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The Relationship Between Usage of Personal Electronic Devices and Musculoskeletal Pain in Children and Adolescents: A Systematic Review

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ABSTRACT

Background
Over the last decade, the use of personal electronic devices has increased rapidly in both children and adolescents. With this growth comes a need to understand the potential association between personal electronic device usage and musculoskeletal disorders. This systematic review aimed to explore the current research to establish whether there is a relationship between children's (aged 5-17 years) musculoskeletal pain and their usage of personal electronic devices, and to determine any associated risk factors.

Methods
Systematic searches were conducted in the following electronic databases: CINAHL, MEDLINE, SPORTDiscus, and PubMed Central. Keywords used related to those to describe personal electronic devices, musculoskeletal pain, and children. The articles were screened using a protocol following a two-phase process, data were extracted, and the quality of the papers assessed.

Results
14,624 articles were screened and 24 were deemed eligible for inclusion. Out of these, 21 were cross-sectional studies, two were longitudinal, and one was a test re-test study. The device used in the majority of studies was a desktop computer (n=14), seven studies asked about different types of devices, and three used mobile devices. Nine studies reported on posture and musculoskeletal pain whilst using personal electronic devices, and 16 studies reported on the length of time spent when using a personal electronic device and associated musculoskeletal pain.

Results showed limited evidence of a relationship between children's personal electronic device usage and musculoskeletal pain. Potential risk factors associated with musculoskeletal pain reported in the included studies were: type of device, length of time, and position adopted when using the device. Due to the use of subjective measures and the lack of longitudinal studies, these risk factors could not be conclusively demonstrated.

Conclusion
The findings of this systematic review suggest that there is a need for further research, which should take the form of cohort and/or longitudinal studies using objective measures and physical examinations as opposed to only subjective measures and questionnaires. This would help to develop a greater understanding of risk factors associated with children developing musculoskeletal pain related to personal electronic device usage.

Key points

- There is limited evidence of a relationship between usage of personal electronics devices and musculoskeletal pain in children and adolescents.
- There is preliminary evidence to support the idea that factors such as duration spent on the device, type of device, and position adopted, may be associated with musculoskeletal pain in children and adolescents.
- Further research is needed that can definitively identify the risk factors for musculoskeletal pain associated with personal electronic device usage in children and adolescents.

Introduction

Over recent years, there has been a considerable increase in the use of personal electronic devices by children and adolescents in both school and their personal lives (Mantilla & Edwards, 2019; Organisation for Economic Co-operation and Development [OECD], 2019). This increase is believed to be related to the more widespread availability of mobile devices such as tablets and smartphones (Office for National Statistics [ONS], 2018). Ofcom (2020) reported 83% of 12–15-year-olds own a smartphone, an 18% increase compared to 2018, and 59% own tablets. Nearly 50% of 8-11-year-olds reported owning a smartphone, and 66% reported that they own a tablet, with both having increased by 17% from 2018 (Ofcom, 2020). Further to this, 99% of 12–15-year-olds go online for up to 12 hours per week: this includes, but is not limited to, homework, gaming, and social media (Ofcom, 2019).

In general, lower limb pain, specifically in the knee and ankle, have been reported to be the most common types of musculoskeletal pain in children (Fuglkjær, Dissing, & Hestbæk, 2017). However, more recently there has been evidence of an increase in the prevalence of children reporting lower back pain and neck pain (Frosch et al., 2022; Kazeminasab et al., 2022). As musculoskeletal conditions may have long term impacts during working life, it is important to understand the mechanisms that underlie musculoskeletal pain in children and adolescents (Fares, Fares, & Fares, 2017). With increases in the use of personal electronic devices, it is also important to understand the degree to which musculoskeletal pain may be related to these devices in children and adolescents.

Several studies have linked chronic musculoskeletal pain in adults to the use of personal electronic devices. Arslan et al., (2016) found sitting for a prolonged period was associated with lower back pain, whereas Bawab et al. (2015) suggested it was not just the length of time sitting, but the positions in which people sit, such as slouching in a chair and leaning forward over a laptop, which were associated with lower back pain. In a recent systematic review, Zirek, Mustafaoglu, Yasaci, and Griffiths (2020) suggested that repetitive movements and prolonged sitting/standing whilst using a mobile phone are associated with musculoskeletal pain. This supports a previous review conducted by Toh, Coenen, Howie, and Straker (2017), who concluded that the tasks undertaken, the length of time whilst using, and the positions adopted when using mobile touch-screen devices are all associated with musculoskeletal pain. However, to date, there has been no review of the literature investigating the relationship between musculoskeletal pain and personal electronic device usage in children and adolescents. The aim of this systematic review was to examine the relationship between the use of personal electronic devices (including computers, laptops, game consoles, mobile phones, and tablets) and risk factors related to musculoskeletal conditions in children and adolescents.

Methods

The systematic searches of the literature were conducted in the following electronic databases: CINAHL (via EBSCO), SPORTDiscus (via EBSCO), MEDLINE (via Ovid), and PubMed Central, in June 2021 and updated in September 2023: the time frame for included studies was January 1993 to September 2023. This systematic review is reported using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (Moher et al., 2015).

