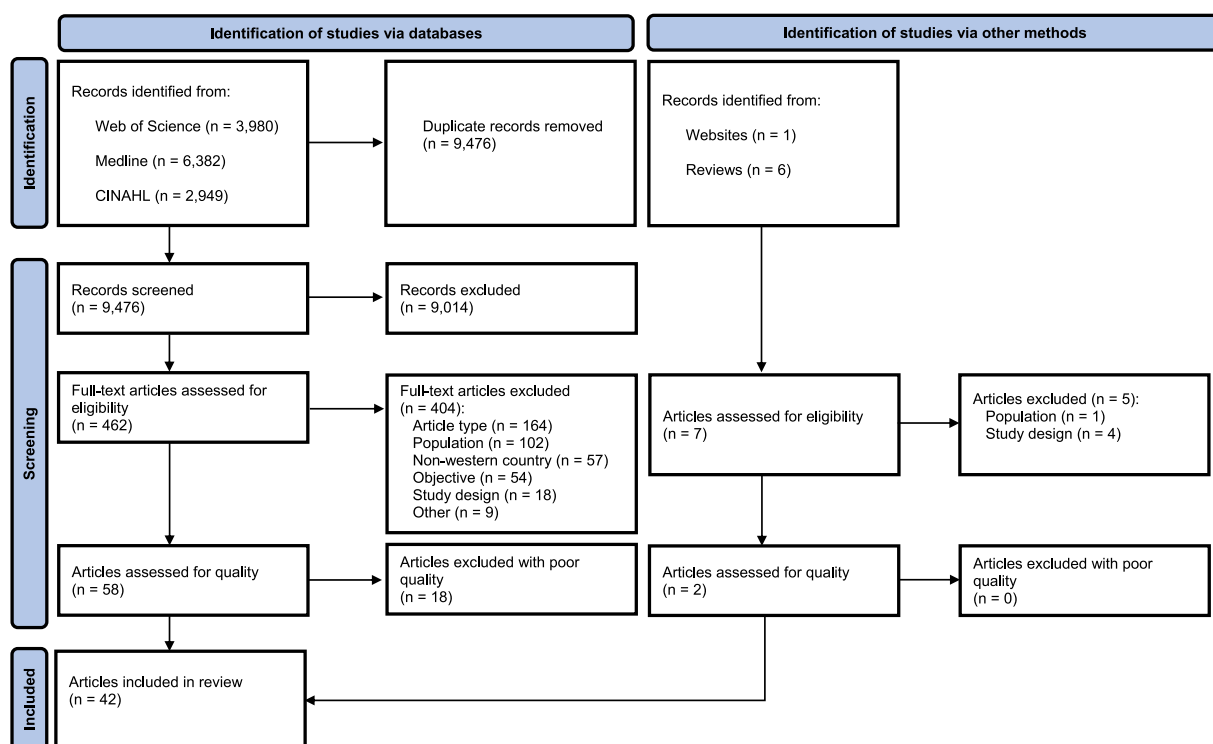


Fig. 1. Flow diagram.

**Table 1**  
Study characteristics.

	n (%)
<b>Country</b>	
USA	13 (31)
Belgium	4 (10)
Canada	4 (10)
Sweden	3 (7)
Norway	2 (5)
New Zealand	2 (5)
Australia	2 (5)
Schweiz	2 (5)
Denmark	2 (5)
UK	2 (5)
Croatian	1 (2)
Holland	1 (2)
Germany	1 (2)
Spain	1 (2)
Scotland	1 (2)
Across different countries	1 (2)
<b>Study design</b> <sup>a</sup>	
Cross sectional	35 (83)
Longitudinal	8 (19)
<b>Sample size</b>	
<100	4 (9)
100–499	10 (24)
500–999	10 (24)
1000–4999	9 (21)
5000–10000	2 (5)
>10000	7 (17)
<b>Sample source</b>	
High school	4 (9)
College/University	13 (31)
Other	25 (60)
<b>Digital media</b> <sup>b</sup>	
Mobile phone/smartphone	18 (43)
Computer/laptop	9 (21)
Tablet	3 (7)
Television	10 (24)
Game console	3 (7)
Internet	5 (12)
Social media	11 (26)
Screen use	14 (33)
<b>Sleep outcome</b> <sup>c</sup>	
Delayed bedtime	5 (12)
Sleep onset and problems falling asleep	5 (12)
Sleep disturbance	3 (7)
Sleep duration	23 (55)
Early awakening	3 (7)
Daytime tiredness and function	8 (19)
Sleep quality	28 (67)

<sup>a</sup> The column does not sum up to 100% because one of the studies consists of both a longitudinal study and a cross-sectional study.

