

A Descriptive Epidemiology of Screen-Based Devices by Children and Adolescents: A Scoping Review of 130 Surveillance Studies Since 2000

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Abstract

Introduction: Excessive use of screen-based devices can be detrimental for child and adolescent health. While epidemiological reviews have been focusing on traditional screen-based activities (e.g., television, computer use), the availability of newer screen-based devices (e.g., mobile phones, tablets) has increased considerably in recent years. However, there is limited understanding of the descriptive epidemiology of these newer devices and their contribution towards health-related screen time guidelines (≤ 2 h/day). This systematic scoping review synthesizes the descriptive epidemiology of screen-based devices, incorporating newer forms of screens, among 5-18-year-olds. **Methods:** Medline, Web of Science, PsycINFO, SPORTDiscus, ERIC, Science Direct, and Scopus databases were searched for articles published in English since year 2000. Search terms included terms that related to screen time and target population. Data were extracted from 130 population-based surveillance studies (minimum sample size $N = \geq 5000$). Screening and data extraction (study characteristics, estimates of prevalence rates and screen time-use point-estimates) were performed in duplicate for accuracy. **Results:** Television viewing (64.3%) was the most common measure of screen time, whilst fewer reported on newer screen-based devices (mobile phones: 4.6%, active gaming consoles: <1%). On average, 52.3% of participants ($k = 19$ studies) exceeded 2 h/day of screen time and total screen time was 3.6 h/day (1.3-7.9 h/day). **Conclusions:** Findings can inform and facilitate future research and policy designed to limit overall screen time among children and adolescents for health gains where appropriate. Moreover, policy makers can use this information to track and monitor screen time among children and adolescents.

Keywords: Children and adolescents; Technology; Screen time; Mobiles; Television; Scoping review

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1. Introduction

Sedentary behaviour involves seated or reclining postures with low energy expenditure during waking hours (Tremblay et al., 2017), and comprises common behaviours, including television (TV) viewing, computer use, sitting in a car, or reading (LeBlanc et al., 2015). Screen time is a major contributor to overall sedentary time among children and adolescents (Gopinath, Hardy, Baur, Burlutsky, & Mitchell, 2012). Screen time refers to the time spent on screen-based behaviours including, but not limited to, TV viewing, recreational computer use, video gaming and more recently, smartphone and computer tablet use (LeBlanc et al., 2017).

Screen time research has expanded exponentially in the past decade, having shown that increased levels of screen time are negatively associated with independent physical health indicators among children and adolescents, often remaining after adjustment for physical activity and other health-related behaviours (e.g., diet, sleep quality) (Saunders, Chaput, & Tremblay, 2014). This includes unfavourable cardiometabolic risk factors, including increased adiposity and low physical fitness (Tremblay et al., 2011; Carson et al., 2016), although associations might be small and complex (Biddle, Garcia Bengoechea, & Wiesner, 2017). Psychological indicators have also been shown to be associated with high levels of screen time, including positive associations with depression, hyperactivity and internalising problems, and negative associations with self-esteem and academic achievement (Hoare, Milton, Foster, & Allender, 2016; Suchert, Hanewinkel, & Isensee, 2015). These findings are a cause for concern for physical and mental health given the increasing availability of screen-based devices, with many children and adolescents engaging in what are considered to be 'excessive' amounts of screen time (LeBlanc et al., 2017).

The Canadian Society for Exercise Physiology and the Australian Government Department of Health recommend that time spent in discretionary screen time be limited to ≤ 2 h/day for children and adolescents (Tremblay et al., 2016; Australian Government Department of Health, 2014). However, the prevalence of those not meeting these guidelines remains high, with epidemiological studies estimating that over 50% of Canadian children report screen time ≥ 2 h/day (LeBlanc et al., 2015). Moreover, there is some evidence to suggest that screen time may be increasing since 2000. Using the United Kingdom Time Use Surveys (UKTUS), Mullan (2017) found that children's screen-based activities increased by approximately half an hour between 2000 (2.9 h/day) and 2015 (3.4 h/day), while a large gender difference (46 m/day) was found for children's time playing video games, being greater for boys.

Given the rapid developments in digital technology, it is important that researchers recognise and keep pace with the shift in trends and time-use of newer screen-based devices such as mobile (cell) phones, smartphones, and tablets (The Lancet Child and Adolescent Health, 2018). In fact, recent evidence suggests that newer screen-based devices are now ubiquitous among children and adolescents. For example, 95% of American teenagers own a smartphone (Anderson & Smith, 2018), and 58% own or have access to a tablet computer (Lenhart, 2015). It is therefore important that researchers consider the time-use in newer screen-based activities, including the time using such devices, in addition to traditional forms of screens such as TVs and computers (Strasburger & Hogan, 2013; Houghton et al., 2015). This includes understanding use of screens while engaging in other potentially more beneficial activities such as physically active gaming (LeBlanc et al., 2017).

