Headache, eyestrain, and musculoskeletal symptoms in relation to smartphone and tablet use in healthy adolescents

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Abstract

Neck pain and headache are leading causes of years lived with disability globally, and the prevalence is gradually increasing from school age to early adulthood. These symptoms have been linked to the use of digital devices. However, there is little knowledge related to this topic in adolescents, who spend increasingly more time using digital media. The aim of the study was to investigate eyestrain, headache, and musculoskeletal symptoms in relation to the use of tablets and smartphones in healthy adolescents with normal vision. Fifty healthy adolescents aged 11 – 13 years (mean = 12.1 ($SD = 0.53$)) with normal vision and development participated. A vision examination was performed by an authorised optometrist and an interview questionnaire measuring eyestrain, headache, and musculoskeletal symptoms in relation to screen use was filled out. In addition, screen time, ergonomics, participation in sports, and outdoor time were obtained. Forty-nine (98%) of the 50 children used a smartphone and 17 (34%) used a tablet. Overall, 12% to 41% experienced symptoms of headache, neck pain, tiredness and/or tired eyes while using smartphones and tablets. Nine (18%) experienced at least one symptom often or always while using their device. Musculoskeletal pain and headache were significantly associated with vision and eyestrain. Tablet use was associated with increased symptom scores compared to smartphone use. Increased screen time and shorter viewing distance were associated with eyestrain, headache, and neck pain. Children with neck, shoulder, and back pain were significantly (2.1 hours) less physically active than children without these symptoms. Most adolescents with good health and vision had no symptoms while using smartphones and tablets. However, a significant proportion still experienced symptoms of headache, neck pain, tiredness and tired eyes, and these symptoms were associated. Symptoms increased with screen time, shorter viewing distance and reduced participation in sports. This suggests that even healthy children with good vision may develop vision symptoms and musculoskeletal pain. Awareness should be raised among parents, teachers, eye– and health–care personnel, of the importance of good visual ergonomics and physical activity to promote health in adolescents.

Keywords: screen time, screen distance, neck pain, visual ergonomics, children, vision, refractive error.

Sammendrag

Nakkesmerter og hodepine er hovedårsaker til sykefravær globalt, og forekomsten øker gradvis fra skolealder til tidlig voksen alder. Disse symptomene har blant annet vært knyttet til bruk av digitale enheter. Imidlertid er det lite kunnskap relatert til dette temaet hos barn og unge, som i økende grad bruker mer tid på digitale medier. Målet med studien var å undersøke symptomer på syn- og øyeplager, hodepine og muskel- og skjelettplager relatert til bruk av nettbrett og smarttelefon hos friske skolebarn med normalt syn. Femti friske skolebarn i alderen 11 – 13 år (gjennomsnitt = 12,1 ($SD = 0,53$) med normalt syn og normal utvikling deltok. En autorisert optiker utførte en synsundersøkelse og fylte inn et intervjuskjema som undersøkte syn- og øyeplager, hodepine og muskel- og skjelettplager i forbindelse med skjermbruk. I tillegg ble skjermtid, ergonomi, fysisk aktivitet og tid utendørs registrert. Førtini (98%) av de 50 barna brukte smarttelefon og 17 (34%) brukte nettbrett. Tilsammen opplevde 12% til 41% symptomer på hodepine, nakkesmerter, tretthet og/eller øyeanstrengelse mens de brukte smarttelefoner og nettbrett. Ni (18%) opplevde minst ett symptom ofte eller alltid mens de brukte enheten. Muskel- og skjelettsmerter og hodepine var signifikant assosiert med syn- og øyeanstrengelse. Nettbrettbruk var assosiert med mer symptomer sammenlignet med smarttelefonbruk. Økt skjermtid og kortere skjermavstand var assosiert med øyeanstrengelse, hodepine og nakkesmerter. Barn med nakke-, skulder- og ryggsmerter var signifikant (2,1 timer) mindre fysisk aktive enn barn uten disse symptomene. De fleste skolebarn med god helse og godt syn hadde ingen symptomer når de bruker smarttelefoner og nettbrett. Imidlertid opplevde en betydelig andel fortsatt hodepine, nakkesmerter, tretthet og trette øyne, og disse symptomene var assosiert med hverandre. Symptomene økte med skjermtid, kortere skjermavstand og redusert fysisk aktivitet. Dette tyder på at friske barn med godt syn også kan utvikle syn- og øyeplager samt smerter i muskler og skjelett. Foreldre, lærere, øye- og helsepersonell bør bli mer bevisst og oppmerksom på viktigheten av god visuell ergonomi og fysisk aktivitet for å fremme helsen hos ungdommer.

