

SPECIAL ISSUE ARTICLE**EFFECTS OF EMERGING TECHNOLOGIES****Excessive use of mobile devices and children's physical health**Sarah E. Domoff  | Aubrey L. Borgen | Ryan P. Foley | Anissa Maffett

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Abstract

Children's mobile device (e.g., smartphone, tablet) access and ownership has grown substantially in the past decade. Concerns exist regarding excessive use and the impact of frequent consumption of mobile media on children's health and well-being. We review the literature on the harmful physical health correlates of excessive mobile device use during childhood and adolescence. Strongest evidence emerged regarding the impact of excessive mobile device use and sleep outcomes. Mixed evidence emerged regarding excessive use of mobile devices and physical activity and obesity. Too few studies were identified to draw conclusions about mobile device use and the following health concerns in children: musculoskeletal outcomes/pain, ocular health, and migraine/headaches. Recommendations for future research on the association between excessive mobile device use and children's physical health outcomes (particularly investigations into the experience of musculoskeletal pain/discomfort, ocular symptoms, and neurological symptoms) are discussed.

KEYWORDS

adolescents, human body, smartphone usage

Children's mobile device (e.g., smartphone, tablet) access and ownership has grown substantially in the past decade (Rideout, 2015; Rideout, 2017). Concerns exist regarding excessive use (Felt & Robb, 2016) and the impact of frequent consumption of mobile media on children's well-being (Common Sense Media, 2018). Prior reviews of the literature have investigated the potential impact of problematic smartphone use on mental health outcomes (e.g., depression: Elhai, Dvorak, Levine, & Hall, 2017; anxiety: Elhai, Levine, & Hall, 2019) and the benefits of mobile phones for improved health outcomes (i.e., via mHealth interventions: Cornet & Holden, 2018; Gindidis, Stewart, & Roodenburg, 2018; Seko, Kidd, Wiljer, & McKenzie, 2014). Heretofore, most literature reviews on the physical health correlates of excessive use of mobile media have focused on sleep (e.g., Hale & Guan, 2015); to date, the literature on other domains of physical health potentially adversely impacted by mobile device use has not been considered in child and adolescent populations. As such, in this article, we review the recent literature on the harmful physical health correlates of excessive mobile device use and use of specific applications ("apps", e.g., social media, gaming) during childhood and adolescence.

1 | MEASUREMENT OF EXCESSIVE USE

There has been much debate regarding what constitutes excessive use of screen media. Research on the physical health correlates of traditional media (e.g., television or TV) typically used hours of screen time, often with a cutoff of greater than 2 hr per day as indicating high use (e.g., Laurson et al., 2008; based on prior American Academy of Pediatrics recommendations: Bar-On et al., 2001; Strasburger, 2011; Strasburger et al., 2013). However, with newer media and mobile technology, studies examining excessive use have gone beyond hours of screen time. Specifically, studies have implemented measures quantifying problematic use or "addictive" use (e.g., Domoff et al., 2019; Lemmens, Valkenburg, & Gentile, 2015; van den Eijnden, Lemmens, & Valkenburg, 2016), often based on the Diagnostic and Statistical Manual's (DSM) criteria (i.e., DSM-5; American Psychiatric Association, 2013) for internet gaming disorder or adaptations of the Internet Addiction Test (Young, 1998; e.g., Lister-Landman, Domoff, & Dubow, 2017) to capture excessive use. With the latter, problematic use is conceptualized as excessive use of screen media that causes problems in a person's functioning or interferes with their life and well-being

(Domoff et al., 2019). Problematic use is not indicated solely by number of hours of use; individuals must experience conflict or disturbance in functioning to indicate a clinically significant problem with screen media use. Given the range of measures used to assess excessive use of screen media, both conceptualizations—hours of screen time and problematic use—will be considered in this review.

2 | PHYSICAL HEALTH CORRELATES OF TRADITIONAL MEDIA USE AND NEWER MEDIA

The most widely supported physical health correlates of traditional media use, such as TV viewing, computer usage, and video game play, are child obesity (Robinson et al., 2017) and poorer sleep health (LeBourgeois et al., 2017). Mechanisms linking TV time, specifically, to child obesity include exposure to advertisements, food consumption while viewing TV, and disrupted sleep (Robinson et al., 2017). Current research on newer media indicate similar mechanisms of effect, particularly because TV programming can be streamed through mobile devices and advertisements are embedded in streaming apps, gaming apps, and social media (Robinson et al., 2017). Specific to traditional media and sleep, screen time appears to delay when children go to bed (i.e., computer usage is associated with later bed times) and having screens in the bedroom may delay sleep onset (Hale & Guan, 2015). Newer media is suggested to have a more detrimental impact on children's sleep health, given the interactive nature of mobile media and apps (Carter, Rees, Hale, Bhattacharjee, & Paradkar, 2016).