Few reviews have summarised the descriptive epidemiology of the use of screen-based devices by children and adolescents. The most recent review was conducted more than 10 years ago by Marshall, Gorely, and Biddle (2006) who reviewed 90 studies published between 1949 and 2004, mainly concerning TV viewing among children and adolescents. However, with continued developments in technology, it is important to update the evidence. Recently, Bauman, Peterson, Blond, Rangul, and Hardy (2018) synthesised 30 ‘population-representative’ studies published between 2012 and 2016, mainly on traditional forms of screen time (i.e., TV viewing and computer use). However, the descriptive epidemiology of newer screen-based devices (e.g., mobile phones) by children and adolescents, and its contribution towards health-related screen time guidelines (≤ 2 h/day) is less well documented, leaving a gap in the current literature.

The purpose of this paper is to conduct a systematic scoping review to describe the descriptive epidemiology (estimates of prevalence of current screen time guidelines and average usage) of screen-based device use, incorporating newer forms of screens, among children and adolescents. In addition, this paper will report gender differences and trends in screen use over time.

2. Methods

Scoping reviews are often used to provide a synthesis of a broad field of literature in terms of its nature, features and volume (Arksey & O’Malley, 2005). The present scoping review used an established methodological framework guided by Arksey and O’Malley (2005), and later refined by the Joanna Briggs Institute (Peters et al., 2015). Consistent with previous approaches (Arksey & O’Malley, 2005), this scoping

review consisted of five stages: (i) identifying the research question; (ii) identifying relevant studies; (iii) study selection; (iv) charting the data; and (v) collating, summarising, and reporting the results.

2.1. Stage 1: Identifying the research question

To identify the research question (*What is known about the current descriptive epidemiology and time-use for screen-based devices among children and adolescents?*), consensus was developed among authors around the critical concepts (Levac, Colquhoun, & O'Brien, 2010). For example, decisions were made to determine what behaviours were to be included in the term 'screen time' to assist the search, screening, and eligibility processes. According to the Sedentary Behaviour Research Network (Tremblay et al., 2017), screen time behaviours can be performed while being sedentary (e.g., watching TV whilst sitting) or physically active (e.g., playing video games whilst moving). Subsequently, our search strategy was designed to identify articles related to the time-use of sedentary and non-sedentary screen-based behaviours.

2.2. Stage 2: Identifying relevant studies

Medline, Web of Science, PsycINFO, SPORTDiscus, ERIC, Science Direct, and Scopus databases were searched up to December 2017 to identify studies related to screen time-use among children and adolescents. All sources were searched with a pre-piloted search strategy that utilised key terms and phrases related to screen time (e.g., TV viewing, computer, active gaming, technology, mobile phone) and age group (e.g., children, adolescents, youth). A complete search strategy for all sources is given in Online Resource 1. Peer reviewed articles written in English and published between 2000 and 2017 were sought. The starting point of the search (i.e., year 2000) was chosen in accordance with the current technological landscape (LeBlanc et al., 2017). Journals, reference lists of included studies, and previous reviews related to screen time-use among children and adolescents were manually searched.

2.3. Stage 3: Study selection

Inclusion criteria were set *a priori*: (i) population-based studies (i.e., cross-sectional, repeated cross-sectional, longitudinal) with a minimum sample size of 5000 participants; (ii) participants aged 5 to 18 years; (iii) studies reporting time-use data on at least one screen-based device; (iv) studies analysing data collected since 2000; (v) studies with apparently healthy populations (no diagnosed disease or disability). This review was limited to nationally representative population-based studies of children and adolescents aged 5 to 18 years. While in many high-income countries, children under 5 years now spend considerable time on the screen, the context is quite different for this age group and is best left to another review, as is

common in the physical activity literature. Two reviewers applied the inclusion criteria to articles identified in databases and manual searches, resolving all disagreements by consensus. A full reference list of included studies is given in Online Resource 2.

2.4. Stage 4: Charting the data

The research team developed a standardized data charting form (Levac et al., 2010). Information was extracted regarding study characteristics, including study year, country, time-period of data collection, study design, and study population. Data extraction was performed in duplicate for accuracy (Mathes, Klaben, & Pieper, 2017) and available in Online Resource 3.

2.5. Stage 5: Collating, summarising and reporting the results

A numerical summary of all studies was conducted (Arksey & O'Malley, 2005). A narrative approach was used to describe the distribution of studies in terms of overall number of studies, study design, geographical location, publication date, and characteristics of study populations (Peters et al., 2015; Daudt, van Mossel, & Scott, 2013).