Nøkkelord: skjermtid, skjermavstand, nakkesmerte, visuell ergonomi, barn og unge, syn, refraktiv status.

Introduction

Children and adolescents in Norway, and globally, spend increasingly more time performing visually demanding near tasks using digital screens, both at school and during their spare time (Løvgren & Svagård, 2019; Norwegian Media Authority, 2020; Saunders & Vallance, 2017; Twenge & Campbell, 2018; Winther et al., 2015). Near tasks require precise and accurate coordination between the visual system and the head-stabilizing muscles, which necessitates a robust visual system to maintain clear and comfortable vision over time. Uncorrected vision problems, such as refractive errors, accommodation anomalies or convergence deficits, can induce unhealthy postures leading to non-ergonomic viewing positions, such as protruding head or asymmetrical neck postures, and headaches (Blehm et al., 2005; de Vries et al., 2016; Dotan et al., 2014; Johnston et al., 2017; Rosenfield, 2011; Sanchez-Gonzalez et al., 2019). Further, digital screen-use has been found to cause headache, eyestrain, and upper body musculoskeletal pain in children and adolescents. The severity of symptoms increases with static non-ergonomic postures, vision problems and prolonged viewing time (Blehm et al., 2005; Costigan et al., 2013; de Vries et al., 2016; Eitivipart et al., 2018; Hakala et al., 2012; Johnston et al., 2017; Kim et al., 2016; Rosenfield, 2011; Sanchez-Gonzalez et al., 2019; Wirth et al., 2018; Xie et al., 2017).

Neck and back pain, and headache are leading causes of years lived with disability globally, and the prevalence is gradually increasing from school age to early adulthood (GBD 2017 Disease and Injury Incidence and Prevalence Collaborators, 2018; Gustafsson et al., 2018; Joergensen et al., 2019). The knowledge regarding risk factors and interventions in children and adolescents is limited. Studies indicate associations between spinal pain and headache, and screen time, bad ergonomics, obesity, and socioeconomic and psychosocial factors, with a higher pain prevalence in females (Batley et al., 2019; Ben Ayed et al., 2019; Bonthius & Hershey, 2020; Connelly & Sekhon, 2019; Gustafsson et al., 2018; Joergensen et al., 2019; Sa & Silva, 2017; Szita et al., 2018). Headache and neck and shoulder pain are among symptoms reducing everyday life activities in adolescents (Hakala et al., 2012), for example, headaches have been found to cause an average yearly loss of 9 days of activity (Krogh et al., 2015). Treatments are both pharmacological and non-pharmacological; physical therapy, lifestyle modifications, psychological and cognitive-behavioural therapy (Bonthius & Hershey, 2020; Hauer & Jones, 2020; Lee et al., 2019). Nonpharmacological treatment typically involves extensive treatment regimes, requiring high motivation from both child and carers (Buchbinder et al., 2015). In contrast, correcting vision problems receives little attention. Approximately 20% of school children require an optical correction to obtain good vision, however, this is rarely mentioned as a potential treatment to prevent and relieve musculoskeletal pain and headache in children (Dotan et al., 2014; Gil-Gouveia & Martins, 2002), even if this is an easily applicable and cost-effective solution. One reason is that vision problems are often not detected due to the lack of compulsory eye examinations during primary and secondary school in most countries (Falkenberg et al., 2019; Hagen et al., 2018; Hopkins et al., 2019; Vikesdal et al., 2019).

It is essential to promote visual and musculoskeletal health so that children are able to perform prolonged periods of digital screen viewing without increasing the risk of future health problems. The purpose of this study was to investigate headache, eyestrain and musculoskeletal symptoms in relation to smartphone and tablet screen use in healthy adolescents with good vision.

Methods

Study sample

This was a cross-sectional study of 11 – 13-year-old children (7th grade) at three schools in Gran and Lunner municipality, Norway, during the school year 2016-2017. All 118 children attending 7th grade were invited to participate and written informed consent was obtained from 83 children (mean = 12.1 years (SD=0.53) and their parents. All children were given a vision examination at school by an authorized optometrist (TRJ). The inclusion criteria were healthy children with normal development and good vision. The study protocol was approved by the Norwegian Regional Committee for Medical and Health Research Ethics (2015/1887) and followed the Declaration of Helsinki. Data collection was undertaken as part of a MSc thesis (TRJ) at University of South-Eastern Norway (unpublished).