Unique features of mobile media and technology bring forth other potential health risks for children. In particular, musculoskeletal pain and discomfort from utilizing smartphones and tablets have been identified as health risks relevant to handheld devices (e.g., Berolo, Wells, & Amick III, 2011; Ning, Huang, Hu, & Nimbarte, 2015). In addition, light emitted from smartphones has been recognized as disruptive of melatonin secretion (LeBourgeois et al., 2017), instrumental for sleep onset. Thus, in addition to examining previously identified physical health correlates of traditional media, this review will also include other domains of physical health that are unique to the design and features of mobile media.

3 | METHODS

We utilized PsycINFO as the primary database for this literature review. The following health-related search terms were used in combination with media-related search terms (i.e., "tablet," "phone," "media use," "smartphone," "cellular device," "social media," "social networking," "texting," "electronic media," "screen media," and "excessive"): "health," "obesity," "sleep," "physical," "strain," "head," "back," "neck," "hand," "eye," "muscular," and "migraine." Only peer-reviewed articles that utilized quantitative methodology, with samples comprised of children and adolescents (less than 18 years of age) were selected for initial review (i.e., case studies and qualitative research were not included). In addition, we selected only articles published

between 2007 (year in which the iPhone was released) and 2018, inclusive.

With these search terms and parameters, 2,068 articles were identified. Abstracts of these articles were further reviewed to confirm that articles met inclusion criteria. We only included articles that met the following inclusion criteria: included at least one measure of physical health; included at least one measure of mobile device use or app (e.g., social media, gaming) use; and reported on the association between mobile device/app use and a physical health outcome. Of the 2,068 originally identified, 42 articles met the inclusion criteria.

4 | RESULTS AND DISCUSSION

Most articles included in this review investigated the link between mobile device use and sleep health ($n = 25$, 60%). The next most commonly studied physical health outcome was physical activity and obesity ($n = 10$; 24%; note that n will not add to 42 given multiple outcomes reported in papers). Very few studies emerged examining mobile device use and musculoskeletal outcomes/pain ($n = 4$; 10%), headaches or migraines ($n = 2$; 5%), and ocular/vision problems ($n = 2$; 5%). We review and discuss the findings by each primary health domain.

4.1 | Sleep health

Over the past decade, one physical health outcome affected by screen use has dominated the research in this area: sleep. Using our search parameters, this review identified 25 research articles that examined the potential impact of mobile devices on sleep health in children and adolescents. Studies are reviewed by category of sleep health: sleep duration, nighttime awakenings, sleep onset-latency, and overall sleep quality.

Sleep duration. Fourteen of the 25 identified studies used some measure of sleep duration, typically by asking participants (or their parent/guardian) to report on sleep and wake times or hours of sleep each night. Overall, these studies suggest that use of technology does adversely impact sleep duration. Ten of the included studies measured bedtime/nighttime media use using various methods, mainly self-report or parent-report, and either asked parents or youth to report on the amount of time using screen media before going to bed, or asked if any screens were present in the youth's bedroom (Arora, Broglia, Thomas, & Taheri, 2014; Dimitriou, Knight, & Milton, 2015; Dube, Khan, Loehr, Chu, & Veugelers, 2017; Lemola, Perkinson-Gloor, Brand, Dewald-Kaufmann, & Grob, 2015; Munezawa et al., 2011; Nathanson & Beyens, 2018a, 2018b; Oshima et al., 2012; Scott & Woods, 2018; Seo, Kim, Yang, & Hong, 2017). All studies that focused on nighttime use specifically found that social media, tablet, or smartphone use was associated with shorter sleep duration. Two studies only measured general use of these types of media throughout the day, but still found adverse effects on sleep duration (Ekinli, Çelik, Savaş, & Toros, 2014; Twenge, Krizan, & Hisler, 2017). One study found that media use had no effect on sleep duration (Lee & Ogbolu,

2018), and another study found mixed results, based on weekdays or weekends (Arrona-Palacios, 2017).

Sleep quality. Nine of the 25 identified studies included a measure of subjective sleep quality. Multiple studies measured overall sleep quality with commonly used inventories such as the Pittsburgh Sleep Quality Index (Liu, Zhou, Niu, & Fan, 2017; Woods & Scott, 2016; Xie, Dong, & Wang, 2018) or the School Sleep Habits Survey (Vernon, Barber, & Modecki, 2015; Vernon, Modecki, & Barber, 2018). A few studies developed measures specific to their research questions (Dube et al., 2017; Ekinci et al., 2014; Kubiszewski, Fontaine, Rusch, & Hazouard, 2014; Munezawa et al., 2011). Results from these nine studies suggest that bedtime use of mobile phones and social media, or addictive use of these devices, adversely affects subjective sleep quality.