Large heterogeneity existed across studies in terms of study population (e.g., gender, age, ethnicity), study design (e.g., cross-sectional, longitudinal) and study outcomes (e.g., prevalence, point-estimates). Therefore, to systematically analyse the time-use on various screen-based devices, we excluded studies that: (i) derived data from identical or generally similar samples and; (ii) stratified results entirely (i.e., did not present results as total sample) by demographic variables (e.g., gender, age, ethnicity). Finally, all remaining studies were condensed into two categories: (i) studies reporting on prevalence; or (ii) studies reporting point-estimates (i.e., typically summarised as measures of central tendency).

All screen time prevalence rates and point-estimates were presented separately for total screen time and by each screen-based device (i.e., TV, computer, video game console, mobile phone, active gaming console). Studies utilised a variety of hourly thresholds to report screen time prevalence (range: 1-5 h/day). Based on current screen time guidelines (Tremblay et al., 2016), studies utilising a 2 h/day threshold were reported, followed by other cut-off points used in the studies. For point-estimate-based studies, average time-use of various screen time behaviours were reported, in addition to condensing daily screen time into three categories: (i) "low" (<2 h), (ii) and "high" (2-4 h), based on international guidance on limiting child and adolescent screen time, and also, "very high" (>4 h) (Sandercock, Ogunleye, & Voss, 2012; Sandercock & Ogunleye, 2013). Given evidence of a gender difference for screen time-use among children and adolescents

(Mullen, 2017), studies that stratified by gender were analysed and reported separately. In addition, to examine whether screen time-use changes over time (Mullen, 2017), studies that reported trends in screen time-use were reported separately.

While the appraisal of methodological quality or risk of bias is not considered necessary for scoping reviews (Peters et al., 2015), we acknowledge there has been a shortage of research validating measures of self-reported and parent-reported screen time among children and adolescents. As such, we incorporated an assessment of quality regarding screen time measurement using the following criteria: (i) scale of known validity; (ii) scale reported as valid but no evidence provided; and (iii) scale of unknown validity.

3. Results

After screening 364 full-text articles, 130 studies (cross-sectional $k = 123$; repeated cross-sectional $k = 4$; longitudinal $k = 3$) were included in the review (see Figure 1). Table 1 summarises the characteristics of all studies. The majority ($k = 102$; 78%) reported prevalence on a variety of screen time behaviours. TV viewing ($k = 84$; 64%) was the most common measure of screen time, while less studied were time-use in newer screen-based devices, such as mobile phones ($k = 6$; 5%) and active gaming consoles ($k = 1$; <1%). No studies reported on the time-use of smartphones or tablets exclusively, while one study explored the time-use of 'small screen recreation' defined as use of smartphones, tablets, video game consoles, and computers. A large number of studies were conducted in the USA, Europe, and Canada, while sample sizes ranged from 5,003 - 443,821. Most (75%) studies were published between 2012 and 2017, a threefold increase from the previous ten-year period (2002 - 2011). Screen time estimates within studies were mostly based on self-report, such as surveys, most of which used items of unknown validity ($k = 87$; 67%).