Search strategies were derived for three key concepts: mobile touch screen devices, computers, and laptops; musculoskeletal pain; and children (see Table 1). The search terms were replicated in each of the four databases and wildcards were used to account for differences between American and English language spellings (i.e. p*ediatrics).

Table 1: Search Terms

Databases: CINAHL (via EBSCO), SPORT Discus (via EBSCO), MEDLINE (via Ovid), and PubMed Central		
Strategy	**#1 AND #2 AND #3**	
#1	Mobile touch screen devices, computers, and laptops	cellular phones; mobile phones; mobile devices; information technology; tablets; laptop; computer games; iPad; computer
#2	Musculoskeletal pain	musculoskeletal disorders; musculoskeletal conditions; musculoskeletal injuries; musculoskeletal diseases; musculoskeletal problems; musculoskeletal pain
#3	Children	children; teenagers; adolescents; juvenile; paediatrics

The inclusion and exclusion criteria are detailed in Table 2. Articles were selected by first screening the titles and abstracts; secondly, full texts of those articles that met the inclusion criteria from the first stage were screened. Studies were included based on consensus of two reviewers (AC and ACR).

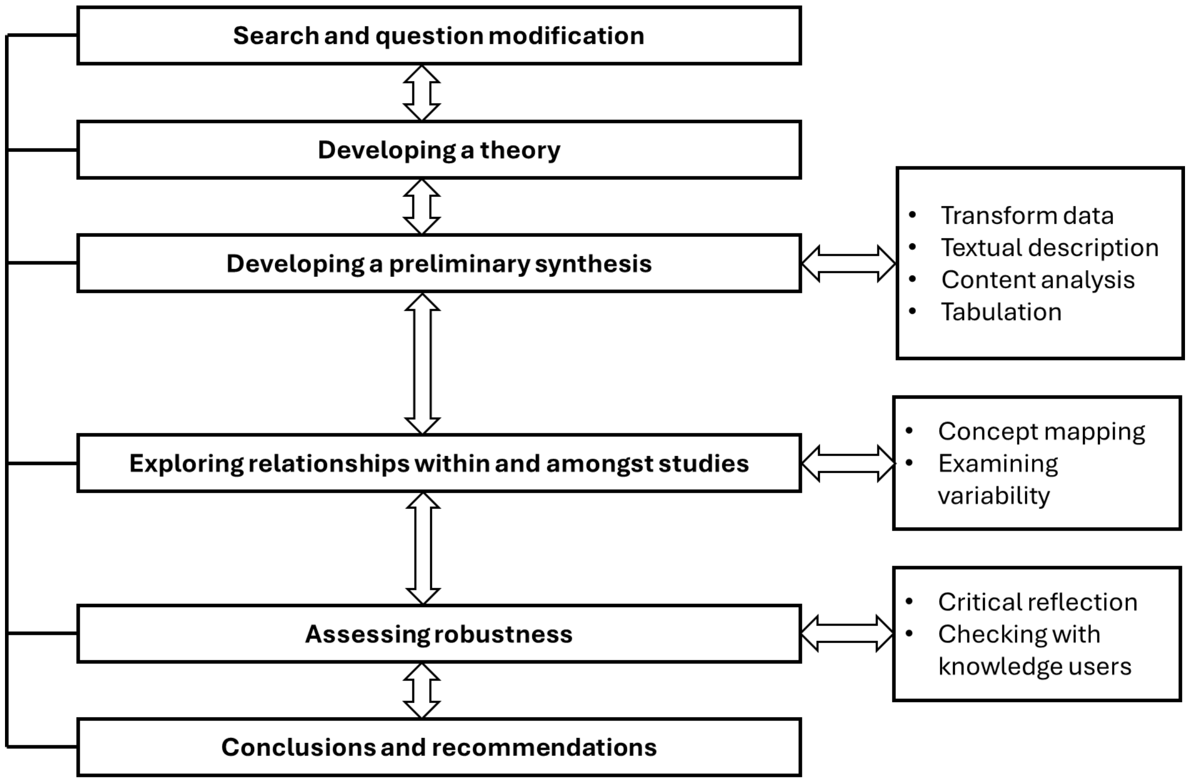
Table 2: Inclusion and Exclusion Criteria

Inclusion criteria	Exclusion criteria	Justification
Original research (including observation and experimental study designs)	Synthesis research (such as reviews and systematic reviews)	An outcome was required
Studies on participants <18	Studies on participants≥ 18	This study looked at children and adolescents and not adults
Main topic to include device usage, posture and/or causing muscle pain/discomfort	Devices used as interventions/ rehabilitation tools for managing health conditions	The study looked at children using devices for personal and school usage
English language	Other languages except for English	For time benefit and avoiding misinterpretation of studies not in English
Articles published after 1993	Articles published before 1993	1993 was when the first touch screen phone was available to the public

Healthy participants with no neurological symptoms	Articles only looking at somatic symptoms (e.g. headaches)	Although headaches have been linked with poor posture (Elizagaray-Garcia, Beltran-Alacreu, Angulo-Díaz, Garrigós-Pedrón, & Gil-Martínez, 2020), headaches can be caused by a variety of other factors that may influence the results

A structured narrative synthesis approach to analysis was adopted (Curran et al., 2014), due to the heterogeneity in study designs, methods, outcomes, and data presented in the included articles. Relevant data from all included articles were extracted and the methodological quality was assessed by two reviewers. The findings of the articles were described and synthesised in a narrative format guided by Popay et al. (2006), as outlined in Figure 1.

