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ORIGINAL ARTICLE

The association between time spent on screens and reading with myopia, premyopia and ocular biometric and anthropometric measures in 6- to 7-year-old schoolchildren in Ireland

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Abstract

Purpose: More time spent on near tasks has consistently been associated with the promotion of myopia. The World Health Organization advises limiting daily screentime to less than 2 h for children aged five and over. This study explored the relationship between time spent on screens and reading/writing with refractive status, ocular biometric and anthropometric factors in 6- to 7-year-olds in Ireland.

Methods: Participants were 723 schoolchildren (377 boys [51.8%]), mean age 7.08 (0.45) years. The examination included cycloplegic autorefraction (1% cyclopentolate hydrochloride), ocular biometry (Zeiss IOLMaster), height (cm) and weight (kg). Screentime and reading/writing time were reported by parents/legal guardians by questionnaire. Myopia (≤−0.50D) and premyopia (>−0.50D ≤ 0.75D) risk assessments were performed using logistic regression, and multivariate linear regression was used to analyse continuous variables.

Results: Reported daily screentimes were 31% <1 h, 49.5% 1–2 h, 15.6% 2–4 h and 3.9% >4 h. Reading/writing times were 42.2% frequently, 48.0% infrequently and 9.8% seldom/never. Linear regression, controlling for age and ethnicity, revealed >2 h/day on screens was associated with a more myopic spherical equivalent [β = −1.15 (95% confidence intervals {CIs}: 1.62–0.69, $p < 0.001$)], increased refractive astigmatism (β = 0.29, CI: 0.06–0.51, p = 0.01), shorter corneal radius (β = 0.12, CI: 0.02–0.22, p = 0.02), higher axial length/corneal radius (β = 0.06, CI: 0.03–0.09, $p < 0.001$), heavier weight (β = 1.60, CI: 0.76–2.45, $p < 0.001$) and higher body mass index (BMI) (β = 1.10, CI: 0.28–1.12, $p < 0.001$). Logistic regression, controlling for age and ethnicity, revealed daily screentime >2 h was associated with myopia (OR = 10.9, CI: 4.4–27.2, p = 0.01) and premyopia (OR = 2.4, CI: 1.5–3.7, $p < 0.001$). Frequent reading/writing was associated with screentime ≤2 h/day (OR = 3.2, CI: 1.8–5.8, $p < 0.001$).

Conclusion: Increased screentime was associated with a more myopic refraction, higher axial length/corneal radius ratio, increased odds of myopia, premyopia, higher degrees of astigmatism, increased weight, BMI and decreased reading/writing time. Dedicated education programmes promoting decreased screentime in children are vital to prevent myopia and support eye and general health.

KEYWORDS
astigmatism, myopia, ocular biometry, premyopia, reading, screen time

INTRODUCTION

Half of the world's population is estimated to be myopic by 2050, with 1 in 10 pathologically myopic.[1] Over two generations, myopia prevalence has increased fourfold in Asia.[2] In addition, the proportion of myopes doubled over the last 50 years in the United Kingdom, where children are becoming myopic at younger ages.[3] As myopia is strongly related to visual impairment (VI) in mid to later life,[4] it is essential to identify children at risk of developing myopia in childhood to facilitate myopia prevention and initiate treatment early to slow progression.[5]

Longitudinal research in Northern Ireland found 6- to 7-year-olds with less than +0.75D [spherical equivalent refraction (SER) (cut-off of +0.63D)] hyperopia were likely to develop myopia by 13 years of age.[6] Children identified as ‘persistent emmetropes’ at age 13 years had, on average, 1.07D of hyperopia at 6–7 years of age. Hence, premyopia (SER > −0.50D ≤ 0.75D),[7] previously identified as a public health concern in Asia,[8] is also an issue in predominately white European populations. Thus, the concept of an age-appropriate hyperopic reserve[9,10] at 6–7 years of age, and lifestyle factors associated with achieving and maintaining emmetropia merit consideration.

Prior research involving schoolchildren in Ireland identified one in five 12- to 13-year-olds as having myopia,[11] and noted that this refractive error was associated with increased screentime, frequent reading/writing and obesity.[11] Over the past decade, the increasing use of digital media and its ubiquitous exposure have changed the landscape of work, education and social engagement.[12] For instance, the Growing up in Ireland Study revealed that 9-year-old ‘Digi-tods’ (born after 2008 and the launch of smartphones) primarily engage with handheld, portable touch-screen digital devices.[13] In contrast, 9-year-olds born in 1998 engaged in TV viewing.[13] More recently, pandemic control measures, including lockdowns, accelerated the universal adoption of screen-based engagement globally.[14,15] In the Netherlands, 12- to 16-year-olds spend on average 4 h per day on their smartphones.[16] Moreover, 12- to 13-year-olds in the United States spend an average of 6 h per day viewing screens.[17] The literature reveals screen media exposure begins at 6 months of age.[18] In a 2014 US study, on average, children under 2 years spent 3 h per day viewing screens.[19] This is concerning as screen media may impact childhood development.[20,21] Indeed, screentime may negatively affect the microvascular structure of the retina.[22] Furthermore, one in five South Korean 4- to 5-year-olds display problematic, obsessive or uncontrollable smartphone use.[23]

The World Health Organization and the American Academy of Pediatrics advise limiting daily screentime to less than 2 h for children 5 years of age and older, emphasizing supervised viewing and co-viewing and avoiding screentime in children younger than 18 months.[24,25] In Ireland, 54% of 9-year-olds own a smartphone.[26] This study examined parent-reported screentime, reading/writing time and associated refractive, ocular biometric and anthropometric factors in 6- to 7-year-olds in Ireland.