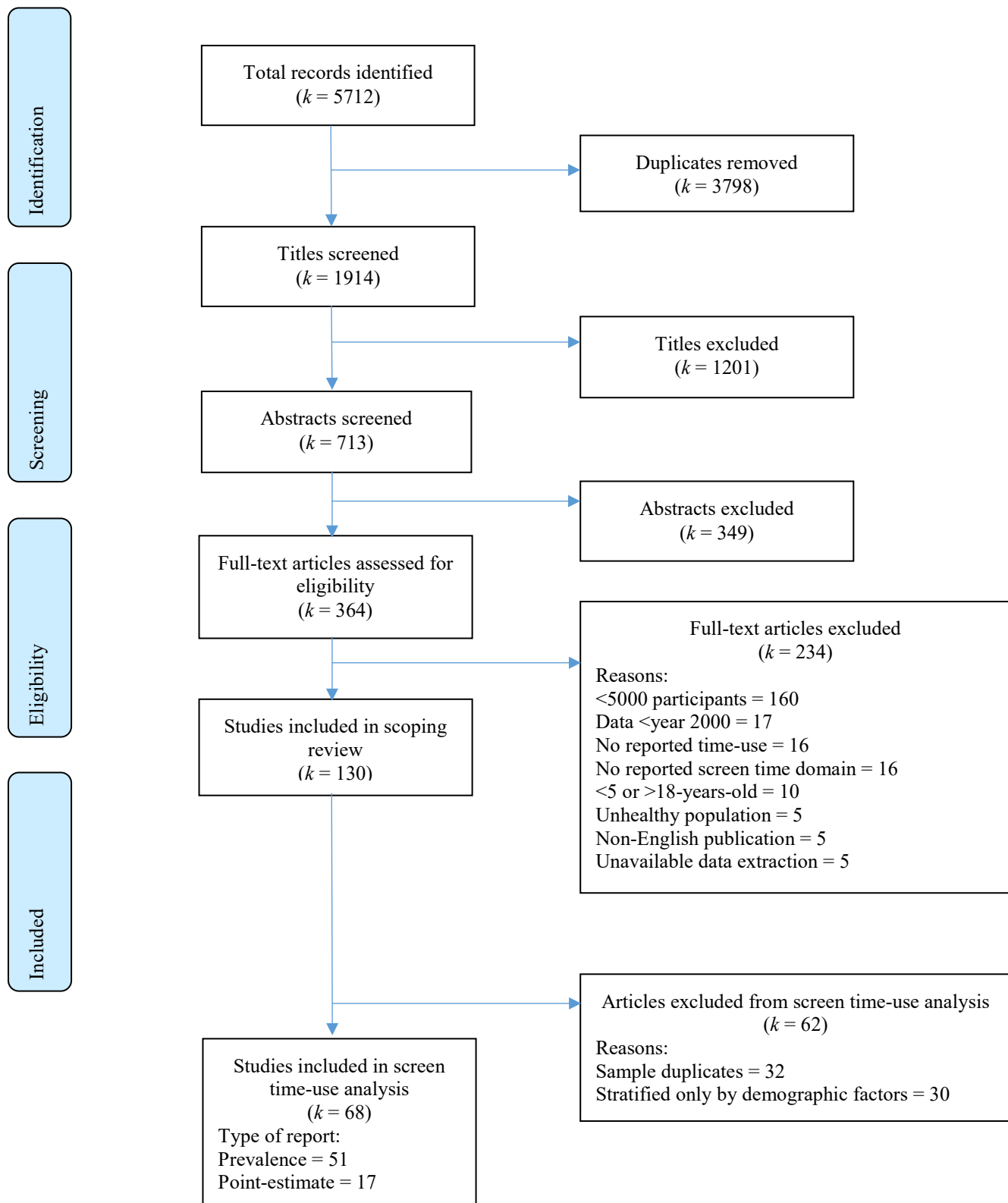


Figure 1. PRISMA flow diagram for selection of studies

Table 1. Study characteristics of included studies ($k = 130$)

Characteristics of study	k (%)
Sample size	
5000-10,000	45 (35)
10,000-20,000	48 (37)
>20,000	37 (28)
Age group (years)	
Children (5-11)	19 (15)
Adolescents (12-18)	52 (40)
Children and Adolescents (5-18)	59 (45)
Study location	
USA	45 (35)
Europe	31 (24)
Canada	16 (12)
China	9 (7)
Global	7 (5)
Iran	7 (5)
Australia	5 (4)
Other	10 (8)
Study date	
2002-2011	33 (25)
2012-2017	97 (75)
Study design	
Cross-sectional	123 (95)
Repeated cross-sectional	4 (3)
Longitudinal	3 (2)
Study report	
Prevalence	102 (78)
Point-estimate	28 (22)
Study measurement	
Self-report	106 (82)
Parent-report	20 (15)
Combined	4 (3)
Measure quality assessment	
Scale of known validity	40 (31)
Scale reported as valid but no evidence	3 (2)
Scale of unknown validity	87 (67)
Screen time devices	
Total screen time	59 (45)
Television	84 (64)
Computer	39 (30)
Video gaming console	24 (18)
Mobile phone	6 (5)
Active gaming console	1 (1)
Combination of devices (CPU/VG, TV/VG, 'small screen recreation')	18 (14)
Screen time usage	
Internet use	10 (8)
Social networking	4 (3)

k = number of studies, CPU = computer, VG = video game console, TV = television

3.1. Screen time-use

Of 130 studies, 68 were eligible for the screen time-use analysis (i.e., unique and non-stratified samples). Prevalence studies ($k = 51$) are summarised, followed by point-estimate-based studies ($k = 17$).

Results are presented separately for total screen time and by each screen-based device (i.e., TV, computer, video

game console, mobile phone). A summary of time-use for social networking and internet use is also provided, though it is not within the scope of this study to determine which device these behaviours were engaged in.