Vision examination

The vision examination consisted of habitual monocular and binocular distance (6 m) and near (40 cm) visual acuity (VA), retinoscopy and cover test (6 m and 40 cm). Near point of convergence (NPC) and monocular and binocular accommodation amplitude (AA) were assessed using an RAF ruler (Neely, 1956). For analysis, spherical equivalent refraction (SER) was calculated in dioptres (D). Refractive errors were defined as emmetropia (−0.50 < SER < +0.50 D), hyperopia (SER ≥ +0.50 D), myopia (SER ≤ −0.50 D), astigmatism (≤ −0.75 DC) and anisometropia (≥ 1.00 D) (Falkenberg et al., 2019; O'Donoghue et al., 2010). Children were included if they had habitual near visual acuity of 0.0 logMAR and no binocular anomalies (horizontal phorias >10 pd, binocular AA ≤ 10 D, NPC > 10 cm). Thirty-four of the children had previously had an optometric examination, and 27 wore glasses for distance and/or near (reading glasses were used for all near vision tests). Children were excluded if they failed the vision examination or if they had, by parental report, a diagnosis of learning disabilities (e.g., dyslexia), attention deficit hyperactivity disorder (ADHD/ADD), developmental delay or migraine. Further, children were excluded if they had an injury, systemic disease or daily medication associated with vision or the musculoskeletal system. Fifty children fulfilled the inclusion criteria and were interviewed with a questionnaire. Of the 33 children who were excluded, two were advised to see their local optometrist. Results of the vision examination for all children can be found in Table 1.

Table 1: *Monocular and binocular results from the vision examination.*

		Included (n=50) Mean [95% CI]	Excluded (n=33) Mean [95% CI]
Age		12.1 [11.8, 12.3]	12.1 [11.9, 12.3]
Habitual distance visual acuity (logMAR)	RE	-0.05 [-0.08, -0.02]	-0.02 [-0.06, -0.02]
	LE	-0.08 [-0.10, -0.05]	-0.04 [-0.08, 0.00]
	Bin	-0.13 [-0.15, -0.10]	-0.08 [-0.11, -0.05]
Refractive error (SER)	RE	+0.08 [-0.01, 0.17]	+0.19 [0.00, 0.38]
	LE	+0.01 [0.01, 0.19]	+0.18 [-0.02, 0.38]
Accommodation amplitude (D)	RE	13.3 [12.9, 13.7]	12.9 [12.4, 13.5]
	LE	13.6 [13.2, 14.0]	13.1 [12.5, 13.7]
	Bin	14.4 [14.0, 14.7]	13.9 [13.5, 14.4]
Horizontal heterophoria[1] (pd)	6 m	-0.5 [-0.93, -0.11]	1.5 [-0.15, 3.19]
	40 cm	-1.6 [-0.26, -0.15]	2.9 [-0.74, 5.14]
NPC (cm)	40 cm	5.86 [5.60, 6.10]	6.42 [5.46, 7.36]

[1] Negative value denotes exophoria.
Note: Vision data from the excluded children have been added for comparison.

Interview questionnaire

A questionnaire was used to investigate how the participants used their smartphones and tablets and their experience of symptoms during use (see Appendix). The questionnaire comprised two parts: 1) Screen time, visual ergonomics (postures, lighting conditions), sports, time outdoors, and 2) Headaches, tiredness, eyestrain, and musculoskeletal symptoms during screen use. Part 1 contained both pre-set categorical answers and space to add free comments. The preferred smartphone viewing distance was measured during the reading of a standardised text message with 1.8 mm font size (iPhone 7, Apple Inc., USA). At 40 cm, the minimum angle of resolution (MAR) is calculated to be 3.1 seconds of arc, giving an acuity demand of 0.5 logMAR (decimal VA 0.3). This was well above visual acuity threshold for all participants. Part 2 had 15 symptom items that were repeated for smartphones and tablets separately; ten items regarding vision from the Convergence Insufficiency Symptoms Survey (Borsting et al., 2003) adapted to the aim of this study, and five items related to musculoskeletal symptoms. All symptom questions were scored on a 5-point scale: Never (0), Rarely (1), Sometimes (2), Often (3), Always (4). The child could see the questions and response options in writing, but questions were read aloud and scored by TRJ. For analysis, scores 0–1 were aggregated into "No symptoms" and scores 2–4 into "Symptoms" (Gustafsson et al., 2018). A total eyestrain symptom score was calculated combining all eye symptoms (8; max score 32), and a total musculoskeletal symptoms score was calculated combining all musculoskeletal symptoms (5; max score 20). The headache and tiredness symptoms were scored separately as they may be associated with both eyestrain and musculoskeletal symptoms (Rosenfield, 2011). Total symptom score included all 15 symptom items.