Key Points

- One in five participants, and over half of the myopes, reported more than 2 h/day viewing screens, exceeding the World Health Organization's recommendations of a maximum of 2 h/day.
- Screentime of more than 2 h/day was associated with a more myopic refraction, higher axial length/corneal radius and higher body mass index.
- Increased screentime was associated with decreased time spent reading/writing in 6- to 7-year-old children.

METHODS

Sampling, recruitment protocols, participation rates, experimental techniques and methods used have previously been described in detail.[27,28] Stratified random sampling was used to obtain representative samples of children in mainstream schools in Ireland. Schools were stratified by urban or rural living and socioeconomic status. The Technological University Dublin, Research Ethics Committee, granted ethical approval, and the study adhered to the tenets of the Declaration of Helsinki.

Public involvement: During the design stage of the study, focus groups assessed the burden associated with and the time to complete the study questionnaire.[16] The study used parent/legal guardian-reported measures as a proxy for daily screentime and reading/writing time. Although parental reports may underestimate screentime activity in older children owning their own devices,[29] 6- to 7-year-olds are less likely to have unsupervised access to screen-based technologies and will more likely ask their caregivers for access to a device.

Data collection occurred between June 2016 and January 2018. Participants were 728 schoolchildren (377 boys) in Ireland. Participants' mean (standard deviation [SD]) age was 7.08 (0.45) years (range 6.01–7.99). Ethnicity was as follows: White (647 participants) and non-White (a total of 81 comprising 31 Black, 21 East Asian, 22 South Asian and 7 Arab).

Participants' parents/legal guardians completed a standardised eye health and lifestyle questionnaire (response rate = 723/728, 99.3%) reporting inter alia, eye and vision problems. The extended details are reported elsewhere.[11] Completed questionnaires were returned to the first author at least 2 weeks before data collection. Parents/guardians reported their child's daily screentime (including computers, Nintendo game players, iPads, smartphones and television) as follows: '<1 h', '1–2 h', '2–4 h' or 'over 4 h'. Reading/writing time was reported as follows: 'all/most leisure time reading/writing', 'frequently reading/writing', 'occasionally reading/writing' or 'seldom/never reading/writing'.

Parental history of myopia related to the child's birth parent was self-reported by the parent/legal guardian.

Examinations

Children with written informed consent from parents/legal guardians and child assent were examined at their school premises within school hours. The examination involved cycloplegic autorefraction (Dong Yang Rekto ORK-11 Auto Ref-Keratometer, everview.kr/) performed at least 30 min post-instillation of anaesthetic (Minims Proxymetacaine Hydrochloride 0.5% weight/volume, bausch.co.uk) and cycloplegic eye drops (Minims Cyclopentolate Hydrochloride 1% weight/volume, bausch.co.uk). The SER value, that is, sphere plus half the cylindrical value, was used in subsequent analysis. The Zeiss IOLMaster 500 (zeiss.com) was used to measure the axial length (AL) and corneal radius (CR). Participant height (in cm) was measured using the Leicester height measure MKII (Invicta Plastics Limited, invictagroup.co.uk/). Weight (in kg) was measured using digital scales Seca 813 (Sönke Vogel, seca.com/en_gb.html). Participants removed their shoes for both height and weight measurements.

Using the following formulae, the astigmatism value was transformed into the rectangular vectors J_0 and J_{45}:

$$J_0 = -\frac{C}{2}(\text{Cos}2\alpha)$$

$$J_{45} = -\frac{C}{2}(\text{Sin}2\alpha)$$

J_0 is the Jackson cross-cylinder power between the 90° and 180° axes, J_{45} is the Jackson cross-cylinder power between the 45° and 135° axes, C is the negative cylinder and α is the axis of the flatest meridian. Positive and negative values of J_0 indicate with-the-rule (WTR) and against-the-rule astigmatism, respectively. Oblique astigmatism is indicated by J_{45}.

For risk factor analysis, the following definitions were adopted: myopia SER ≤ −0.50D, premyopia (SER > −0.50D to ≤+0.75D), hyperopia ≥ +2.00D, astigmatism ≥1.00D, and age-appropriate hyperopic reserve (clinical emmetropia): SER > +0.75D to ≤+1.75D. Body mass index (BMI) was divided into three categories: non-overweight (including underweight), overweight and obese, with half-yearly intervals for boys and girls.[30]

Follow-up: After the examination, all parents/legal guardians received a detailed report of the study findings and the need for any further treatment if required.

Statistical methodology

Data were analysed using SPSS statistical software package version 27 (IBM-SPSS Inc., ibm.com). The statistical programming language R, RStudio version 1.1.456 (r-project.org/) was used to generate random numbers for the sampling procedure and to provide prevalence data with 95% confidence intervals (CIs). The 5% significance level has been used throughout. Categorical data are presented as a percentage, and continuous data are presented as the mean [standard deviation (SD)].

The Kolmogorov–Smirnov test was used to check the normality of distributions. Only right eye data are presented for continuous variables as the right and left eye data were significantly correlated for all the following: SER (r = 0.89, p < 0.001), refractive astigmatism (r = 0.64, p < 0.001), AL (r = 0.92, p < 0.001), horizontal corneal radius (CR H) (r = 0.96, p < 0.001) vertical corneal radius (CR V) (r = 0.95, p < 0.001) and corneal astigmatism (r = 0.68, p < 0.001).