3.1.1. Prevalence studies ($k=51$)

Of 51 prevalence-based studies, 72.5% ($k = 37$) used a 2 h/day threshold to report the time-use in various screen time devices. The remaining studies utilised numerous cut-off points including 1 h/day ($k = 4$), 3 h/day ($k = 9$), 4 h/day ($k = 4$), and 5 h/day ($k = 1$). The average prevalence rates for the time-use of various screen-based devices are presented in Table 2.

Table 2. Average prevalence of those exceeding hourly thresholds for various screen-based devices and behaviours ($k = 51$)

Screen time device	% exceeding the threshold, (range)				
	1 h	2 h	3 h	4 h	5 h+
Total screen time	NA	52.3 (18.6-84.9) $k = 19$	41.4 (18.1-72.2) $k = 3$	39.3 (39.3-39.3) $k = 2$	5.6 $k = 1$
Television	NA	44.8 (4.7-89.3) $k = 23$	31.5 (14.3-59.1) $k = 7$	13.1 (13.0-13.2) $k = 2$	NA
Computer	53.0 (35.0-70.9) $k = 2$	23.9 (5.4-63.7) $k = 12$	7.0 $k = 1$	NA	NA
Video game console	NA	32.6 (13.7-60.2) $k = 8$	NA	NA	NA
Video game console/computer	NA	8.8 $k = 1$	30.5 (24.9-41.7) $k = 3$	9.5 $k = 1$	NA
Mobile phone	10.8 (6.8-14.3) $k = 2$	NA	NA	NA	NA
Small screen recreation ^a	NA	57.1 $k = 1$	NA	NA	19.5 $k = 1$
Internet use ^b	NA	43.7 (30.1-51.1) $k = 2$	NA	NA	NA
Social networking ^b	NA	42.2 (36.9-47.4) $k = 2$	NA	NA	NA

k = number of studies;

h = hourly threshold;

NA = No study available

^asmartphones, tablets, computers, video games console

^bdevice unknown

Of 19 studies that reported total screen time, 52.3% (18.6%-84.9%) of participants exceeded 2 h/day. For TV viewing ($k = 23$), 44.8% (4.7%-89.3%) of participants, exceeded 2 h/day, whereas 23.9% (5.4%-63.7%) of participants exceeded 2 h/day on the computer ($k = 12$). Of eight studies that reported video gaming, 32.6% (13.7%-60.2%) of participants exceeded 2 h/day. For video gaming and computer use combined, 8.8% of participants exceeded 2 h/day. No studies reported mobile phone use that utilised a 2 h threshold, though 10.8% (6.8%-14.3%) of participants exceeded 1 h/day ($k = 2$). A singular study existed that summed time-use of smartphones, tablets, computers, and video games (see small screen recreation in Table 2) with a 2-hour threshold in which 57.1% participants exceeded this limit. For internet use ($k = 3$) and social networking ($k = 2$), 43.7% (30.1%-51.1%) and 42.2% (36.9%-47.4%) of participants exceeded 2 h/day respectively.

3.1.2. Point-estimate studies ($k = 17$)

Average time-use point-estimates for various screen time devices are presented in Table 3. Participants, on average, spent 3.6 h/day using a combination of TVs, computers, and video game consoles. For TV viewing and computer use, participants spent 2.0 h/day and 1.4 h/day respectively. More time was spent using video game consoles (2.4 h/day) and to the lesser extent, participants spent 1.5 h/day using a mobile phone. Active gaming consoles were less used (0.6 h/day), whereas internet use was more common (1.7 h/day).

Overall, 23.5% ($k = 4$) of studies reported low levels of daily total screen time (<2 h/day), 53% ($k = 9$) reported high levels of daily screen time (2-4 h/day), and 23.5% ($k = 4$) reported very high levels of daily screen time (>4 h/day). Of studies reporting high or very high levels of daily screen time (76.5%), the majority were engaged in through 'total screen time' (41%) and TV viewing (29%).

Table 3. Average time-use point-estimates on various screen-based devices ($k = 17$)

Screen time device (k)	Average point-estimate h/day, (range)
Total screen time ($k = 8$)	3.6 (1.3-7.9)
Television ($k = 9$)	2.0 (0.6-3.4)
Computer ($k = 4$)	1.4 (0.5-2.8)
Video game console ($k = 5$)	2.4 (0.2-7.3)
Mobile phone ($k = 2$)	1.5 (0.08-2.9)
Active gaming console ($k = 1$)	0.6
Internet use ^b ($k = 3$)	1.7 (0.6-2.3)
Level of daily total screen time	(%)
Low (<2 h/day)	23.5
High (2-4 h/day)	53.0
Very high (>4 h/day)	23.5

k = number of studies; h/day = hours per day

^bdevice unknown

3.2. Gender differences

Of 29 available studies that provided time-use data by gender, the majority ($k = 24$) reported screen time prevalence, while the remaining studies ($k = 5$) reported point-estimates for various screen time devices. More than half of the studies ($k = 15$) used a scale of unknown validity.