Figure 1: Integrative narrative synthesis process. Adapted from Popay et.al. (2006)



The quality of the articles was assessed using the *Standard Quality Assessment Criteria for Evaluating Primary Research Papers from a Variety of Fields*, using a checklist to assess the internal validity of the studies (Kmet, Cook, & Lee, 2004). All articles were assessed by the primary author (AC) for quality and 20% were systematically sampled and assessed by an associate author (ACR) to ensure that the results were comparable.

Results

Search results and quality appraisal

The literature search returned 14,624 titles of which 153 full-text articles were screened for eligibility. There were 24 papers (published between 2002-2022) included in the final review. Full retrieval details, the screening process and reasons for exclusion are presented in Figure 2. There was agreement between both authors, and therefore all the papers at this stage (n=24) were included in the review.

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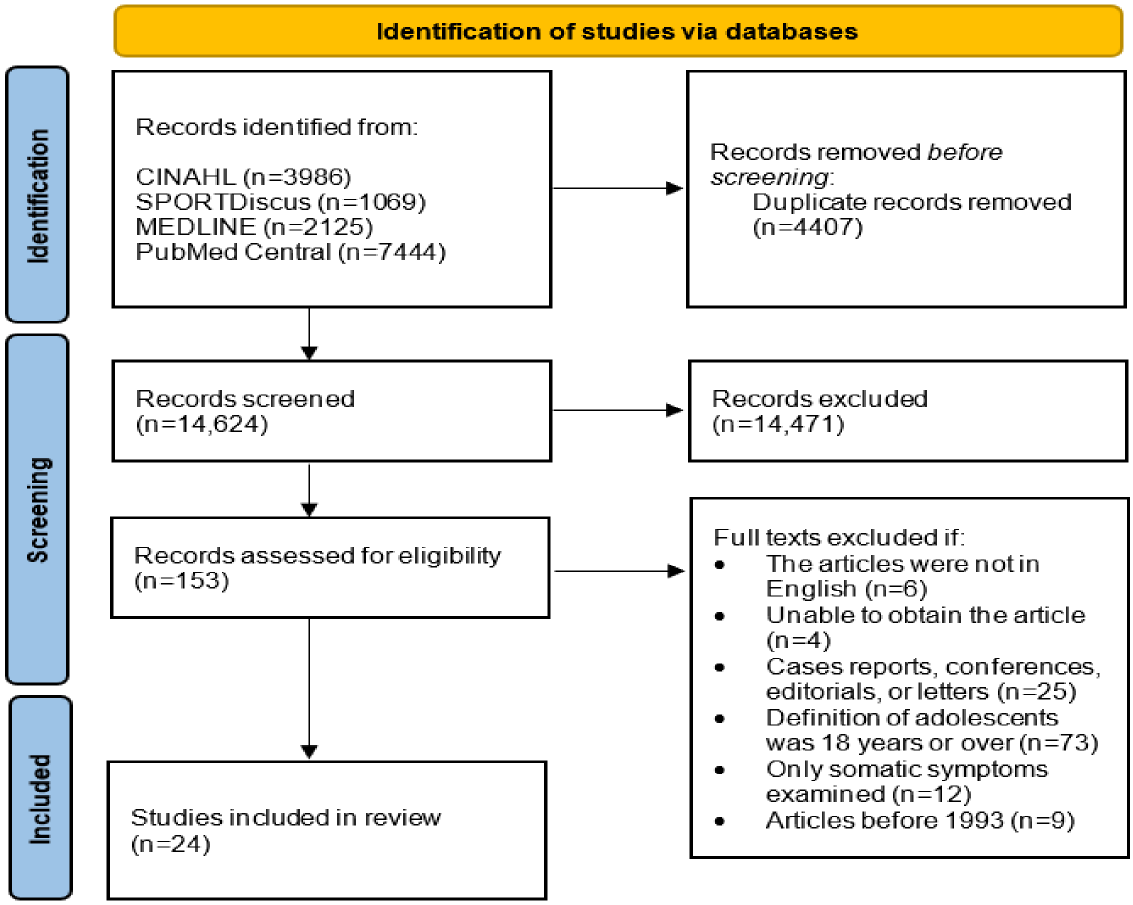
The articles ranged in quality from 0.61 to 0.95 (the closer the figure is to 1.00, the higher quality of article), demonstrating a spread of academic rigour (Appendix 1). All 24 articles remained in the review for analysis as the minimum quality assessment score (0.61) was higher than the liberal threshold of 0.55 as recommended by Kmet, Cook, and Lee (2004).