Sleep disruption/nighttime awakenings. Four of the identified studies measured frequency of sleep disruptions or nighttime awakenings for the youth. Two of the studies found that problematic social networking was related to increased sleep disruptions (Vernon et al., 2015; Vernon, Modecki, & Barber, 2017), while one found that internet addiction was also associated with disruptions (Ekinci et al., 2014). One study examined specific effects of adolescents taking their mobile phones to bed with them; results indicated that those who do so are woken up by text messages at least two times each week (Adachi-Mejia, Edwards, Gilbert-Diamond, Greenough, & Olson, 2014).

Sleep-onset latency. Six of the identified studies measured sleep-onset latency, or how long it takes youth to fall asleep after going to bed. Two studies did not find significant associations between media use and sleep-onset latency (Arora et al., 2014; Heath et al., 2014). Three of the studies found a significant association between bedtime social media or smartphone use and increased latency (Fobian, Avis, & Schwebel, 2016; Pieters et al., 2014; Scott & Woods, 2018), while one study found increased latency associated with a measure of internet addiction (Ekinci et al., 2014).

4.2 | Physical activity and obesity risk

Contrasting with results found regarding mobile device use and sleep health, research examining physical activity (PA) and obesity as outcome variables were equivocal. Two studies reported positive associations between mobile device use and PA, such that greater mobile device or application use associated with increased PA (i.e., measured by hours of electronic communication time: Leatherdale, 2010; measured by ownership of cell phone and cell phone hours: Mojica, Parra-Medina, Yin, Akopian, & Esparza, 2014). Among studies that found positive associations between mobile device use and PA, it should be noted that Mojica et al. (2014) found that those who owned cell phones had a greater chance of reporting 5 days of PA in the last week, as well as participating in physical education classes, than those without cell phones. In addition, hours of cell phone use correlated with five or more days of PA each week (though no association was found between social media use and PA). Leatherdale (2010) found no

association between amount of electronic communication time (i.e., texting, calling) and overweight in children.

Four studies reported negative associations between screen time or device ownership and PA or obesity. Kenney and Gortmaker (2017) found that hours of device use (including smartphones and tablets) associated with increased obesity risk and less than 60 min of PA in the past 7 days. Another study (Dube et al., 2017) reported that access to cell phone in the bedroom (regardless of whether in use) was associated with greater obesity risk. Two studies specifically examined excessive use of social media and/or gaming and found significant association with sedentary behaviors or obesity. For example, Mérelle et al. (2017) found that both problematic social media and problematic video gaming were associated with greater sedentary behaviors (i.e., greater than 2 hr of sedentary behavior/day). Furthermore, Tsitsika et al. (2016) found that odds for obesity increased for youth who reported two or more hours of social media use per day.

Four studies reported null findings (e.g., Beltrán-Carrillo, Beltrán-Carrillo, González-Cutre, Biddle, & Montero-Carretero, 2016; Jackson, Von Eye, Fitzgerald, Witt, & Zhao, 2011; Williams, Li, Haynie, & Simons-Morton, 2018 found no association mobile phone use and PA or obesity) or mixed results (Devís-Devís, Peiró-Velert, Beltrán-Carrillo, & Tomás, 2012). Jackson et al. (2011) and Williams et al. (2018) found no association between cell phone use (hours per day) or social media use (hours per day) and obesity, respectively. For the study with mixed results, Devís-Devís et al. (2012) found that while greater mobile device use was associated with higher light PA on weekdays, it was inversely associated with light and moderate PA on weekends.

Overall, more research is needed on the associations between excessive mobile device use, PA, and obesity in children. Methodological limitations in the current literature, especially surrounding the wide range of methods used to quantify mobile device use, inhibit the ability to accurately assess these results and draw conclusions. Further, studies reviewed in this section used cross-sectional design, as well as relied largely on self-report to quantify both mobile device use and PA.

4.3 | Other indicators of physical health

The potential impact of excessive mobile device use on other factors of physical health, particularly musculoskeletal pain and discomfort, headaches, and eye strain, has become a concern for researchers and clinicians. Phone use, specifically, has been linked to increased neck and back pain (Kim & Koo, 2016), eye strain (Acharya, Acharya, & Waghrey, 2013), and increased risk for headaches (Wang, Su, Xie, & Yu, 2017). However, studies have primarily concentrated on adult populations and few studies thus far have investigated these physical health outcomes as they relate to excessive mobile device use in youth. Using the parameters of this current search, eight studies were identified as investigating the impact of phone use on other indicators of health.