Statistical analysis

Raw data were assessed for normality using Q-Q plots and the Shapiro-Wilk test. Dependent variables were analysed using paired sample *t*-tests. Independent variables were compared using one-way analysis of variance (ANOVA) and independent-samples *t*-tests. Chi-square independence tests were used to evaluate associations between categorical variables. Pearson's correlation coefficient (r) was used to investigate associations between continuous variables. Point-biserial correlations were run to determine the relationship between categorical and continuous variables. Correlation coefficients (r) above 0.3 were included. Analysis using refractive error included right eye only, as there were no significant differences between right and left eyes (paired sample *t*-test, $p>0.05$). A statistical difference was set at $p<0.05$ (two-tailed), and analyses were performed in IBM SPSS Statistics (Version 24, US).

Results

The smartphone and tablet symptoms questionnaire was completed by 50 healthy children (32 females, 18 males) with normal vision. As shown in Table 1, the average monocular and binocular visual acuities were good, the mean refractive error (SERs) was +0.08 and +0.01 for the right and left eye, respectively. Forty-nine children (98%) used a smartphone and 17 (47%) used a tablet on a daily basis (outside school hours). The children spent on average 1.8 hours using their smartphone and 1 hour on their tablet on a weekday. During the weekend they spent significantly more time using their smartphone (2.6 hours, $t(47)=-4.9, p<0.001$) and tablet (1.7 hours, $t(16)=-3.98, p=0.001$). The mean time spent outdoors was 17.7 hours per week, and the children participated in sports on average 4.7 hours per week.

The mean viewing distance to the smartphone was 33.3 cm, range 16–52 cm, with a calculated visual acuity demand of 0.58 logMAR. The most common posture when using a smartphone was sitting, $n=33$ (69%) or lying down, $n=16$ (33%). Only two children reported that standing was their preferred posture/position. These were also the most common postures when using a tablet (sitting, $n=9$ (53%), lying down, $n=8$ (47%)). Forty-three children (90%) preferred to support the smartphone using their hands. For tablet use, six (35%) preferred their hands, and seven (41%) preferred the table/lap as support. The most preferred lighting was ambient indoor room lighting for 27 (55%) of the children when using their smartphone or tablet. However, 17 (35%) stated that they most often used their device in a dark room, with no other lighting than the device screen itself.

Symptoms

Table 2 shows the reported presence of vision or musculoskeletal symptoms while using smartphones and tablets. Thirty-three children (67%) had no symptoms while using their smartphone. The most commonly reported symptoms were tired eyes $n=15$ (31%), neck pain $n=14$ (29%) and tiredness $n=11$ (22%). Headache was reported by six (12%) children. The mean total symptom score was 6.6 for smartphone use, and females had significantly higher total symptom score ($t(47)=-2.24, p=0.03$) and more eyestrain ($t(48)=-2.57, p=0.013$) during smartphone use compared to males. Although the overall symptom scores were low, eight (16%) children reported experiencing one or more symptoms often or always, and 13 (27%) children reported three symptoms or more when using their smartphone (see Table 2). About half (53%) of the children reported no symptoms when using their tablet. Table 2 shows that the most common symptoms related to tablet use were tired eyes $n=7$ (41%), tiredness $n=7$ (41%) and neck pain $n=5$ (29%). Two (12%) children reported headache when using a tablet. Three (18%) children reported often or always experiencing one or more symptoms, and five (29%) children reported three symptoms or more when using their tablet. The mean total symptom score was 7.7 for tablet use, and this was significantly higher than for smartphone use (paired *t*-test; $t(15)=3.24, p=0.005$). Also, higher scores were found for eyestrain ($t(15)=3.72, p=0.002$), neck pain ($t(15)=2.61, p=0.020$), and tiredness ($t(15)=2.45, p=0.027$) during tablet use compared to use of smartphones.