Multivariate analyses: Multinomial logistic regression and multivariate linear regression models were used for analyses involving more than two variables.

Dependent variables

The primary analyses used continuous dependent variables: SER, AL, CR, height, weight and BMI, refractive and corneal astigmatism and refractive and corneal J_0 and J_{45}. Refractive error categories, myopia, premyopia, etc., were examined using multinomial logistic regression analyses. Near visual tasks were quantified using two measures: (i) time spent on screens daily and (ii) time spent reading/writing.

Moderating and control variables

Sociodemographic variables were selected as covariates for the regression models, age, sex, ethnicity (White, non-White), socioeconomic status, living environment (urban, rural) and parental myopia.

RESULTS

Table 1 presents the study characteristics.

Parents/legal guardians reported their child's daily screentime as follows: 31% <1 h, 49.2% 1–2 h, 15.5% 2–4 h, 3.9% >4 h, and reading/writing time as follows: 2.7% all/most of leisure time, 39.1% frequently, 47.7% occasionally and 9.8% seldom/never. As there were very few participants (n = 20) in the 'all/most leisure time reading writing', this group was combined with the 'frequently reading/writing' group. Furthermore, daily screentime categories <1 h/day and 1–2 h/day were combined and 2–4 h and >4 h were also combined in logistic regression analysis models. Table S1 displays descriptive statistics for study dependent variables overall and by screentime category.

TABLE 1 General characteristics and summary statistics of study variables of the 728 participants between 6 and 7 years of age.

Child factors	
Demographics	
Age (mean (SD) [min–max]) years	7.08 (0.45) [6.00–7.99]
Sex, male, *n* (%)	377 (51.8)
Ethnicity, *n* (% White)	647 (88.9)
Living environment, *n* (% urban)	368 (50.5)
Socioeconomic status, *n* (% disadvantaged)	243 (33.4)
Refractive error	
SER (mean (SD) [min, max]) D	1.43 (1.24) [−0.50, 9.00]
Astigmatism (mean (SD) [min, max]) D	−0.61 (0.58) [−4.25, 0.00]
Myopia (SER ≤ −0.50D), *n* (%) [95% CI]	27 (3.7) [2.5 to 5.5]
Premyopia (SER > −0.50D ≤ 0.75D), *n* (%) [95% CI]	236 (32.4) [29.3 to 36.2]
Clinical emmetropia (SER > +0.75 ≤ +1.75), *n* (%) [95% CI]	242 (33.2) [30.1 to 37.1]
Hyperopia (SER ≥ +2.00D), *n* (%) [95% CI]	223 (30.6) [27.1 to 34.4]
Anthropometrics	
Height (mean (SD) [min, max]) mm	123.77 (6.25) [105.00, 145.00]
Weight (mean (SD) [min, max]) kg	25.63 (4.62) [17.00, 55.10]
Body mass index (mean (SD) [min, max]) kg/m^2	16.66 (2.16) [11.48, 29.63]
Ocular biometrics	
Axial length (mean (SD) [min, max]) mm	22.53 (0.79) [19.14, 25.73]
Corneal radius horizontal meridian (mean (SD) [min, max]) mm	7.89 (0.28) [7.20, 8.87]
Corneal radius vertical meridian (mean (SD) [min, max]) mm	7.73 (0.28) [6.98, 8.63]
Near-vision activities	
Daily screentime, *n* (%)	
<1 h	224 (30.8)
1–2 h	358 (49.2)
2–4 h	113 (15.5)
>4 h	28 (3.9)
Participation rate	723 (99.3)
Missing	5 (0.7)
Reading writing time, *n* (%)	
All/most of leisure time reading/writing	20 (2.7)
Frequently reading/writing	285 (39.1)
Occasionally reading/writing	347 (47.7)
Seldom/never reading/writing	71 (9.8)
Participation rate	723 (99.3)
Missing	5 (0.7)
Parental myopia, *n* (%)	
Neither parent myopic	392 (53.8)
One myopic parent	231 (31.7)
Both parents myopic	52 (7.1)
Missing[a]	53 (7.3)

Abbreviations: CI, 95% confidence intervals; CYL, cylinder; D, dioptre; kg, kilogram; m, metre; max, maximum; min, minimum; mm, millimetres; *N*, *n*, Number; SD, standard deviation; SER, spherical equivalent refraction.

[a]Parental myopia relates to participants' birth parents; some legal guardians did not have this information.

Linear regression models were constructed to assess the effect of age, sex and ethnicity on the distribution of SER, ocular biometric and anthropometric parameters. For example, with SER as the dependent variable and age, sex and ethnicity as explanatory variables, increased age (β = −0.29 D, CI: −0.47 to −0.11, p = 0.002) and non-white ethnicity (β = −0.74D, CI: −0.99 to −0.42, $p < 0.001$) were associated with a more myopic SER; however, sex (p = 0.73) was not.

A longer AL (β = 0.20 mm, CI: 0.09–0.31, $p < 0.001$) was associated with increased age (β = 0.21, CI: 0.09–0.31, $p < 0.001$) and males (β = 0.15, CI: 0.40–0.62, $p < 0.001$), but not ethnicity (p = 0.11). Table 2 presents the relationship between daily screentime and refractive, ocular biometric and anthropometric variables in the study participants, controlling for confounders. In Table 2 (see β coefficient values in column 1), positive associations of the covariates with the dependent variable indicated an increase in the value of the dependent variable, while negative values indicated a decrease in the value of the dependent variable.