Musculoskeletal and pain complaints. Our literature search yielded four cross-sectional studies that examined the association between

phone use and musculoskeletal pain and discomfort. Of the four, two studies (Palmer, Ciccarelli, Falkmer, & Parsons, 2014; Shan et al., 2013) investigated pain complaints and two studies investigated posture during tablet use in youths (Howie, Coenen, Campbell, Ranelli, & Straker, 2017; Straker et al., 2008). Of the two studies investigating pain complaints, one (Shan et al., 2013) found that a period of mobile phone use longer than 2 hr per day was related to significant increase in the prevalence of reported lower back pain and neck and shoulder pain among youth. In contrast, Palmer et al. (2014) found no relationship between phone exposure and self-reported discomfort (however, this study had a small n). Two studies investigated postural differences during real-time use of technology. Straker et al. (2008) found that greater muscle activity and asymmetry in the trunk and shoulders during tablet use compared to desktop computer use. Another study found that children displayed greater mean head, trunk, and upper arm angles while using a tablet than while playing with toys or watching television (Howie et al., 2017).

Given the small number of studies investigating musculoskeletal pain and discomfort, limited generalizations can be made. For example, one study (Shan et al., 2013) asked questions specifically about other factors relevant to phone behavior and posture (e.g., the eye-to-computer screen distance, height from screen, and duration of use), whereas Palmer et al. (2014) assessed total hours spent on phone regardless of activity. Additionally, no uniform questionnaires were used; thus, studies varied in their approach to assessing phone use and pain complaints. For example, one study had youth self-report phone use per day in a technology and pain diary and one study had youth indicate hours on a scale (e.g., <0.5 hr, 0.5–1 hr, 1–1.5 hr, or >1.5 hr). Studies also varied in assessment of musculoskeletal outcomes, with two studies (Palmer et al., 2014; Shan et al., 2013) relying on youth self-reported discomfort and the other two studies analyzing posture during real-time use with motion analysis systems. Regarding posture, results are difficult to synthesize due to small sample sizes ($N = 18$ and $N = 10$).

Headaches and migraines. To date, much of the research on the effects of phone use on headaches and migraine prevalence has been conducted with adults (Cerutti, Presaghi, Spensieri, Valastro, & Guidetti, 2016). Based on the search parameters, two studies were identified in this review (each cross-sectional in design). Both studies (Cerutti et al., 2016; Milde-Busch et al., 2010), found no significant relationship between phone use and reports of headaches and migraines.

Although both studies used self-reported headache symptoms and frequency to classify headaches or migraines categories based on the International Classification of Headache Disorders-second edition (Headache Classification Subcommittee of the International Headache Society, 2004), one (Milde-Busch et al., 2010) categorized mobile phone use as “time spent on voice calls” whereas the other study defined phone use as “duration of phone spent on during the day” (Cerutti et al., 2016). Furthermore, Cerutti et al. (2016) also assessed “phone addiction” risk, and found no significant relationship between youth with and without headaches and mobile phone addiction.

Ocular complaints. Our literature search revealed that studies investigating ocular complaints and phone use in youth are limited. This search also only identified two articles—both of which found positive associations between phone use and ocular complaints in a cross-sectional design. Specifically, Moon, Kim, and Moon (2016) found that mean daily duration of smartphone use was higher in children who met diagnostic criteria for dry eye disease than those who did not (odds ratio = 13.07, $p < .001$). Kim et al. (2016) examined “excessive use” and found a higher prevalence of ocular complaints in youth with excessive use (>2 hr)—both persistence (>2 hr daily and >2 hr continual use) and intermittent use (>2 hr daily and <2 hr continual use) patterns—compared with shorter use (<2 hr). Despite positive findings across both studies, the few number of investigations limit our ability to draw firm conclusions.

5 | SUMMARY AND RECOMMENDATIONS FOR FUTURE RESEARCH

Taken together, this literature review identified strong support for the link between excessive mobile device use and sleep health (concurring with prior literature reviews on the impacts of media and mobile phones on adolescents' sleep health; e.g., Hale & Guan, 2015). Mixed evidence on the impact of excessive mobile device use on PA and obesity limit our ability to draw conclusions. Future research should utilize validated measures of problematic mobile device use (e.g., Problematic Media Use Measure; Domoff et al., 2019), as well as objective measures of mobile device use (e.g., passive sensors on smartphones) to clarify these relationships. Additionally, most research on PA utilized self-report instead of objective assessment via Actigraphy. To clarify the mixed findings, we recommend using objective and/or observational methods in future research. In addition, too few studies examined other aspects of a child's physical health, such as musculoskeletal, pain, neurological, and ocular concerns. Although research with adults suggests that these physical health domains may be impacted by excessive mobile device use, few investigations have examined these associations in children and no investigations, to our knowledge, have utilized longitudinal design. Researchers are encouraged to address prior limitations of the research, and expand the scope of investigations to include mobile device-related health concerns heretofore identified in adults.

CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

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