Table 2: *Frequency of symptoms.*

		Smartphone (n=49) n (%)	Tablet (n=17) n (%)
Vision symptoms	Tired eyes	15 (31)	7 (41)
	Uncomfortable eyes	7 (14)	2 (12)
	Double vision	4 (8)	0 (0)
	Blurred vision	4 (8)	1 (6)
	Jumping letters	1 (2)	0 (0)
	Eye pain	6 (12)	3 (18)
	Sore eyes	4 (8)	1 (6)
	Pulling feeling around eyes	2 (4)	2 (12)
	≥ 3 symptoms	8 (16)	2 (12)
Musculo-skeletal symptoms	Neck pain	14 (29)	5 (29)
	Shoulder pain	4 (8)	1 (6)
	Back pain	1 (2)	3 (18)
	Arm/hand pain	1 (2)	1 (6)
	Hand/finger pain	4 (8)	1 (6)
	≥ 3 symptoms	2 (4)	0 (0)
	Headache	6 (12)	2(12)
	Tiredness	11 (22)	7(41)
Overall symptoms	No symptoms	33 (67)	9 (53)
	≥ 3 symptoms	13 (27)	5 (29)
	Often or always ≥ 1 symptom	8 (16)	3 (18)

Associations between symptoms and viewing distance, screen time and participation in sports

Shorter viewing distance to the smartphone was related to increased neck pain ($r=-0.35, n=49, p=0.014$. Further, eyestrain during smartphone use was related to neck and shoulder and back pain ($r=0.71, n=49, p=0.000$), and arm/hand pain ($r=0.48, n=49, p<0.001$). Eyestrain was also associated with increased neck and shoulder pain during tablet use ($r=0.53, n=17, p=0.027$). The children with best VA had less eyestrain ($r=0.47, n=49, p=0.001$) during smartphone use and less shoulder pain ($r=0.55, n=17, p=0.023$) during tablet use than those with poorest VA. Eyestrain ($r=0.369, n=49, p=0.001$) and total symptom score ($r=0.50, n=49, p=0.000$) were significantly correlated to the experience of tiredness during smart phone use.

Increased time using a tablet was significantly associated with sore eyes and blurred vision ($r=0.63, n=17, p=0.007$), and more time using a smartphone was associated with headache ($r=0.34, n=49, p=0.016$). Reduced participation in sports was related to increased neck, shoulder and back pain during both tablet ($r=-0.59, n=17, p=0.015$) and smartphone use ($r=-0.36, n=49, p=0.01$), and increased presence of headache during smartphone use ($r=-0.42, n=49, p=0.003$). Analysis of variance showed that seven (41%) of the tablet users, and 17 (35%) of the smartphone users who reported neck, shoulder and back pain, were significantly less physically active (on average 2.1 hours per week) compared to children without these symptoms when using tablets $F(1,15)=4.974, p=0.041$, or smartphones ($F(1,47)=7.122, p=0.010$). There were no significant associations between screen time and participation in sports.

Further, headache showed significant positive correlations with eyestrain ($r=0.62, n=49, p<0.001$), and associations with neck, shoulder and back pain ($\chi^2(1, n=49)=15.50, p<0.001$) and arm/hand pain ($\chi^2(1, n=49)=11.82, p=0.001$) during smartphone use. Headache was also associated with eyestrain ($r=0.86, n=17, p<0.001$) and neck and shoulder pain, ($\chi^2(1, n=17)=5.44, p=0.02$) during tablet use.

In summary, short distance to the screen, increased screen time, and reduced participation in sports may increase the risk of symptoms of eyestrain, headache, and upper body musculoskeletal pain in otherwise healthy children with good vision. Also, eyestrain, headache, and upper body musculoskeletal pain are correlated symptoms.