Spherical equivalent refraction

Overall, participants on screens >2 h/day had a lower mean SER [0.98 (1.19) D] than those on screens <2 h/day [1.54 (1.23) D, β = 0.56, 95% CI: 0.33–0.78, $p < 0.001$] (Figure 1). The mean SER among myopes on screens >4 h/day was −1.75 (1.39) D, lower than for myopic participants who reported screentime <2 h/day [−0.50 (0.20) D], (β = 0.1.33, CI: 0.18–2.48, p = 0.02). Also, the mean SER among premyopes on screens >2 h/day [−0.30D (0.94D)] was more myopic than for premyopes on screens ≤2 h/day [0.26 (0.37) D] (β = 0.56, CI: 0.32–0.79, $p < 0.001$).

Refractive and corneal astigmatism

Participants on screens >2 h/day had 0.12D more astigmatism [−0.71 (0.72), D] than those on screens ≤2 h/day [−0.59

TABLE 2 Relationship between the dependent variables refractive status, ocular biometrics and anthropometric parameters and daily screentime controlling for confounders.

Average daily screentime	B coefficient	SE	t
Spherical equivalent refraction (D)[b,c]			
≤2 h ($n = 582$)	0[a]		
>2 h ($n = 141$)	−0.56***	0.12	−4.81
Refractive astigmatism (D)			
≤2 h ($n = 582$)	0[a]		
>2 h ($n = 141$)	−0.12*	0.06	−2.18
Refractive J_0 (D)			
≤2 h ($n = 582$)	0[a]		
>2 h ($n = 141$)	0.13*	0.06	2.01
Axial length (mm)[b,d]			
≤2 h ($n = 582$)	0[a]		
>2 h ($n = 141$)	0.14	0.07	1.83
Corneal radius vertical meridian (mm)[d]			
≤2 h ($n = 582$)	0[a]		
>2 h ($n = 141$)	−0.07	0.03	−2.91
Corneal radius (mm) horizontal meridian[d]			
≤2 h ($n = 582$)	0[a]		
>2 h ($n = 141$)	−0.07**	0.03	−8.37
Mean corneal radius (mm)[d]			
≤2 h ($n = 582$)	0[a]		
>2 h ($n = 141$)	−0.07**	0.03	−8.72
Axial length/mean corneal radius ratio[b,c]			
≤2 h ($n = 582$)	0[a]		
>2 h ($n = 141$)	0.04***	0.01	4.79
Weight (kg)[b,c]			
≤2 h ($n = 582$)	0[a]		
>2 h ($n = 141$)	1.61***	0.43	3.73
Body mass index (kg/m^2)[c]			
≤2 h ($n = 582$)	0[a]		
>2 h ($n = 141$)	0.92***	0.20	4.54

Abbreviations: β, beta co-efficient; D, dioptre; mm, millimetre; SE, Standard error.
[a]This parameter is set to zero because it is redundant.
[b]Controlling for age.
[c]Controlling for ethnicity.
[d]Controlling for sex.
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

(0.54) D, $\beta = -0.13$, CI: 0.012–0.23 $p = 0.01$] (Table 2). No association between daily screentime and corneal astigmatism was found ($p = 0.31$).

Refractive and corneal J_0 and J_{45}

Participants on screens >2 h/day had 0.13D higher refractive J_0 [0.46 (0.79) D] than those in the ≤2 h/day [0.33 (0.62) D, $\beta = -0.13$, CI: −0.24 to −0.01, $p = 0.04$] daily screentime group (Figure 2 and Table 2). Corneal and refractive J_{45} and corneal J_0 were not associated with screentime (all $p > 0.05$).

Ocular biometrics

Mean CR was 0.07 mm shorter for the >2 h/day daily screentime group [7.75 (0.27) mm] compared with the ≤2 h group [(7.82 {0.27} mm) $\beta = 0.07$, CI: 0.02–0.12, $p = 0.02$]. The AL/CR ratio was significantly higher for participants >2 h/day [2.92 (0.09)] than for participants ≤2 h/day [2.88 (0.08) $\beta = -0.04$, CI: −0.05 to −0.02, $p < 0.001$] on screens (Figure 3 and Table 2). There was no significant difference in AL across the screentime categories (Table 2). However, a longer AL approached significance ($\beta = 0.14$, CI: −0.28 to 0.01, $p = 0.06$) in the >2 h/day [22.64 (0.83) mm] group, compared with the ≤2 h/day participants [22.50 (0.75) mm].

Anthropometrics: Increased screentime was associated with increased weight [≤2 h/day: 25.32 (0.19) kg, >2 h: 26.93 (0.39) kg, $\beta = -1.60$, CI: −2.45 to −0.76, $p < 0.001$] and increased BMI [≤2 h/day: 16.48 (2.03) kg/m^2, >2 h/day: 17.39 (2.49) kg/m^2, $\beta = -0.91$, CI: −1.30 to −0.52, $p < 0.001$] (Figure 4 and Table 2) but not height ($p = 0.57$).

Reading/writing time was not associated with any refractive, ocular biometric or anthropometric parameters (Table S2).