Figure 2: PRISMA flow chart for selecting articles adapted from Page et al. (2021)



Characteristics of included studies

Table 3 provides a summary of the results of the data extracted from the included papers, which includes: location of the study, sample size, and assessment setting. Further details on the types of devices used and the participant characteristics are also reported in Table 3. The included studies were conducted across all continents, ranging in sample size from 15 to 6143 participants (mean 1133), with the majority (n=20) assessed within schools. Other study settings included home (n=7), laboratory (n=4), or a combination of settings (n=3).
Type of personal electronic device used during the study

In this review, 14 of the articles examined computer usage exclusively (Breen, Pyper, Rusk, & Dockrell, 2007;Brink, Hillier, Louw, & Schreve, 2009; Brink, Louw, Grimmer, & Jordaan, 2015; Coleman et al., 2009; Diepenmaat et al., 2006; Dockrell, Earle, & Galvin, 2010; Fernandes et al., 2015; França et al., 2020; Hakala et al., 2012; Harris, Straker, Smith, & Pollock, 2012; Jacobs & Baker, 2002; Kelly, Dockrell, & Galvin, 2009; Py Szeto et al., 2014; Ramos et al., seven studies asked about multiple electronic devices (computers, laptops, video consoles) (Fares et al., 2017; Franca et al., 2020; Hakala et al., 2016; Ince et al.,2017; Lui et al., 2011; Palmer et al., 2014 Sui et al., 2009), and three looked at mobile devices, tablets or games consoles solely when investigating children using personal electronic devices (Intolo et al., 2019; Minghelli, 2020; Sekiguchi et al., 2017).

Participant characteristics

Gender of children reporting pain

This review highlighted gender could be a factor in children reporting pain. Diepenmaat (2006) found that lower back pain was reported more in females than in males; this was also found in studies by França et al. (2020), Fernandes et al. (2015), Hakala et al. (2010), Hakala, Rimpela, Saarni and Salminen (2006), Harris, Straker, Smith, and Pollock (2015), Sekiguchi et al. (2017), and Siu, Tse, Yu and Griffiths (2009). However, this was not found in all studies in this review; for instance, Breen et al. (2007) and Ramos, James, and Bear-Lehman (2005) both stated that they did not find a difference between genders and pain, and fourteen articles did not comment on any gender differences.

Ages of children reporting pain

The age range of the participants was five to seventeen years, with six of the studies finding an association between age and reported musculoskeletal pain. Hakala et al. (2010), Harris et al. (2012), Minghelli (2020), Ramos et al. (2005), Sekiguchi et al. (2017), and Siu, Tse, Yu, and Griffiths (2009) all found that the older children (over 13 years) reported more pain compared to younger children (under 13 years old). Conversely, Ince, Swearingen, and Yazici (2017) found that in a cohort of 171 younger children (mean age 9.3±1.7), significantly more pain was reported for each one year decrease in age.

Table 3: Data extraction of the papers: EMG-Electromyography, VAS=Visual Analogue Scale, RULA=Rapid Upper Limb/Assessment below:

Author	Setting: Country	Sample size and age ranges of participants	Risk Factors related to pain			Assessment Setting	Measurement tools	Study Design
			Devices Used	Ergonomics/ Posture	Reported length of time using the device			
Breen et al. (2007)	Ireland	N=68 mean: 9- 10yrs	Computer	Yes	No	School	RULA, Body Discomfort chart and VAS	Cross-sectional
Brink et al. (2009)	South Africa	N=104, 15-17yrs	Computer	Yes	Yes	Lab	Questionnaire, Photographic posture analysis method (PPAM)	Longitudinal – 6 months
Brink et al. (2015)	South Africa	N=994, 15-17yrs,	Computer	Yes	No	Lab	3D posture analysis tool, Questionnaire	Longitudinal – 12months
Coleman, Straker, and Ciccarelli (2009)	Australia	N=77, 11-16yrs	Computer	Yes	Yes	School	Questionnaire	Cross-sectional
Diepenmaat et al. (2006)	Holland	N=3485, 12-16yrs	Computer	No	Yes	School	Questionnaire	Cross-sectional
Dockrell et al. (2010)	Ireland	N=23, 9-10yrs	Computer	Yes	No	School	RULA, VAS, Body Chart, Visual display unit workstation	Test re-test
Fares et al. (2017)	Lebanon	N=207:	Mobile phones,	Yes	No	Lab	ROM, Pain evaluation	Cross-sectional

Author	Setting: Country	Sample size and age ranges of participants	Risk Factors related to pain			Assessment Setting	Measurement tools	Study Design
			Devices Used	Ergonomics/ Posture	Reported length of time using the device			
		8-11ys or 12-17yrs	Tablet, Computer					
Fernandes et al. (2015)	Brazil	N=1461, 12-14yrs	Computer	No	Yes	School	Questionnaire	Cross-sectional
Franca et al (2020)	Brazil	N=577, 10-16yrs	Computer , Tablet, Mobile phone Video Games	No	Yes	School	Questionnaire	Cross-sectional
Hakala et al. (2006)	Finland	N=6003, 14-17yrs,	Computer Digital games, Mobile phones	No	Yes	Home	Questionnaire	Cross-sectional
Hakala et al. (2012)	Finland	N=689, 12-16yrs.	Computer	No	Yes	School	Questionnaire, VAS	Cross-sectional
Harris et al. (2012)	Australia	N=1351, 6-17yrs	Computer	No	No	Home and School	Questionnaire	Cross-sectional
Ince et al. (2017)	USA	Study 1: N=171 Study 2: N=307 7-10yrs	Laptops and gaming systems	No	Yes	Home	Questionnaire, VAS	Cross-sectional
Intolo et al. (2019)	New Zealand	N=25, 10-12yrs	Tablet	No	No	Lab	VAS, Body Chart, EMG	Cross-sectional
Jacobs and Baker (2002)	USA	N=152, 11-12yrs	Computer	No	Yes	Home	Questionnaire	Cross-sectional
Kelly et al. (2009)	Ireland	N=40, 15-17yrs	Computer	Yes	Yes	School	RULA, Body Discomfort chart and VAS	Cross-sectional
Lui, Szeto, and Jones (2011)	Hong Kong	N=476, 8-13yrs	Computer Games consoles,	No	Yes	School	Questionnaire	Cross-sectional