Discussion

This study found that most healthy adolescents with good vision reported low scores on symptoms of headache, eyestrain and musculoskeletal pain while using their digital device. Still, about one-third experienced symptoms of tired eyes and/or neck pain and 12% reported headache. Three symptoms or more were present in about one-third, and almost 20% experienced symptoms often or always while using their devices. Also, girls experienced more symptoms than boys. This is in line with earlier studies showing that eyestrain, headache, and neck pain are generally common in the adolescent population, and that girls have more complaints than boys (Batley et al., 2019; Ben Ayed et al., 2019; Gheysvandi et al., 2019; Gustafsson et al., 2018; Gustafsson et al., 2019; Joergensen et al., 2019; Kim et al., 2016). Studies of symptoms specific to digital screen use in adolescents are scarce. We have identified only three studies, and our results support and elucidate these studies (Hakala et al., 2012; Ichhpujani et al., 2019; Lui et al., 2011). A Hong Kong study showed that approximately one third of 8-13-year-olds experienced musculoskeletal symptoms during electronic game use, and neck complaints (28%) were most commonly reported (Lui et al., 2011). In the Hong Kong study, headaches and eyestrain were not reported. Among Finnish 12–16-year-olds, neck and shoulder pain (21%), headache (20%) and eye symptoms (14%) were the most often reported computer-associated symptoms (Hakala et al., 2012). A more recent Indian study found that 18% of 11–17-year-olds experienced eyestrain after working on digital devices, however, they did not investigate musculoskeletal pain or headaches (Ichhpujani et al., 2019). The slight differences in symptom frequencies compared to the current study, are most likely due to differences in population, study design, and sample size. One important difference is that the current study had very strict inclusion criteria related to vision and general health, contributing with new knowledge of screen related symptoms in healthy adolescents with good vision.

The present study is, to our knowledge, the first study showing correlations between neck, shoulder and back pain, and vision/eyestrain in healthy adolescents with good vision. These associations have only previously been shown in adults (Mork, 2019; Mork et al., 2019; Sanchez-Gonzalez et al., 2019). Eyestrain and headache were also associated with arm/hand pain during smartphone use. The most likely explanation is that almost all children (90%) supported their smart phone only with their hands, whereas lap/table were used as tablet-support. Further, our study showed strong correlations between eyestrain and headache. This supports other studies examining vision problems in relation to headaches (Akinci et al., 2008; Dotan et al., 2014; Falkenberg et al., 2019; Gil-Gouveia & Martins, 2002; Gunes et al., 2016; Hendricks et al., 2007). These associations are not surprising, as near tasks, such as screen use, require high visual-motor function and precise coordination between the visual system and the head-stabilizing muscles. Even small imbalances have been shown to provoke eyestrain, headaches, and musculoskeletal symptoms (Blehm et al., 2005; de Vries et al., 2016; Johnston et al., 2017; Rosenfield, 2011; Sanchez-Gonzalez et al., 2019).

Shorter viewing distance to the smartphone was related to increased neck pain. In our study, the average distance was 33 cm, and seven children held their smartphone at less than 25 cm. Our findings are in line with other studies in school children of a similar age (Ichhpujani et al., 2019; Salmerón-Campillo et al., 2019), but are 10 cm longer than the average viewing distances measured in a study of young adults reading from smartphones and tablets (Miranda et al., 2018). The differences in viewing distance are most likely due to different methods, tasks, and setups. Often, as in the current study, viewing distance is a point measure between the cornea and the handheld display while reading a short text. Miranda and colleagues however, measured convergence distance to reading a continuous text for a much longer period, while using an eye tracker. Shorter viewing distances have been shown to increase the load on the visual system and binocular vision, increasing the risk of eyestrain and neck pain (Ichhpujani et al., 2019; Jaiswal et al., 2019; Long et al., 2017; Sanchez-Gonzalez et al., 2019). Therefore, longitudinal studies are necessary to understand the mechanisms behind preferred short viewing distances when using handheld devices in both children and adults. Increased screen time was associated with increased presence of eyestrain and headache in the current study, in line with several studies (Alonso-Blanco et al., 2011; Costigan et al., 2013; Fernandez-de-las-Penas et al., 2011; Hakala et al., 2012; Kim et al., 2016; Moon et al., 2016; Taehtinen et al., 2014; Torsheim et al., 2010). It is exhausting for both vision and head-stabilising musculature to perform continuous near work with short viewing distances (Blehm et al., 2005; Sanchez-Gonzalez et al., 2019). The current study supports the theory that longer viewing distances and taking breaks while using digital screens may be important in preventing symptom development.