Multivariate analyses: SER, AL/CR and BMI were strongly related to screentime; hence, multivariate linear regression models relating these parameters to all potential explanatory variables were constructed. Table 3 presents multivariate linear regression models for SER (column 1), AL/CR (column 2) and BMI (column 3). In Table 3, positive associations of the covariates (β value) with the dependent variable indicate an increase in the dependent variable (less myopic SER, higher AL/CR, higher BMI), and negative values indicate a decline in these values. Increased screentime remained associated with a more myopic SER, higher AL/CR and higher BMI. Maternal myopia was associated with a more myopic SER; however, paternal myopia was not.

Sociodemographic factors associated with near-vision activities

Multinomial logistic regression relating daily screentime to sociodemographic factors revealed that increased screentime was associated with socioeconomic disadvantage [odds ratio (OR) = 2.11 (CI: 1.36–3.26, $p < 0.001$)], and non-White ethnicity (OR = 3.69, CI: 2.20–6.21, $p < 0.001$), but not age ($p = 0.81$), sex ($p = 0.07$) or urban/rural living ($p = 0.06$). Frequently reading/writing was associated with females (OR = 4.04, 2.30–7.18, $p < 0.001$), non-White ethnicity (OR = 2.48, CI: 1.07–5.79, $p = 0.04$) and urban living (OR = 2.06, CI: 1.45–3.69, $p = 0.02$), but not age ($p = 0.21$) or socioeconomic status ($p = 0.32$). Frequently reading/writing was associated with <2 h/day on screens (OR = 3.23, CI: 1.80–5.77, $p < 0.001$).

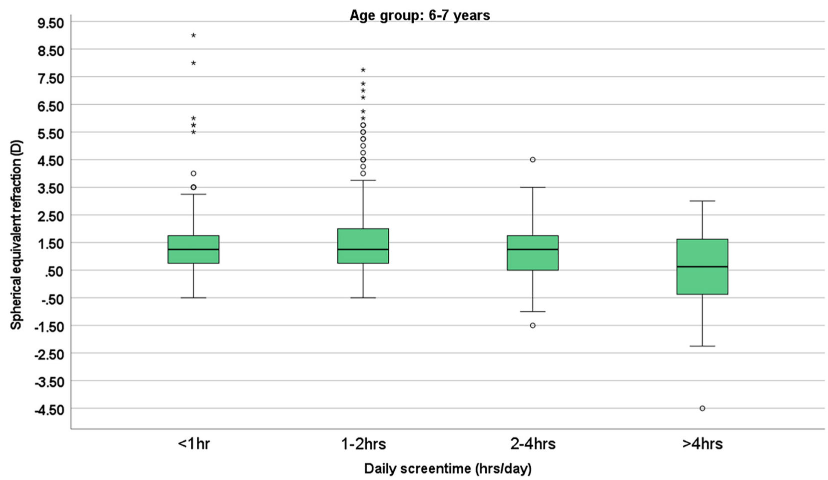

FIGURE 1 Box and whisker plots displaying the mean spherical equivalent refraction (SER) in dioptres (D) in 723 participants' right eyes by screentime category. Higher values represent a less myopic SER.

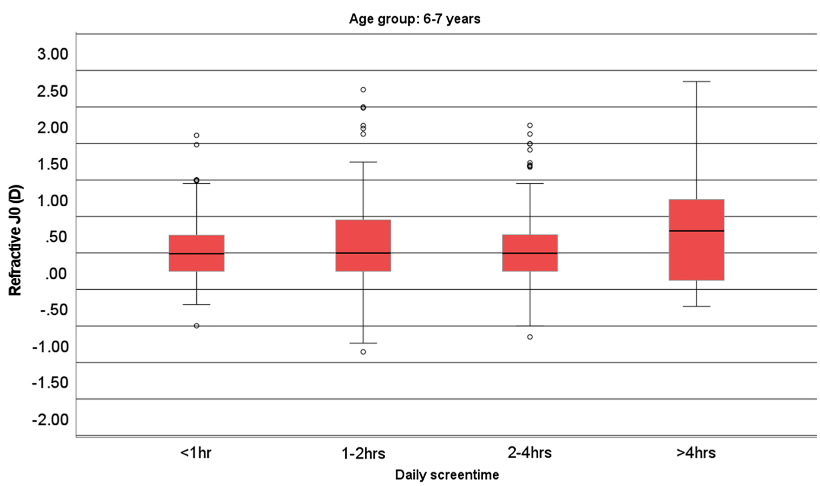

FIGURE 2 Box and whisker plots displaying the mean refractive J_0 (D) in 723 participants' right eyes by screentime category. Higher values represent greater levels of with-the-rule astigmatism.

Overweight/obesity

Screentime >2 h/day was associated with overweight/obesity (OR = 2.79, CI: 1.84–4.21, $p < 0.001$). Among participants who reported >2 h/day on screens, 34.5% were overweight/obese, whereas among participants ≤2 h/day on screens, 15.8% were overweight/obese. Time spent reading/writing was not associated with overweight/obesity ($p = 0.99$).

Parental myopia

Neither maternal (OR = 0.40, CI: 0.15–1.11, $p = 0.08$) nor paternal myopia (OR = 0.47, CI: 0.16–1.40, $p = 0.18$) was associated with myopia in the child. However, premyopia was associated with both maternal myopia (OR = 2.73, CI: 1.31–5.71, $p = 0.008$) and paternal myopia (OR = 2.72, CI: 1.31–5.03, $p = 0.04$).