<sup>b</sup> The column does not sum up to 100% because some of the studies examines different types of digital media within the same study.

<sup>c</sup> The column does not sum up to 100% because some of the studies examines different sleep outcomes within the same study.

### 3.2. Synthesis of findings

We synthesized the findings of the different sleep outcomes separately. Summary of studies and their findings are described in [Table 2](#). In addition, detailed descriptions of study design and results are available in the supplementary appendix [Table S2](#).

### 3.3. Delayed bedtime

Five studies investigated the relationship between digital media use and bedtimes [37–41], and four found an association between digital media use and delayed bedtimes [37–40]. For example, a study found that sending and/or receiving text messages at night

was associated with later bedtimes among 15–17-year-olds [37]. Another study found that the association between use of internet and mobile phone after 6 p.m. and bedtimes depended on the country in which it was investigated [38]. Using mobile phone and internet contributed to delayed bedtimes in Australian, but delayed bedtimes was only associated with mobile phone use in the Netherlands, and internet use in Canada. A third study found an association for gaming duration (hours per weekday) and gaming engagement, but not for gaming accessibility (number of devices owned), and later bedtimes [39]. Gaming engagement was assessed using the Game engagement questionnaire (GEQ). The participants were asked nine questions measuring the flow dimension of game engagement, for example, 'If someone talks to me, I don't hear', 'I feel like I can't stop playing'.

### 3.4. Sleep onset latency and problems falling asleep

Five studies investigated the relationship between digital media use and sleep onset latency or problems falling asleep and found inconsistent evidence for the association [41–45]. Four of the studies investigated sleep onset latency, defined as the time it takes a person to fall asleep after bedtime [41,43–45]. Self-reported problems with falling asleep was only investigated in one study, which did not find an association to smartphone use [42].

Hysing et al. found that use of computer, mobile phone, tablet, game console or television in the last hour before bedtime was associated with increased odds of sleep onset latency of more than 60 min [44]. Results further revealed that young people using more than 4 h of total screen time after school was related to a sleep onset latency of more than 60 min (OR: 1.49, 95% CI: 1.36–1.64). On the contrary, Cabre-Riera et al. found no association between either use of laptop, mobile phone, tablet, game console or television and sleep onset latency [43].

### 3.5. Sleep disturbances

Three studies investigated the relationship between digital media use and sleep disturbances, including restless sleep, nightmares, and nightly awakenings [42,43,46]. Of these two studies linked digital media use to sleep disturbance [43,46]. One study showed that time spent with a tablet was associated with multiple awakenings at night but found no association for other devices, including laptop, mobile phone, television, and total screen time [43]. Another study investigated associations between text messaging frequency, awareness of mobile phone notifications at nighttime, compulsion to check notifications at nighttime, and sleep across a seven-day period and found that awareness of nighttime notifications was the only predictor for sleep disruptions and for women only [46].

### 3.6. Short sleep duration

A total of 23 studies investigated the relationship between the use of digital media and sleep duration [36–38,40–44,47–61], of which three studies have longitudinal design [36,50,61]. Most studies (n = 16) found an association between digital media use and short sleep duration [38,41–44,47–52,55,57–60]. However, the association depended on the type of digital media investigated. The studies showed evidence for mobile phones, computers (primarily gaming on a computer), the internet, social media, general use of screens, and inconsistent results for tablets, game console, and television. Nine studies investigated digital media use specific at nighttime [36,38,41,43,44,47–50], and seven of these found association with shorter sleep duration [36,38,44,47–50]. However, in some studies the association depended on other factors,

**Table 2**  
Summary of studies and their findings on the relationship between digital media use and sleep outcomes among 16-25-year-olds.