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Author	Setting: Country	Sample size and age ranges of participants	Risk Factors related to pain			Assessment Setting	Measurement tools	Study Design
			Devices Used	Ergonomics/ Posture	Reported length of time using the device			
			Mobile phones					
Minghelli (2020)	Portugal	N=304, 10-17yrs	Mobile phone	Yes	Yes	School	Questionnaire/ photo analysis	Cross-sectional
Palmer et al. (2014)	Australia	N=33, 12-15yrs	Computer Game console Mobile phones Portable devices	No	Yes	Home	Diary, VAS	Cross-sectional
Py Szeto et al. (2014)	China	N=15, 8-11yrs	Computer	Yes	No	Home	Questionnaire verbally measurement and observations	Cross-sectional
Ramos et al. (2005)	USA	N=479, 9-10yrs	Computer	No	Yes	Home and School	Questionnaire	Cross-sectional
Sekiguchi et al. (2017)	Japan	N=6143 6-15yrs	Game consoles	No	Yes	Home	Questionnaire	Cross-sectional
Siu et al. (2009)	China	N= 3191, 10-15yrs	Desktop, Notebook , Portable devices.	No	Yes	Home	Questionnaire	Cross-sectional
Zapata, Moraes, Leone, Doria-Filho, and Silva (2006)	Brazil	N=833 10-17yrs	Computer	No	Yes	Home and Lab	Questionnaire, Physical exam	Cross-sectional

Narrative Synthesis Findings

Table 4 shows how the data were synthesised into the following themes, which were also used to narratively synthesise the findings in terms of: types of studies, methods of data collection, and the risk factors associated with children and adolescents developing musculoskeletal pain due to using personal electronic devices (posture when using a device and the length of time using a device).

Types of studies
Cross-sectional studies were conducted in 21 of the studies (Breen et al., 2007; Coleman et al., 2009; Diepenmaat et al., 2006; Fares et al., 2017; Fernandes et al., 2015; França et al., 2020; Hakala et al., 2010; Hakala et al., 2012; Harris et al., 2012; Ince et al., 2017; Intolo et al., 2019; Jacobs & Baker, 2002; Kelly et al., 2009; Lui et al., 2011; Minghelli, 2020; Palmer et al., 2014; Ramos et al., 2005; Sekiguchi et al., 2017; Siu et al., 2009; Zapata et al., 2006), with two longitudinal studies (Brink et al., 2009; Brink et al., 2015;) that ranged in length from 6 months to 3 years (mean-18 months), and one test-retest study (Dockrell et al., 2010).

Methods of data collection

Subjective and objective data collection
The two main methods that were used to collect data in the studies in this review were subjective and objective. Fourteen studies used solely subjective methods in the forms of questionnaires (Coleman et al., 2009; Diepenmaat et al., 2006; Fernandes et al., 2015; França et al., 2020; Hakala et al., 2010; Hakala et al., 2012; Harris et al., 2012; Ince et al., 2017; Jacobs & Baker, 2002; Lui et al., 2011; Palmer et al., 2014; Ramos et al., 2005; Siu et al., 2009), and ten studies used both subjective and objective methods (Breen et al., 2007; Brink et al., 2009; Brink et al., 2015; Dockrell et al., 2010; Fares et al., 2017; Intolo et al., 2019; Kelly et al., 2009; Minghelli, 2020; Py Szeto et al., 2014; Zapata et al., 2006).

The objective measures used in the studies in this review were, the Rapid Upper Limb Assessment (RULA) to measure posture (Breen et al., 2007; Dockrell et al., 2010; Fares et al., 2017; Kelly et al., 2009; Minghelli, 2020; Py Szeto et al., 2014), 3D motion analysis (Brink et al., 2009; Brink et al., 2015), and electromyography (EMG) to measure muscle contraction (Intolo et al., 2019).

Methods of Reporting Pain

All the papers in this review asked children about pain and twelve studies asked if the participants experienced pain in a certain body part, answering “yes/no” (Brink et al., 2009; Brink et al., 2015; Diepenmaat et al., 2006; Fernandes et al., 2015; França et al., 2020; Harris et al., 2015; Lui et al., 2011; Minghelli, 2020; Palmer et al., 2014; Py Szeto et al., 2014; Sekiguchi et al., 2017; Siu et al., 2009), two used VAS questions, seven studies used a combination of methods (questionnaires, VAS, and body charts) (Breen et al., 2007; Coleman et al., 2009; Dockrell et al., 2010; Fares et al., 2017; Hakala et al., 2010; Hakala et al., 2012; Kelly et al., 2009). One of the studies (Ramos et al., 2005), asked the participant to describe their pain and if they had any pain when using a device. Only one of the studies used a physical, palpation method to diagnose pain (Zapata et al., 2006).