Neck pain, eyestrain, and tiredness scores were higher during tablet use compared to smart phone use in the present study. To our knowledge, this has not been shown in earlier studies. One explanation could be differences in viewing time and continuous use without breaks. This is unlikely as screen viewing time did not differ significantly between tablet and smartphone in this study. The frequency of breaks was not registered when using the different devices. Another explanation could be differences in position or support while using the digital device. In this study, there was no difference in position, while there was a difference in how the device was supported. The preferred tablet support was in the lap or on a table, while hands were preferred when using the smartphone. This difference in support indicates increased head flexion angle during tablet compared to smartphone use, increasing the load on the neck and inducing neck pain (Eitivipart et al., 2018; Oliveira & Silva, 2016; Straker et al., 2008). This is supported by studies showing that mechanical load on the neck muscles increases 3-5 times during seated tablet computer use compared to seated neutral posture in adults (Vasavada et al., 2015). Further, neck imbalance may increase the load on the visual system explaining the increased eyestrain and tiredness symptoms when using the tablet (de Vries et al., 2016; Johnston et al., 2017; Sanchez-Gonzalez et al., 2019).

Decreased participation in sports was related to increased neck, shoulder and back pain, and headache during tablet and smartphone use. This is in line with indications of a relation between neck pain and reduced muscle endurance and strength of neck and back musculature in adolescents (Andias & Silva, 2019). This suggests that reduced physical activity and lack of muscle strength and endurance can increase the risk of musculoskeletal pain symptoms. Moderate physical activity has been shown to be protective regarding neck, shoulder and back pain in adolescents (Hakala et al., 2012; Myrtveit et al., 2014). As such, this supports public health advice of being physically active, and both parents and schools should encourage and facilitate participation in sports for adolescents.

In this study, 35% stated that they most often used their device with no other lighting than the device screen light itself. We did not find any associations between lighting conditions and symptoms, in contrast to other studies. This is probably due to differences in study design, where our participants self-reported on lighting conditions in natural settings, while other studies are controlled lab experiments. Too large a difference in luminance between the screen and immediate surroundings may lead to contrast glare, thereby increasing the load on the visual system and the risk of eye and musculoskeletal symptoms (Antona et al., 2018; Mork, 2019; Mork et al., 2019).

A strength of this study was the strict inclusion criteria related to health and visual status, providing new knowledge of symptoms and associated risk factors in adolescents while using digital devices. Although the data are from a relatively small sample, the study population of fifty 11– to 13–year-old Norwegian adolescents is representative for 7th grade school children in Norway (Statistics Norway, 2020), strengthening the potential generalisability of the study results to healthy Norwegian adolescents of the same age. Further, similar findings have been shown in adults. Since the data collection, the use of digital devices in Norwegian schools has escalated, and many children use a tablet computer as their main tool for school– and homework. Combined with even easier access to private digital devices, this study probably underestimates the viewing times spent on digital viewing (Norwegian Media Authority, 2020) and the frequency of symptoms. Frequency of breaks during screen viewing and viewing distance to tablet were not registered in this study, something that may have allowed us to elaborate some of the results. However, it has been shown that tablets are held at a similar distance to our measured smartphone distance (Salmerón-Campillo et al., 2019), and that the viewing distance is the same for smartphones and tablets (Miranda et al., 2018). The school setting did not allow the use of cycloplegic refraction, which is the standard clinical practice for refraction of children. This limits the conclusion to be drawn on the average hyperopic refractive error found in these children. However, the results are similar to other larger studies on Norwegian adolescents (Falkenberg et al., 2019; Hagen et al., 2018). A cycloplegic refraction would have shifted the refractive errors slightly towards more hyperopia (on average +0.5 D) in the whole sample (Yazdani et al., 2018), and we doubt this shift would have affected the results significantly. Another limitation is the use of self-reported symptoms and visual ergonomics, which could bias the results. However, an experienced optometrist asked the questions, and could explain and ask follow-up questions, minimising recall errors. Despite this, our study contributes important knowledge of headache, eyestrain, and musculoskeletal pain in adolescents, which may guide further research and clinical practice. Larger, controlled studies are necessary to elucidate the prevalence of these symptoms related to screen use, and must in addition include psychosocial variables such as stress and quality of life, as they are known to be associated with the experience of pain in adolescents.

Conclusions

Most adolescents with good health and vision had no symptoms while using smartphones (67%) and tablets (53%). However, a significant proportion still experienced headache, neck pain, tiredness and tired eyes, and these symptoms were associated. Symptoms increased with screen time, shorter viewing distance and reduced participation in sports. This suggests that even healthy children with good vision may develop vision symptoms and musculoskeletal pain. Awareness should be raised among adolescents, parents, teachers, eye– and healthcare personnel, of the importance of good visual ergonomics while using digital devices to promote health. Further, this study supports public health advice of being physically active, and both parents and schools should encourage and facilitate participation in sports for adolescents.

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