Myopia, premyopia and near-vision activities (screentime and time reading/writing)

Multinomial logistic regression analysis relating myopia to screentime, reading/writing time, socioeconomic demographics, parental myopia and BMI revealed myopia was associated with non-White ethnicity (OR = 6.16, CI: 2.21–17.14, $p = 0.01$) and screentime >2 h/day (OR = 6.64, CI: 2.44–18.12, $p < 0.001$), but not age ($p = 0.77$), sex ($p = 0.09$), parental myopia ($p = 0.07$), urban/rural living ($p = 0.16$), BMI ($p = 0.68$) or reading/writing time ($p = 0.15$).

Figure 5 presents the relationship between myopia prevalence and screentime in the study participants. Three in four myopes reported >2 h/day on screens, compared with one in five overall. Controlling for age and ethnicity in all analyses, screentime >2 h/day was associated with increased odds (OR = 10.88, CI: 4.35–27.24, $p < 0.001$) for myopia and premyopia (OR = 2.41, CI: 1.57–3.71, $p < 0.001$). Furthermore, an age-appropriate hyperopic

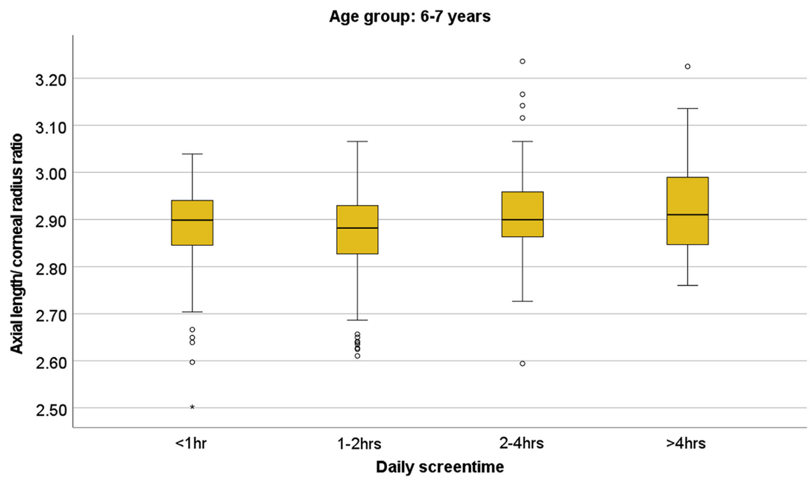

FIGURE 3 Box and whisker plots displaying the mean axial length/corneal radius ratio in 723 participants' right eyes by screentime category. Higher values are associated with a more myopic spherical equivalent refractive error.

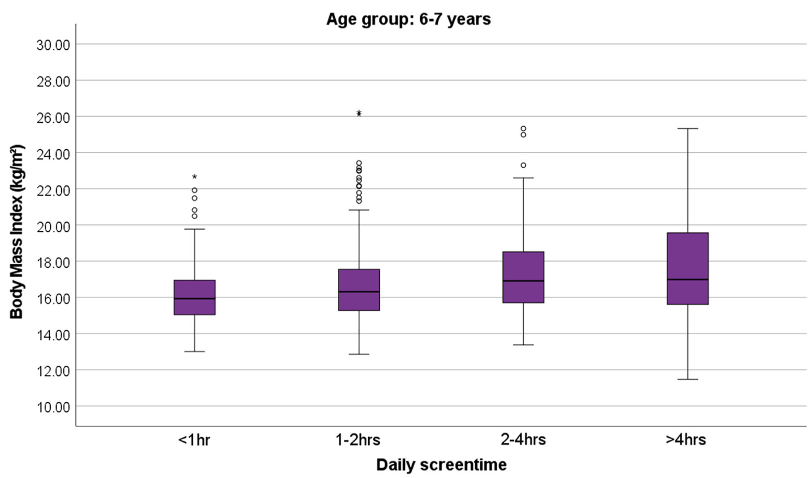

FIGURE 4 Box and whisker plots displaying mean body mass index (kg/m^2) by screentime category in 723 participants aged 6–7 years.

reserve (SER > 0.75, ≤1.75D) was associated with <1 h/day on screens (OR = 3.03, CI: 1.08–8.55, p = 0.04). Neither hyperopia (p = 0.16) nor astigmatism (p = 0.37) was associated with daily screentime. Reading/writing time was not associated with refractive status (p > 0.05 for all categories).

DISCUSSION

This study is the first to examine parent/legal guardian-reported near-vision tasks (screentime and reading) and their relationship with refractive error, ocular biometric and anthropometric parameters in 6- to 7-year-olds in Ireland. Increased screentime was associated with a more myopic SER, shorter CR, higher AL/CR, higher WTR refractive astigmatism and higher BMI. Controlling for confounders, participants on screens >2 h/day were 10 times more at risk of myopia and twice as likely to be premyopic. In contrast, children who reported <1 h per day on screens were three times more likely to have an age-appropriate hyperopic reserve (SER > 0.75 ≤ 1.75D). The present study demonstrates that in Ireland, one in five 6- to 7-year-olds and three in four 6- to 7-year-old myopes, reported more than 2 h/day on screens, with 3.9% reporting over 4 h daily, exceeding the World Health Organization recommendations of a maximum of 2 h/day.[25]

In addition to the main findings, this study revealed screen media appears to be eclipsing reading. All participants were born after 2008, so-called 'Digi-tods', after the launch of mass-market smartphones,[13] with different device engagement patterns to children born 10 years earlier, as handheld portable touch-screen digital devices have now replaced TV time. Moreover, socioeconomically disadvantaged participants were twice as likely and non-White participants almost four times as likely to exceed WHO screentime guidelines (max 2 h/day), aligning with the literature, where increased screentime is consistently related to socioeconomic status.[31] Due to the ubiquity of screen media, culturally sensitive education to support

TABLE 3 Linear regression models on 723 participants for (column 1) spherical equivalent refractive error (SER), (column 2) axial length/corneal radius (AL/CR) ratio and (column 3) body mass index (BMI).