3.2.1. Prevalence studies ($k = 24$)

As shown in Table 4, about half of boys and girls exceeded 2 h/day of total screen time. For TV viewing, these amounts were also comparable (boys: 46.5%; girls: 43.6%), as was time spent on a computer (boys: 18.1%; girls: 21.6%). More than double the number of boys (23.1%) exceeded 2 h/day on video game consoles compared to girls (10.5%). Table 4 also gives an overview of the proportions exceeding 2 h/day for small screen recreation (smartphones, tablets, computers, and video game consoles), internet use, and social networking for boys and girls separately.

Table 4. Average prevalence on various screen-based devices by gender ($k = 24$)

Screen time device (k)	% exceeding 2 h/day (range)	
	Boys	Girls
Total screen time ($k = 9$)	54.5 (25.1-83.1)	50.6 (21.4-77.1)
Television ($k = 12$)	46.5 (25.6-70.3)	43.6 (23.2-65.0)
Computer ($k = 4$)	18.1 (12.3-28.3)	21.6 (6.9-31.7)
Video game console ($k = 5$)	23.1 (4.0-37.9)	10.5 (1.3-21.5)
Small screen recreation ($k = 1$) ^a	58.2	56.0
Internet use ($k = 1$) ^b	39.3	39.7
Social networking ($k = 1$) ^b	16.1	18.1

k = number of studies; h/day = hours per day

^asmartphones, tablets, computers, video game consoles

^bdevice unknown

3.2.2. Point-estimate studies ($k = 5$)

Table 5 shows that boys and girls spend similar amounts of daily total screen time, TV viewing, and internet use. Boys spend more time on the computer and video game consoles compared to girls, while girls spend more time using their mobile phone compared to boys.

Table 5. Average point-estimates on various screen-based devices by gender ($k = 5$)

Screen time device (k)	Average point-estimate h/day, (range)	
	Boys	Girls
Total screen time ($k = 2$)	8.2 (8.0-8.3)	8.0 (7.9-8.0)
Television ($k = 5$)	1.9 (1.0-2.5)	1.9 (0.9-2.4)
Computer ($k = 2$)	3.4 (3.1-3.7)	2.7 (2.5-2.9)
Video game console ($k = 2$)	2.1 (2.1-2.1)	0.6 (0.6-0.6)
Mobile phone ($k = 2$)	2.2 (2.0-2.3)	3.1 (2.8-3.3)
Internet use ($k = 2$) ^b	2.0 (1.9-2.0)	2.4 (2.3-2.4)

k = number of studies; h/day = hours per day
^bdevice unknown

3.3. Trends in screen time-use ($k = 7$)

Seven studies (repeated cross-sectional $k = 4$; longitudinal $k = 3$) were available that reported trends in screen time-use over time. Most studies were conducted in the USA ($k = 6$) as part of the Early Childhood Longitudinal study ($k = 2$), Youth Risk Behaviour study ($k = 2$), Health Behaviour in School-aged Children study (USA edition; $k = 1$) and CHOICE study ($k = 1$). The remaining study derived data from the cross-national edition of the Health Behaviour in School-aged Children study, comprising 30 different countries in Europe and North America. Most studies ($k = 6$) used a scale of unknown validity. Time-use trends of various screen-based devices were reported (see Table 6).

Table 6. Trends over time on various screen-based devices ($k = 7$)

Screen time device (k)	Years of follow-up	Direction of trend (+/-)	
USA			
Television ($k = 5$)	2001-2014	+/-	
Computer ($k = 2$)	2006-2014	+	
Video game console ($k = 1$)	2010-2011	+	
Cross-national monitoring			
Total screen time ($k = 1$)	2002-2010	+	
Television ($k = 1$)		Boys	Girls
Computer ($k = 1$)		-	-
		+	+

k = number of studies
 + = positive trend
 - = negative trend

A cross-national monitoring study reported an increase in total screen time between 2002 and 2010 for 11-year-olds (+1.4 h/day), 13-year-olds (+1.9 h/day), and 15-year-olds (+2.1 h/day). The same study reported a decline in TV viewing for boys (-0.4 h/day) and girls (-0.3 h/day), while computer use increased, with an increase of 2.2 h/day and 2.1 h/day for boys and girls, respectively. Of studies conducted in the USA ($k = 5$), three reported an increase in TV viewing between 2001 and 2010 among 6-15-year-olds, while two noted declines between 2007 and 2015 among 14-17-year-olds. Two American studies reported increases in computer use between 2001 and 2014 among 11-16-year-olds. Precise estimates of change were not possible due to method and reporting differences. A singular American study reported an increase (+2.8 h/day) in sedentary video gaming between 2010 and 2011 among 11-14-year-olds.