Location of musculoskeletal pain reported

One study looked at only lower back pain (Fernandes et al., 2015), three studies looked at neck pain (Brink et al., 2009; Coleman et al., 2009; Fares et al., 2017), one looked at upper limb pain (Ince et al., 2017), and nineteen studies looked at a combination of pain (e.g. lower back, neck , shoulder, etc.) (Breen et al., 2007; Brink et al., 2015; Diepenmaat et al., 2006; Dockrell et al., 2010; França et al., 2020; Hakala et al., 2006; Hakala et al., 2010; Harris et al., 2015; Intolo et al., 2019; Jacobs & Baker, 2002; Kelly et al., 2009; Lui et al., 2011; Minghelli, 2020;

Palmer et al., 2014; Py Szeto et al., 2014; Ramos et al., 2005; Sekiguchi et al., 2017; Siu et al., 2009; Zapata et al., 2006). Out of the 24 studies, only five found no association between personal electronic device usage and musculoskeletal pain (Diepenmaat et al., 2006; Dockrell et al., 2010; Hakala et al., 2012; Palmer et al., 2014; Siu et al., 2009; Zapata et al., 2006).

Risk factors

Ergonomics when using a device and linked to pain

Posture has been defined as the position in which someone holds their body when standing or sitting (Jacobs, 2014). It has been suggested that slumped posture can affect neck and back pain (Brink et al., 2009). Ramos et al. (2005) found that children adopt a range of postures when playing computer games, including sitting in a car, lying on the floor/bed and sitting on the couch. More than half of the participants (58.2%) reported discomfort whilst playing video games, with neck pain being the most commonly reported pain (34.9%), followed by lower back pain (18.3%). Fares et al., (2017) found that all participants used a mobile phone with their head in a flexed position, and that the prevalence of self-reported neck pain increased when participants were studying. Coleman et al. (2009) observed a relationship between musculoskeletal pain, poor posture, and positioning of the participant when using a computer. However, this study relied on questionnaires to classify posture, possibly leading to misclassification bias (Casas, Patiño, & Camargo, 2016). Py Szeto et al. (2014) aimed to examine ergonomic issues of children's computer usage within their homes. The study found that children's postures were in general poor, with children (aged 8-11) having unergonomic sitting positions when sitting at a computer desk. This could be due to the home computer set-up, specifically, as desks were mainly set up for adults, and were unchanged for child use. However, this study only included 15 participants; nevertheless, this observation supports the idea that children may use electronic devices differently in school than they do at home (Ramos et al., 2005; Breen et al., 2007; Palmer et al., 2021).

Playing video games whilst sitting in different positions may increase neck pain (Ramos et al., 2005; Hakala et al., 2006), whereas back pain appears to be associated with prolonged sitting (Ramos et al. 2005). Breen et al. (2007) found that children sitting slumped increased both neck and back pain. They also found that children had increased neck pain the longer they were at sat at a desktop computer. Desk set-up, for example the height of the chair, computer screen and desk, was highlighted in Py Szeto et al. (2014), Jacobs and Baker (2002), and Ince et al. (2017), as a potential risk factor of children developing musculoskeletal pain when using computers. Unfortunately, 'poor posture' was not defined in any of the papers, and only one of the studies (Py Szeto et al., 2014), looked at participants in a free-living environment rather than lab-based. However, the three studies that looked at desk set-up included participants using predominantly desktop computers, which does not accurately represent children's personal electronic device usage in a free-living environment, i.e., does not include mobile devices (Ofcom, 2020). As such, more research needs to be conducted to look at children in a free-living environment using mobile devices, reflecting the devices used by children in the postures that they use them in.

Length of time using a device and linked to pain

Increased time spent on personal electronic devices appeared to be associated with musculoskeletal pain. Coleman et al. (2009) found that the length of time using a computer was associated with neck pain but concluded that it could also have been the posture adopted, rather than the length of time that could have caused the neck pain, or a combination of both time and posture. Nevertheless, there does appear to be a relationship between musculoskeletal pain and the length of time children spend on a personal electronic device (Hakala, et al 2006; Ince et al. 2017). In support of this, Hakala, et al. (2006) observed a higher prevalence of increased lower back pain in children who spent more than five hours per day using a computer or playing games compared to less than one hour per day. In contrast, Diepenmaat et al. (2006) found that increased computer usage was not associated with musculoskeletal discomfort and Kelly et al. (2009) also reported that length of time at a computer did not affect musculoskeletal pain. These differences in findings may be the result of the different definitions of neck and back pain used between the studies.

Two of the more recent studies (Intolo et al., 2019; Minghelli, 2020), which looked solely at mobiles devices (mobile phones and tablets), suggested that children (aged 10-17) who use these devices for long periods of time increase the chance of them reporting neck pain. Minghelli (2020) suggested that participants who used a mobile phone for more than 10 hours per week were more likely to develop neck and/or back pain compared to the participants who used it for fewer than 10 hours per week. These results support those of Liu et al. (2011), who found that using a hand-held computer console for more than two hours a day was linked with neck pain in 8–13-year-olds. This was the only significant result in the study, which included laptops, computers as well as handheld consoles, when looking at the length of time using a device.