Digital media	Measured at bedtime/night	Sleep outcomes							Study design	Quality assessment	
		Delayed bedtime	Sleep onset latency; problems falling asleep	Sleep disturbances	Short sleep duration	Early awakening	Daytime tiredness; poor daytime function	Poor sleep quality			
<b>Mobile phone/smartphone</b>											
Adams et al. (2013) [70]	Yes								+	CS	Moderate
Amez et al. (2020) [51]	No				+				+	CS	High
Bartel et al. (2016) [38]	Yes	+/-			+/-					CS	Moderate
Billari et al. (2018) [36]	Yes				-					CS & LD	High
Cabre-Riera et al. (2019) [43]	No		-	-	-				+/-	CS	Moderate
Dissing et al. (2021) [76]	No								+/-/x	LD	Moderate
Fossum et al. (2014) [62]	Yes							-	+	CS	High
Galland et al. (2020) [48]	Yes				-				-	CS	High
Garmy et al. (2018) [37]	Yes	+			+	+	+			CS	Moderate
Hysing et al. (2015) [44]	Yes		+		+					CS	Moderate
Johansson et al. (2016) [47]	Yes				+	+	+			CS	Moderate
Li et al. (2015) [71]	Yes								+	CS	Moderate
Murdock et al. (2017) [46]	Yes			+/-				+/-	+/-	CS	Moderate
Rod et al. (2018) [42]	Yes		-	-	+	-			-	CS	Moderate
Rosen et al. (2018) [66]	Yes								+/x	CS	Moderate
Sohn et al. (2021) [24]	No								+	CS	Moderate
Tashjian et al. (2019) [59]	No				+					CS	Moderate
Thomé et al. (2011) [73]	No								+/-	LD	Moderate
<b>Tablet</b>											
Cabre-Riera et al. (2019) [43]	No		-	+	+				-	CS	Moderate
Fossum et al. (2014) [62]	Yes							-	-	CS	High
Hysing et al. (2015) [44]	Yes		+							CS	Moderate
<b>Computer/laptop</b>											
Billari et al. (2018) [36]	Yes				+/-					CS & LD	High
Cabre-Riera et al. (2019) [43]	No		-	-	-				-	CS	Moderate
Fossum et al. (2014) [62]	Yes							-	+/-	CS	High
Galland et al. (2020) [48]	Yes				+				+	CS	High
Hysing et al. (2015) [44]	Yes		+		+					CS	Moderate
Lemola et al. (2011) [60]	Yes				+/-			+/-	-	CS	Moderate
Kakinami et al. (2017) [56]	No				-				+	CS	High
Smith et al. (2017) [39]	No	+/-								CS	High
Thomee et al. (2012) [74]	No								+/-	LD	Moderate
<b>Television</b>											
Billari et al. (2018) [36]	Yes				+/-					CS & LD	High
Cabre-Riera et al. (2019) [43]	Yes		-	-	-				-	CS	Moderate
Fossum et al. (2014) [62]	Yes							-	-	CS	High

(continued on next page)

**Table 2** (continued)

Digital media	Measured at bedtime/night	Sleep outcomes							Study design	Quality assessment
		Delayed bedtime	Sleep onset latency; problems falling asleep	Sleep disturbances	Short sleep duration	Early awakening	Daytime tiredness; poor daytime function	Poor sleep quality		
Galland et al. (2020) [48]	Yes				+			+	CS	High
Hysing et al. (2015) [44]	Yes		+		+				CS	Moderate
Johansson et al. (2016) [47]	Yes					+			CS	Moderate
Kakinami et al. (2017) [56]	No				-			+	CS	High
Kenney et al. (2017) [57]	No				-/x				CS	High
Lund et al. (2010) [72]	No							-	CS	Moderate
Tavernier et al. (2014) [61]	No				-			-	LD	High
<b>Game console</b>										
Cabre-Riera et al. (2019) [43]	No		-	-	-			-	CS	Moderate
Fossum et al. (2014) [62]	Yes						-	-	CS	High
Hysing et al. (2015) [44]	Yes		+		+				CS	Moderate
<b>Internet</b>										
Bartel et al. (2016) [38]	Yes	+/-			+/-				CS	Moderate
Belanger et al. (2011) [55]	No				+/-				CS	Moderate
Billari et al. (2018) [36]	No				+			+	CS & LD	High
Johansson et al. (2016) [47]	Yes				+		+		CS	Moderate
Galland et al. (2020) [48]	Yes				+			+	CS	High
<b>Social media</b>										
Das-Friebel et al. (2020) [50]	Yes				+/-/x			-	LD	Moderate
Dissing et al. (2021) [76]	No							-/x	LD	Moderate
Galland et al. (2020) [48]	Yes				+			+	CS	High
Hysing et al. (2015) [44]	No		+		+				CS	Moderate
Johansson et al. (2016) [47]	Yes				+		+		CS	Moderate
Levenson et al. (2016) [68]	Yes							+	CS	Moderate
Levenson et al. (2017) [67]	No							+	CS	Moderate
Tavernier et al. (2014) [61]	No				-			-	LD	High
Thomé et al. (2012) [74]	No							+	LD	Moderate
van der Velden et al. (2019) [75]	No							-	LD	Moderate
Xanidis et al. (2016) [64]	No						+	+	CS	Moderate
<b>Screen use</b>										
Baiden et al. (2019) [52]	No				+				CS	High
Cabre-Riera et al. (2019) [43]	Yes		-	-	-			-	CS	Moderate
Exelmans et al. (2017a) [63]	No						+	+	CS	Moderate
Exelmans et al. (2017b) [45]	Yes		+/-						CS	Moderate
Exelmans et al. (2018) [40]	No	+			-				CS	Moderate
Galland et al. (2017) [49]	Yes		+		+			+	CS	High
Hysing et al. (2015) [44]	Yes		+		+				CS	Moderate
Jones et al. (2019) [41]	Yes	-	+/-		-				CS	Moderate