Model		1. SER coefficients	2. AL/CR coefficients	3. BMI coefficients
		B (SE)	*B* (SE)	*B* (SE)
	(Constant)	3.73*** (0.81)	2.71*** (0.48)	16.20*** (1.43)
	Daily screentime	−0.37** (0.12)	0.03*** (0.01)	0.88*** (0.22)
	Reading/writing	0.01 (0.07)	0.00 (0.01)	−0.20 (0.13)
	Socioeconomic status	−0.05 (0.11)	0.01 (0.01)	−0.38 (0.20)
	Urban/rural living	0.08 (0.10)	−0.01 (0.01)	−0.42* (0.18)
	Sex	−0.04 (0.10)	−0.03 (0.01)	0.24 (0.17)
	Ethnicity	0.72*** (0.17)	−0.03** (0.01)	−0.52 (0.29)
	Mother myopic	−0.25* (0.10)	0.01* (0.01)	−0.39* (0.18)
	Father myopic	−0.22 (0.12)	0.02* (0.01)	−0.13 (0.21)
	Age in years	−0.32** (0.10)	0.02** (0.01)	0.15 (0.18)
	Adjusted R^2	0.069	0.069	0.079

Note: Standard errors in parentheses
$^*p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$.

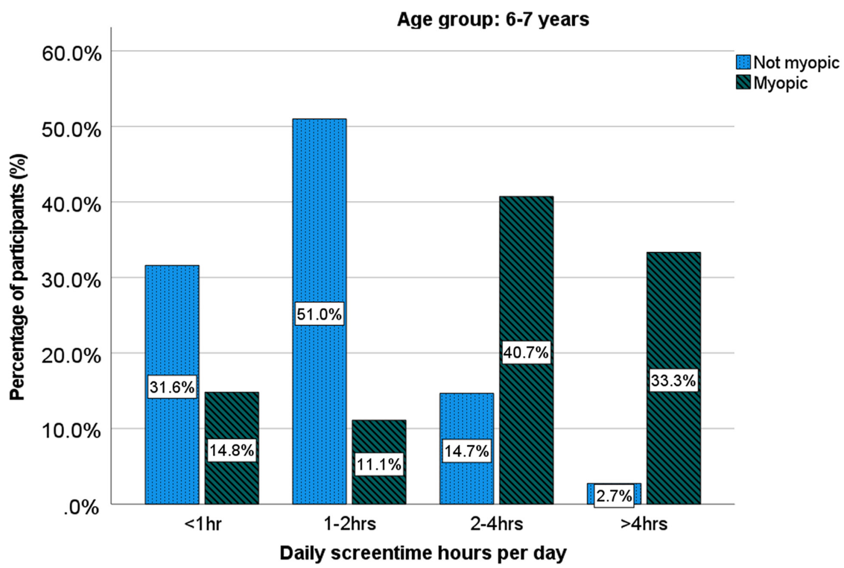

FIGURE 5 Relationship between myopia (≤−0.50) (dark green bars) and screentime in 723 participants aged 6–7 years. Myopic participants (n = 27) were more likely to spend more than 2 h on screens daily ($p<0.001$).

screen-limiting strategies is vital when addressing myopia management.

The Ireland Eye Study (IES) previously reported myopia prevalence (6–7 years: 3.7%, 12–13 years: 22.8%)[11]; however, the premyopia prevalence (6–7 years: 32.4%) is new. Interestingly, when adding myopic individuals to the premyopic participants, the total (36.1%) exceeded that found in the IES 12- to 13-year-olds (22.8%) but aligns with the Northern Ireland Childhood Errors of Refraction (NICER) study, which demonstrated a significant increase in myopia in White children.[3] Furthermore, longitudinal NICER research demonstrated over +0.75D of hyperopia was required at age 6–7 years to achieve persistent emmetropia.[6] Hence, evaluating risk factors associated with premyopia is critical to support lifestyle behavioural change, thereby postponing myopia onset and slowing myopia progression.