4. Discussion

This paper is a systematic scoping review of the descriptive epidemiology (estimates of prevalence of current screen time guidelines and average usage) of screen-based device use, incorporating newer forms of screens, among children and adolescents.

To our knowledge, this is the first review to comprehensively describe the population-based literature concerning the descriptive epidemiology of screen-based device use among children and adolescents. We also provided an expanded update to previous syntheses (Marshall et al., 2006; Bauman et al., 2018) by incorporating newer forms of screen use into our review. Overall, we identified that screen time was common among children and adolescents, with over 50% of individuals exceeding screen time guidelines of 2 h/day. Given the negative health outcomes associated with excessive screen time among children and adolescents (Carson et al., 2016), these high prevalence levels are concerning from a public health perspective.

Consistent with previous time-use surveys (Mullen, 2017), we found evidence that the combination of watching TV, using computers and playing video games has increased over time, while TV viewing decreased by a relatively small amount. It is possible that the increase in total screen time is compensated by time spent on video game consoles, especially among boys (Mullen, 2017), with our review highlighting that boys reported higher time spent engaged in this activity, compared to girls (2.1 vs 0.6 h/day). These findings might reflect a displacement of TV viewing by the use of newer screen-based devices that support high levels of screen time. The issue of substituting time spent on traditional devices (e.g., TV) to engage in newer screen-based devices (tablets, smart phones etc.) needs to be examined in future research. Moreover, a recent review suggested that changes to time spent in sedentary behaviours (i.e., screen time) may be displaced into either movement (including standing) or sleep, and thus these other behaviours also need to be investigated (Okely, Tremblay, Reilly, Draper, & Bull, 2018).

We also identified few longitudinal studies assessing the extent and nature of change in the time children and adolescents spend in screen-based activities, especially during a period that has witnessed rapid technological change (LeBlanc et al., 2017). We showed evidence, albeit small, that TV viewing has decreased in recent years. It is unclear whether this decrease is in part the result of parents following public health recommendations to limit screen time or reflects a displacement of TV viewing by the use of novel platforms (Chassiakos et al., 2016). Longitudinal studies are needed to examine the time-use in newer screen-based devices over time, and whether there are unique health consequences compared with more traditional forms of screen time. This includes understanding the use of mobile devices and tablets while engaging in other more beneficial activities (e.g., watching TV while running on a treadmill) (LeBlanc et al., 2017). Moreover, further

understanding is needed on whether using a screen has simply replaced a similar behaviour that previously did not use a screen (e.g., switching from reading a hard-copy book to a screen-based device) or whether the screen behaviour is a new one that has replaced a previously 'healthy' behaviour.

A key finding of the present review was that among population-based surveillance studies, there was limited information on the time-use of newer screen-based devices, including smartphones, mobile phones, tablets, and active gaming consoles, at least in the large-scale studies ($N = \geq 5000$) we included. Using data from two nationally representative UK time-use surveys (2000-2015), Mullan (2017) found an increase in the time children spent using mobile devices and tablets, especially when engaging in other activities throughout the day (i.e., time at school, during travel, and when eating). These findings reflect a rapid growth in digital media usage, including interactive and social media (The Lancet Child and Adolescent Health, 2018; Chassiakos, Radesky, Christakis, & Moreno, 2016), and highlights the importance of acknowledging that the use of mobile devices and tablets form a part of daily life among children and adolescents. Therefore, mobile devices such as smartphones and tablets should be included in future assessment of screen time activities for children and adolescents.

It is important to consider that while TV viewing appears to be associated with negative behavioural and health outcomes (Carson et al., 2016; Hoare et al., 2016; Hale & Guan, 2015), evidence for newer forms of screen time (e.g., active gaming, online communication such as Skype) remains less certain and, in some cases, may be beneficial (Li & Atkins, 2004; Bell, Bishop, & Przybylski, 2015). Active video gaming has gained interest as a way to increase physical activity in children and adolescents, with a systematic review showing that active video gaming increased energy expenditure above rest and when compared to sedentary video gaming (Peng, Crouse, & Lin, 2013). Moreover, Gao, Chen, Pasco, and Pope (2015) conducted a meta-analysis of 35 studies and found that compared to sedentary behaviours, active video gaming had a large positive effect on physiological and psychological responses including heart rate and enjoyment. These results suggest that active video gaming can be used to replace young people's sedentary behaviour, such as screen time, while maintaining game enjoyment. However, if or how active gaming leads to increases in habitual physical activity or decreases in sedentary behaviour remains unclear (LeBlanc et al., 2013).