**Table 2** (continued)

Digital media	Measured at bedtime/night	Sleep outcomes							Study design	Quality assessment
		Delayed bedtime	Sleep onset latency; problems falling asleep	Sleep disturbances	Short sleep duration	Early awakening	Daytime tiredness; poor daytime function	Poor sleep quality		
Kenney et al. (2017) [57]	No				+/-				CS	High
Leech et al. (2017) [54]	No				x				CS	Moderate
McManus et al. (2020) [65]	No						-/x	-/x	LD	High
Stefan et al. (2019) [58]	No				x/+				CS	High
Walsh et al. (2020) [69]	Yes							+	CS	High
Xu et al. (2019) [53]	No				-			+	CS	High

Note. (CS) Cross-sectional design; (LD) Longitudinal design; (+) More digital media use has an association with delayed bedtime, sleep latency onset, problems falling asleep, sleep disturbances, short sleep duration, early awakening, daytime tiredness, poor daytime function or poor sleep quality; (x) Association is the opposite (e.g., more digital media use has an association with better sleep); (-) No association; A combination of (+, -, x) means that the directions of the associations differ across subgroups or measures.

including country of origin [38] and the presence of depressive symptoms [50]. Four studies showed an association between digital media use and longer sleep duration [50,54,57,58]. One study showed that social media use at bedtime was associated with shorter sleep duration among undergraduate students with high levels of depressive symptoms, but for students with low levels of depressive symptoms, results showed that bedtime social media use was associated with longer sleep duration [50].

### 3.7. Early awakening

Two cross-sectional studies found an association between digital media use and early awakening or a discrepancy between wake-up times [37,47]. In one study adolescents who sent or received text messages on their mobile phone at night on a weekly basis had more discrepancy between wake-up time during the school week and weekends [37]. In another study, number of devices used, and television and mobile phone use were associated with the response “woke too early” [47]. However, one cross-sectional study found no association between digital media use and premature awakenings [42].

### 3.8. Daytime tiredness and poor daytime function

Six cross-sectional studies investigated the relationship between digital media use (especially mobile phone/smartphone use at night) and daytime tiredness [37,46,47,60,62,63], and all except for one study found association between digital media use and daytime tiredness [37,46,47,60,63]. Use of mobile phone or smartphone at night were linked to being more tired or sleepy during the day [37,46,47]. For example, one study found association between being awakened by mobile phone notifications in the middle of the night and more daytime sleepiness among students, but for men only [46]. Two studies examined digital media use and daytime function and found inconsistent results on whether digital media exacerbates or improves functional difficulties during the day [64,65]. [64,65].

### 3.9. Poor sleep quality

A total of 28 studies investigated the association between digital media use and sleep quality, of which 19 was cross-sectional [24,42,43,46,48,49,51,56,60,62–64,66–72] and eight were longitudinal [36,50,61,65,73–76]. The studies in this section used

instruments of sleep quality or sleep problems that covered the above sleep outcomes (e.g., sleep duration, daytime tiredness, and sleep onset). For example, the Pittsburgh sleep quality index and the Insomnia severity index. Studies that examined sleep quality based on one global measure of sleep satisfaction was also included. Most studies (n = 20) found that digital media use was associated with poor sleep quality [24,36,43,46,48,49,51,56,62–64,66–71,73,74,76]. Overall, the studies indicated that screen time and use of mobile phone/smartphone, computer, internet, and social media worsened sleep quality.