Table 4: Narrative synthesis:

Type of study	N=21 cross sectional	N=14 of these cross-sectional studies used solely subjective methods (Coleman et al., 2009; Diepenmaat et al., 2006; Fernandes et al., 2015; França et al., 2020; Hakala et al., 2006; Hakala et al., 2012; Harris et al., 2012; Ince et al., 2017; Jacobs and Baker (2002); Lui et al., 2011; Palmer et al., 2014; Ramos et al., 2005; Sekiguchi et al., 2017; Siu et al., 2009)
		N=7 used a combination of subjective and objective measures (Breen et al., 2007; Fares et al., 2017; Intolo et al., 2019; Kelly et al., 2009; Minghelli, 2020; Py Szeto et al., 2014; Zapata et al., 2006)
	N=1 test re-test	Dockrell et al. (2010)
	N=2 longitudinal 6months-3years (mean=18 months)	Brink et al. (2009); Brink et al. (2015)
Methods of data collection and reporting of musculoskeletal conditions	N=24	N=15 self-reported questionnaires (Brink et al., 2009; Brink et al., 2015; Coleman et al., 2009; Diepenmaat et al., 2006; Fernandes et al., 2015; França et al., 2020; Hakala et al., 2006; Harris et al., 2012; Jacobs & Baker, 2002; Lui et al., 2011; Minghelli, 2020; Py Szeto et al., 2014; Ramos et al., 2005; Sekiguchi et al., 2017; Siu et al., 2009) N=4 visual analogue scale (VAS) and/or body discomfort chart (Breen et al., 2007; Dockrell et al., 2010; Intolo et al., 2019; Kelly et al., 2009) N=2 self-reported questionnaires with a combination of the VAS (Hakala et al., 2012; Ince et al., 2017) N=1 asked the participant if they had pain at the start of the study (Fares et al., 2017) N=1 VAS and asked the patient to complete a pain diary (Palmer et al., 2014) N=1 questionnaire and physical exam; (Zirek et al., 2020)
Posture whilst using electronic devices	N=9	N=2 photograph analysis (Brink et al., 2009; Brink et al., 2015) N=3 Rapid Upper Limb Assessment (RULA) tool (Breen et al., 2007; Dockrell et al., 2010; Kelly et al., 2009) N=3 subjective assessment only (Coleman et al., 2009; Fares et al., 2017; Minghelli, 2020) N=1 observation analysis (Py Szeto et al., 2014)
Length of Time using a device	N=16	Brink et al. (2009); Coleman et al. (2009); Diepenmaat et al. (2006); Fernandes et al. (2015); Hakala et al. (2006); Hakala et al. (2012); Ince et al. (2017); Jacobs and Baker (2002); Kelly et al. (2009); Lui et al. (2011); Minghelli (2020); Palmer et al. (2014); Ramos et al. (2005) ; Sekiguchi et al. (2017); Siu et al. (2009); Zapata et al. (2006).

Discussion

To our knowledge, this is the first systematic review to summarise evidence for possible associations between musculoskeletal pain and personal electronic device usage in children. Our review builds on previous research in adult populations (Toh et al., 2017). While no definitive risk factors were identified, the review highlights those factors such as device position, type of device used, and duration of use may contribute to an increased risk of musculoskeletal pain in children and adolescents. Consistent with adult literature, gender differences may influence pain reporting, with suggestions that females may find it more socially acceptable to report pain compared to males (Nasser & Afify, 2019). For future studies, employing objective ergonomic measures, larger sample sizes, and conducting research in free-living environments would enhance both internal and external validity.

A notable limitation in the studies reviewed is the focus on computer or laptop use, with only a few examining mobile phone usage. This is crucial, as mobile phones have become the primary personal device for children and adolescents (Ofcom, 2019). Prolonged smartphone use has been associated with musculoskeletal issues, such as neck pain, in adults (Fares et al., 2017). However, research examining whether similar associations exist in children remains limited. Additionally, children's device preferences have shifted, with mobile device usage increasing and computer use decreasing (Ofcom, 2019). Despite this increase, only two studies in this review compared different devices and their association with musculoskeletal pain, leading to mixed evidence. Therefore, further robust studies are essential to establish clear relationships between device types, usage patterns, and musculoskeletal pain in children.

Many studies lacked clarity on whether the questionnaire used was validated for children, which could lead to misinterpretation and affect research findings. Children's ability to accurately report pain varies by age and developmental stage, impacting their perception and reporting of pain (Pate et al., 2019). For younger children, simplified language or visual aids, like visual analogue scale questions with facial illustrations, can aid comprehension (Bell, 2007; Powell et al., 2001). One of the challenges with carrying out a questionnaire with children is that they answer questions every day and are used to trying to get the 'right' answer (Patten, 2016). This could mean they might put what they believe the truth or desired answer is e.g., for the question "how long do you spend on a device?", the participants might think they spend too long on a personal electronic device and put a lower time frame for their answer (Andersson & Titov, 2014; Lefever, Dal, & Matthíasdóttir, 2007). This could also be closely linked to social desirability bias, which suggests that people overestimate the good aspects and underestimate the bad aspects of their behaviour (Dolinski et al., 2021; Sharot, 2011). This bias could also affect responses to questions about device usage, with children possibly underreporting screen time (Andersson & Titov, 2014).

Additionally, it was unclear with the younger participants in these studies if the answers were provided by the children themselves, or if they were completed by their parents/guardians. This creates an element of bias; parents may reflect on their own experiences onto their children's usage patterns rather than the experience of the children. However, there is a growing recognition that children's responses to questions should be respected and taken into consideration when carrying out research (Spriggs & Gillam, 2017).