It is also emerging that forms of screen time (e.g., computer use) may be beneficial for cognitive development, while others (e.g., TV viewing) tend to be associated with poorer mental health, although the field is still in its infancy and somewhat mixed (Hoare et al., 2016; Biddle & Bandelow, 2017). Research has also showed that the context in which children and adolescents use the internet might affect mental health outcomes

differently. For instance, in children who perceive that their friendship qualities were low, using the internet to communicate was related to less depression and fewer internalising problems, whereas using the internet for non-communication, such as browsing, was associated with higher depression and social anxiety (Foley & Maddison, 2012). The effect of the content children encounter online should also be the focus of future studies (The Lancet Child and Adolescent Health, 2018). With the need for children to have 21st Century skills, the balance between ‘healthy’ and ‘unhealthy’ screen use is likely to be a challenge.

4.1. Limitations

A key limitation of the present study was that most studies used self-reported measures of screen time, which may not be the most valid and reliable assessment method given the challenges some children and adolescents will have in accurately recalling behaviours (Saunders, Prince, & Tremblay, 2011). A small number of studies used parent-reported measures of screen time, which also lack precision and are prone to numerous biases (Lubans et al., 2011; Robinson, Winiewicz, Fuerch, Roemmich, & Epstein, 2006). LeBlanc et al. (2017) suggests that unobtrusive, low-burden, device-based measures of screen time are needed to provide better estimates of screen time and its associations with health outcomes. One such alternative approach might be life logging, which involves the digital capture of life activities through first-person point-of-view images, or wearable cameras (Kelly et al., 2011). However, this method of surveillance presents ethical challenges related to privacy and participant burden (Kelly et al., 2013).

Secondly, given that the current review excluded studies with a sample size <5000, it is possible that some data were lost and not included in the present review. For example, this could explain why time spent on modern screens, such as mobile phones, were significantly lower compared to traditional screens (e.g., TVs, computers). Therefore, researchers in behavioural epidemiology are encouraged to utilise measures (e.g., national surveys) that assess children and adolescents’ time spent on modern screens (e.g., mobile phones, tablets, active gaming consoles), in addition to traditional forms of screens (e.g., TVs, computers).

Thirdly, it was not within the scope of this review to ascertain the devices for children and adolescents’ internet use and social networking. Given the nature and multi-functionality of contemporary screen use, it is possible that these behaviours were performed on various screen-based devices (e.g., social networking on laptop, mobile phone or tablet). More intensive research, using a mix of qualitative and quantitative methodologies, are needed to understand the nature of various screen time activities, including but not limited to, internet use and social networking.

Finally, while we were able to conduct a basic numerical analysis of screen time-use among children and adolescents, we recognise that there was a large variation in results. For instance, across 23 prevalence-based studies, children and adolescents exceeding 2 h/day of TV viewing ranged from 4.7% to 89.3% and thus, average screen time prevalence must be considered with caution.

4.2. Future directions

The issue of multitasking and the nature of how children and adolescents interact with multiple screens requires further consideration. For example, TV programmes are watched on tablets, smartphones play music, and ‘Smart TVs’ can be used to surf the internet and play games. There is evidence to suggest that children and adolescents embrace the multi-functionality of devices to engage in multiple forms of screen viewing simultaneously, known as ‘multitasking’ (Jago, Sebire, Gorely, Cillero, & Biddle, 2011). At present, most questionnaires assess each screen time behaviour independently, and thus it is likely that estimates of total screen time are exaggerated for individuals who multitask. For research to advance in this field, questionnaires, or other measures must assess multitasking behaviours in order to produce accurate estimates of total screen time amongst children and adolescents, in addition to explore the subsequent associations with health outcomes.

5. Conclusion

Among large population-based surveillance studies of children and adolescents, we showed that over half exceed the current screen time guidelines. Policy makers can use this information to track and monitor screen time among children and adolescence. In addition, we found limited information on the time-use of newer screen-based devices, including smartphones, mobile phones, tablets, and active gaming consoles. We also identified a lack of validated questionnaires and device-based assessment of screen time within studies. Accurate and consistent measurement of screen time is essential to guide evidence-based public health practice and facilitate health promotion initiatives. Longitudinal studies that provide greater precision for device-based data concerning newer forms of screen time-use are warranted to improve our understanding of the true nature of screen time, and to inform future research and policy designed to limit overall screen time among children and adolescents for health gains where appropriate.

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