Use of mobile phone/smartphone was examined in 12 studies [24,42,43,46,48,51,62,66,70,71,73,76]. For example, one study found that a one standard deviation increase in students’ frequency of smartphone use for different activities (such as “reading e-mails” and “taking pictures”) is associated with 10.3% lower odds of experiencing very good sleep quality [51]. Another study found an association between a high level of call and text interactions (>30 per day) for women [76]. However, 4-month follow-up analysis revealed no association. Four studies used a measure of smartphone addiction and found an association between smartphone addiction and poor sleep quality [24,43,51,66]. Six studies measured smartphone/mobile phone use at bedtime or during nighttime [42,46,48,62,70,71] and four studies found an association to poor sleep quality [46,62,70,71]. In contrast, one study, which examined the use of smartphone/mobile phone to texting 1 h before bedtime (>3 nights per week), found no association between use of smartphone/mobile phone at bedtime and poor sleep quality [48]. A second study also found no association between smartphone use during nighttime and poor sleep quality [42].

Three studies indicated that use of smartphones and social media may have an association with less sleep problems [65,66,76]. For example, a longitudinal study with a four-month follow-up period reported that a big network size of smartphone interactions (call and text contacts and Facebook friends) was associated with less sleep problems, but for men only [76]. Most studies (4 of 6) found no association between television and sleep quality [43,48,56,61,62,72]. Furthermore, there was no association between playing on a game console or using a tablet and poorer sleep quality [43,62]. However, these results were only based on two studies. A total of 10 studies examined digital media use specific at bedtime or nighttime [43,46,48–50,62,66,67,69,70] and eight found association between some types of digital media and poor sleep quality [46,48,49,62,66,67,69,70].



### 3.10. Summary of results

Overall, there is general support that the timing of digital media use is important for young people's sleep. Using digital media at bedtime/nighttime is associated with delayed bedtime, short sleep duration, sleep quality and daytime tiredness. A second result is that particularly the use of smartphones revealed as having a potential negative impact on sleep. Particularly, the use of the smartphone before going to bed and notifications from the smartphone during night were identified as related to delayed bedtime, short sleep duration, sleep quality and daytime tiredness. Other digital media devices also showed associations with sleep outcome (e.g., computer), but no associations were found for television. A third aspect of findings is the engagement with digital media content. The identified studies suggested that gaming, internet use and social media use are associated with shorter sleep duration, and poor sleep quality. Moreover, the findings revealed that especially addiction to and problematic use of social media or smartphone are related to poor sleep quality while high level of gaming engagement is associated with delayed bedtime.

## 4. Discussion

This review investigated the evidence on the association between digital media use and a range of sleep outcomes in late adolescence and young adulthood. Digital media use was linked to delayed bedtimes, daytime tiredness, and early awakening, but the strongest evidence was found for shorter sleep duration and poor sleep quality. Despite it is difficult to conclude definitely, because there are inconsistencies in how digital media and sleep were measured, there are still some noteworthy findings.

### 4.1. Timing of digital media use

One strong finding was that the majority of studies investigating digital media use at bedtime or nighttime found associations to poor sleep outcomes, making this an important time period. Two main and not mutually exclusive hypotheses to explain how digital media use at bedtime/nighttime affects sleep are hyperarousal and blue light explanations [20,77]. The first hypothesis is that the engagement with digital media may induce mental arousal or hyperarousal, leading to difficulties falling asleep and poor sleep quality [78]. Our findings cautiously suggest that more communicative digital media (such as smartphones and social media), have a greater impact on sleep than more passive media (such as television), and one could imagine that more communicative digital media entails a greater arousal than passive media. However, this theory can be difficult to deduce because different digital media devices and platforms are often used for the same activities. For example, nowadays, many young people watch films and tv-series on their computer instead of on a television. Therefore, the lack of association between television viewing and sleep outcomes may be due to a declining consumption of television among young people. The digital media content and type of communication may influence sleep depending on the degree to which they are arousing. In contrast to texting and sending a message through social media platforms, talking on the phone may provide more immediate, contingent feedback, which may positively influence the emotional state and the sleep initiation and continuity. For example, a prospective three-day study with adolescents (mean age 14.5 years) found that adolescents sleep fewer hours when they use more time than usual on texting and computer work, whereas talking on a mobile phone was associated with a longer sleep duration [79]. The results from this study may also be due to the fact that texting and computer work involves looking intensively at a screen while