Most studies employing objective measures were conducted in laboratory settings, which may not accurately reflect the real-life postures children adopt at home. Studies in this review that measured posture when using a personal electronic device suggested that posture may affect musculoskeletal pain; however, this depended on a range of factors, such as, position when using the device, the type of device being used, and the type of pain reported. The results in this review support the research that has been conducted in adults when looking at posture when using personal electronic device and associations with musculoskeletal pain (Kim, Kim, Lim, Yi, & Han, 2024; Lee, James, Edwards, & Snodgrass, 2021).

Objective assessments of device usage in natural settings are needed to better understand how children engage with devices daily. Additionally, understanding biomechanical risk factors, such as neck flexion, and their association with device usage is essential, though previous studies yielded mixed findings in linking these factors to musculoskeletal pain (Dockrell et al., 2010; Hakala et al., 2012; Zirek et al., 2020). Future research should focus on developing comprehensive measures that capture biomechanical risks in both controlled and real-life settings.

A limitation of this review is that the search strategy may not have captured all relevant studies due to variability in terminology describing personal electronic devices. Despite the broad search strategy used, it is possible some studies were missed. The review quality also depends on the quality of primary studies. Notably, no randomised controlled trials have investigated musculoskeletal pain in children related to device use, highlighting a potential area for future research. All included studies met a quality threshold above 0.60, surpassing the threshold Kmet et al. (2004) recommended for systematic review inclusion, suggesting a reasonable standard of evidence.

Conclusion

In summary, there appears to be preliminary evidence to support the idea that factors such as duration spent on a personal electronic device, type of device, and position adopted may be associated with musculoskeletal pain in younger people. However, the studies have relatively low subject numbers and are mostly cross-sectional in design, and therefore temporal relationships could not be established. As such, the strength of the evidence presented in this review was not sufficiently robust to identify definitive risk factors. More research is needed due to the ever-evolving technology used by children and adolescents and the positions children adopt when using electronic devices. The benefits of conducting future research could provide guidance to children, parents, and schools on the risk factors of personal electronic device usage and the associated risk of musculoskeletal pain in children and adolescents.

The potential cost of the development of musculoskeletal pain in children is unknown but is likely to mirror the societal and personal burden that musculoskeletal pain imposes on the adult population. Therefore, there is an urgent need for further research that can definitively identify the risk factors for musculoskeletal pain associated with personal electronic device usage in children.

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Appendix 1: Quality Assessment of Papers

Author	Year	Quality Assessment of papers
Breen, Pyper, Rusk, & Dockrell. (2007)	2007	0.67
Brink, Hillier, Louw, & Schreve. (2009)	2009	0.68
Brink, Louw, Grimmer, & Jordaan. (2015)	2015	0.78
Coleman, J., Straker, L., & Ciccarelli, M. (2009)	2009	0.83
Diepenmaat, A., Van der Wal, M., De Vet, H., & Hirasing, R. (2006)	2006	0.65
Dockrell, S., Earle, D., & Galvin, R. (2010)	2010	0.82
Fares, J., Fares, M. Y., & Fares, Y. (2017)	2017	0.65
Fernandes, J. A., Genebra, C. V., Maciel, N. M., Fiorelli, A., de Conti, M. H., & De Vitta, A. (2015)	2015	0.65
França, E. F., Macedo, M. M., Mafra, F. F. P., Miyake, G. M., da Silva, R. T., de França, T. R., . . . Junior, N. M. (2020).	2020	0.64
Hakala, P. T., Rimpela, A. H., Saarni, L. A., & Salminen, J. J. (2006)	2006	0.67
Hakala, P. T., Saarni, L. A., Punamaki, R. L., Wallenius, M. A., Nygard, C. H., & Rimpela, A. H. (2012)	2012	0.83
Harris, Straker, Smith, & Pollock. (2012)	2012	0.88
Ince, D., Swearingen, C., & Yazici, Y. (2017)	2017	0.65
Intolo, Prasongsansuk, Srilabutr, P., Sittichoksakulchai, W., Khutok, K., & Baxter, D. G. (2019)	2019	0.77
Jacobs, & Baker. (2002)	2002	0.61
Kelly, Dockrell, & Galvin. (2009)	2009	0.86
Lui, Szeto, & Jones. (2011)	2011	0.83
Minghelli. (2020)	2020	0.80
Palmer, K., Ciccarelli, M., Falkmer, T., & Parsons, R. (2014)	2014	0.83
Py Szeto, G., Tsui, M. M., Sze, W. W., Chan, I. S., Chung, C. C., & Lee, F. W. (2014)	2014	0.83
Ramos, James, & Bear-Lehman. (2005)	2005	0.75
Sekiguchi, T., Hagiwara, Y., Momma, H., Tsuchiya, M., Kuroki, K., Kanazawa, K., . . . Nagatomi, R. (2017)	2017	0.72
Siu, D. C. H., Tse, L. A., Yu, I. T. S., & Griffiths, S. M. (2009)	2009	0.89
Zapata, A. L., Moraes, A. J., Leone, C., Doria-Filho, U., & Silva, C. A. (2006)	2006	0.95

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