talking on a mobile phone would typically not involve looking at a screen. Nevertheless, social media use benefits networking with friends but may also introduce fear of missing out and social media stress [80]. Two experimental studies examined the hypothesis that gaming would elevate arousal level, negatively influencing sleep [81,82]. Both studies found that gaming at nighttime implied longer sleep onset time. The second hypothesis is that exposure to blue light emitted from screens can disrupt the 24-h circadian rhythm and delay the secretion of melatonin [20,77]. Several lab-based experimental studies have shown that exposure to blue light from screens in the evening or prior to bedtime can impair melatonin secretion and the ability to fall asleep [83–90]. The effect is present when light is presented at time for dim light melatonin onset (DMLO), e.g., light exposure may delay DMLO and reduce nocturnal melatonin peak, an effect which is most pronounced for blue light (480 nm) [91]. For example, a randomized crossover study showed that nighttime use of light-emitting e-readers on handheld devices compared to reading a printed book decreased melatonin levels, delayed sleep onset, and reduced the feeling of evening sleepiness [88]. In contrast, a study examining 1-h evening exposure to light from devices found no differences in sleep onset latency and sleepiness [92]. Another explanation for the negative influence of digital media use on sleep is the interplay between blue-light screen exposure and the content watched on the screen [93]. Another hypothesis is the sleep displacement hypothesis where digital media is used as an activity to fall asleep, which may adversely impact sleep by delaying bedtime and sleep onset [77]. The mechanisms behind the relationship between digital media use and sleep are not well empirically established, but central mechanism in explaining changes in bedtime, circadian rhythm and sleep must be found in the two-process model, which is fundamental for sleep regulation. Two main processes should be in sync for normal sleep and awake regulation and functioning: the circadian and the homeostatic (sleep-wake) process. Evening light exposure and prolonged bedtime will inevitably affect sleep process and sleep duration and subsequent daytime function. Shorter sleep time is further associated with more sleep problems including insomnia [7].

### 4.2. Type of digital media device

With respect to type of device, this review found support for a negative association between mobile phone use and sleep. Some studies found negative impacts on sleep from notification or other disturbances from the digital media during night time. For example, Rod et al. demonstrated that those with frequently smartphone interrupted sleep on average reported sleeping almost 1 h less than those with uninterrupted sleep [42]. The authors concluded that smartphone interrupted sleep was not associated with sleep quality. Still, other studies found that nighttime mobile phone use and awakenings or notifications from the mobile phone were negatively associated with sleep quality [46,66,70]. It is possible that addition or problematic use of smartphone/mobile phone explain the effect of disturbances during nighttime on subjective sleep quality. For instance, it was shown that people who are more anxious about and dependent on digital media have more nighttime phone awakenings which was associated with more sleep problems [66].

Additionally, it is possible that this negative sleep effect results from small size devices. Small-sized devices such as smartphones are held closer to the face with risk of blue light exposure, interact with the user and are easier to use in constant interaction routine (including sleeping with the mobile phone in bed), which may impair the circadian rhythm. Also, these devices are usually placed near the user where vibrations for notifications could interrupt

sleep. The nighttime use of smartphones and social media may be particularly likely to influence sleep, as young people who are exchanging messages right before bed may find it difficult to disengage from these conversations for sleep, or content in social media can be psychologically stimulating inducing hyperarousal reactions.

Three studies included in the current review examined gender differences in the association between smartphone use and sleep quality [46,73,76]. There was some consistency across studies that call and text interactions, nighttime notifications or availability demands (the perceptions that you have to be reachable via the mobile phone at any time) are associated with immediate disturbed sleep among women (cross-sectional analyses) [46,73,76]. In contrast, a study that examined smartphone interactions found that more Facebook friends and call/text interactions were associated with better sleep for men at 4-month follow-up [76]. Thus, smartphone use may have a positive impact on sleep among men, although the authors argued that these results may reflect a person's sociability [76]. The negative impact of digital media use may be reflected to a greater extent by the content, timing, and amount of digital media use rather than the network size. This is supported by a longitudinal study showing that number of friends on Facebook is associated with better mental health, but use of Facebook features is related to poorer mental health [94]. Same mechanism may be applicable for the relationship between digital media use and sleep. Moreover, potential gender differences may reflect gender-specific digital media use. This was, however, not a part of the current review, but Murdoch et al. reported that women have more daily text messaging and more nighttime notifications from the smartphone compared to men [46].

#### 4.3. Strengths and limitations

Our systematic review had several strengths. This study is the first to try gather the literature on any type of digital media and sleep parameters among 16–25-year-olds. Furthermore, we made a comprehensive systematic review that complied with guidelines from the Cochrane Rapid Reviews method group, and we used a validated assessment tool to qualify studies, and only included those with the best quality. Current review also had limitations. Only papers written in English, Danish, Norwegian, and Swedish as well as samples from Western countries were included, thereby limiting the generalizability of findings. Likewise, some of the included studies were done on a sample of college students or self-referred, which also limited the generalizability of the findings. In some of the studies an age range was not explicitly provided, which made it difficult to ensure that the results from these studies were consistent with late adolescent and young adults. Another limitation is the heterogeneity of included studies, which precluded a meta-analysis.

Our review highlights several gaps in the current evidence base on the association between digital media use and sleep. First, many studies (about half of the included studies) used a global measure when assessing digital media use, thus not exploring the timing of screen use (e.g., daytime or nighttime specific usage). For example, Murdock et al. assessed the average number of daily texts by asking the participants to count the number of text messages they had sent and received during the previous 24-h period [46]. Despite many studies in the current review included nighttime digital media use, the lack of daytime specific use precludes from examining whether digital media use in the daytime can affect sleep. Second, most studies used a cross-sectional design, making it difficult to draw conclusion about causal directions and our results

may be due to reversed causality. Studies examining strategies for improving sleep by reducing digital media use at night can support our findings and provide some indirect evidence of causation and that reducing media use has a positive effect on sleep. However, few studies focus on young adults, but interventions in adolescents have shown positive effects on sleep [95–97]. For example, a targeted strategy of mobile phone restriction in the hour before bed among adolescents resulted in “lights out” 17 min earlier and a total sleep time increase of 19 min per night [97]. Still, more longitudinal studies, interventional or experimental studies manipulating the use of digital media are required to better disentangle the relationships observed from the included studies. Third, most of the studies used self-reported measurements of digital media use and sleep outcomes, and therefore had a risk of misclassification, recall and social desirability bias. Future studies should to a greater extent use objective measurement for sleep, e.g., sleep diaries, actigraphy, and applications to smartphones. Moreover, there is a need for validated measures of digital media use to determine when and how digital media is used. Fourth, there is a need for future studies to examine gender differences.

## 5. Conclusion

Associations were consistently demonstrated for digital media use and delayed bedtimes, daytime tiredness, early awakening, sleep deficits, sleep duration as well as sleep quality in late adolescents and young adults. There were inconsistent results for sleep onset latency, problems falling asleep, sleep disturbances and daytime function. The strongest evidence was seen for digital media use, including general screen use, use of mobile phones, computers (including gaming), internet and social media, and shorter sleep duration as well as poor sleep quality. Awareness of these findings may have practice implications to public health due to the increasing use of digital media worldwide and high prevalence of short sleep and poor sleep quality among young people. The age range of 16–25 years is characterized by increasingly autonomy regarding how to use own time and a period where social media use may become more intense. Therefore, young people themselves should become aware of how use of digital media may impact sleep negatively. Both families, schools, public health campaigns and clinical practice could be relevant to assist young people in developing good sleep habits.

### Practice points

1. The findings in current review contribute to increasing awareness on the possible negative impact of digital media use on sleep in late adolescence and young adulthood.
2. Current evidence demonstrates that particularly bedtime and nighttime use of digital media may result in later bedtime, shorter sleep time, poorer sleep quality and daytime tiredness.
3. More awareness on screen use and activating processes before sleep is needed.

## Research agenda

Future research could benefit from.

1. More rigorous experimental or longitudinal designs. It is warranted to clarify the causal relationship between digital media use and sleep, and investigation of both light and content suppressing the sleep wake and circadian process.
2. More research utilizing objective measures of sleep outcomes and validated measures of digital media use.
3. Measures of a broad range of digital media activities and how content may cause activation or deactivation.
4. Explore when digital media are used to determine the impact of using digital media at different times throughout day and night.
5. Investigate gender difference and other possible moderators in the relationship.

## Declaration of competing interest

The authors declare not to have any conflict of interest.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.smr.2022.101742>.

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