The relationship between overweight/obesity increased screentime and myopia, and premyopia is of concern. Children on screens over 2 h daily were almost four times more likely to be overweight/obese, aligning with the literature where two or more hours per day on screens in childhood is strongly associated with overweight and obesity.[32] Furthermore, high myopia has been associated with overweight/obesity in children.[33] Obesity-associated insulin resistance may promote axial elongation.[34]

Myopia and astigmatism frequently coexist, and as demonstrated here, both were significantly associated with increased screentime. While refractive astigmatism was associated with screentime in the present study, corneal astigmatism was not. Of note, Gwiazda et al.[35] demonstrated refractive rather than corneal astigmatism was associated with axial elongation. Hence, risk factors related to increased astigmatism merit attention when addressing myopia progression. The relationship between screentime and increased levels of WTR refractive astigmatism found here is in line with Tong et al.,[36] who found playing video games and using computers was associated with Cartesian (J_0) WTR astigmatism severity in Singaporean 7- to 9-year-olds. Interestingly, Tong et al.[36] also found no association between J_0 or J_{45} astigmatism and reading books. Prior research established that astigmatism is generally WTR in children 6 years of age.[37] It is assumed that this is due to lid tension. The present study showed that astigmatism associated with engaging in near activities may be lenticular and not predominately corneal in origin. Crystalline lens changes are reported, such as thinning before axial elongation in children 6 years of age and older.[38] As a longer AL in children on screens more than 2 h/day approached significance ($p = 0.06$) in this group of 6- to 7-year-olds, it may be that these children with a more myopic SER are about to undergo a further myopic shift. Unfortunately, longitudinal evaluations were not possible due to school closures following the SARS-Cov-2 pandemic. Future longitudinal research involving children in Ireland is needed.

The association between more time spent reading, longer AL and a more myopic SER found in 7- to 9-year-olds in Singapore contrast with the present study, where no association between ocular biometric parameters and time spent reading was found.[39] However, more recent studies demonstrated that increased screentime and time spent engaged in online gaming was associated with a longer AL and myopic SER in 18-year-olds.[40] Moreover, the association between increased screentime, a higher AL/CR and more myopic SER found in the present study aligns with objectively measured smartphone use in Dutch 13-year-olds,[16] where continuous use during schooldays was positively associated with AL/CR and negatively associated with SER.

Children use short working distances,[41,42] particularly when using screen devices.[43] An accommodative demand over 6D is associated with axial elongation,[44] and 6- to 8-year-old children appear to be more susceptible to environmental changes than older children.[15] Prior research revealed faster axial elongation between 8 and 11 years of age and slowing between the ages of 13–16 years.[45] Hence, those in the higher screentime categories may be more susceptible to myopia development during the period of faster axial elongation around 8–11 years. Of further concern, digital devices emit high levels of narrow band short-wavelength light,[46] which results in instability in refraction trending to myopia.[47]

In the present study, premyopia was strongly associated with parental myopia, whereas myopia was not. This finding is unexpected as early-onset myopia is typically considered genetic.[48] Furthermore children already myopic at 6–7 years of age are more likely to become highly myopic in adulthood without intervention.[49] A previous publication from the IES (involving both 6- to 7-year-olds and 12- to 13-year-olds) found that parental history of myopia was associated with myopia controlling for age.[11] As myopia in 6- to 7-year-olds was not associated with parental myopia in the present study, it appears the association with parental myopia was strong in the older participants aged 12–13 years. Thus, premyopic children may inherit their parent's myopogenic lifestyle rather than a myopic gene.[50,51] The central question may be which environmental and lifestyle factors result in changes in gene expression, potentially leading to myopia.[50] In the present study, the association with near visual tasks is clear; however, the type of close visual task appears to have evolved. Screen-based activities remained closely associated with a more myopic SER, myopia and premyopia despite controlling for recognised confounders such as reading and writing, ethnicity and age.

The literature on screentime and myopia is equivocal,[52] with more recent studies demonstrating trends and associations.[53,54] In contrast, investigations in the last decade, before the ubiquitous use of handheld digital devices, did not indicate a relationship.[55,56] Of interest, when near visual tasks were jointly related to myopia and premyopia, screentime remained significant, whereas time spent reading did not.

The association between near-vision activities such as reading and writing are long known to be associated with myopia;[57,58] however as evidenced here, reading is becoming eclipsed by near-visual tasks involving screens and portable devices,[59] which is concerning as time spent reading is associated with increased functional connectivity in the reading-related brain, and screentime is associated with reduced functional connectivity.[59] Of further concern, the ubiquitous use of screens may increase sedentary activity and decrease outdoor activity. As social media platforms are designed to be addictive,[60] the potential acceleration of myopia progression and increased BMI in young children is concerning. Hence, public health interventions designed to limit screentime are needed. The premyopic participants are of particular interest. They may be at an age where lifestyle modifications such as increased time outdoors during daylight may help delay the onset and slow myopia progression in teenage years and early adulthood.[61,62]

Study strengths include the size, randomly selected population, questionnaire completion rate (99%), standardised cycloplegic refraction and ocular biometry. The findings are cross-sectional, and so risk factors have the potential to be associated with myopia, premyopia, obesity, etc., thus limiting conclusions regarding the directionality of associations. In addition, possible seasonal effects on measurements are hard to establish in a cross-sectional evaluation. Furthermore, parent-reported screentime may be biased against extreme reports and more socially acceptable responses.[63] Also, some parents/legal guardians may have had difficulty reporting screentime usage as the devices were portable.[64] However, since the participants were 6–7 years of age, individual ownership of screen devices is unlikely, and parents were more likely to facilitate access to devices, thereby limiting the impact of potential inaccuracy. Thus, longitudinal evaluations, including objectively measured screentime and near visual task analysis, are required to explore the relationships better.

CONCLUSION

Increased screentime was associated with a more myopic SER, higher AL/CR, greater WTR astigmatism, higher BMI, increased odds for myopia, premyopia and being overweight/obese and was inversely related to reading/writing time. Myopia and premyopia were associated with near visual tasks; however, while novel in 6- to 7-year-olds in Ireland, screentime eclipsing reading/writing time was expected. One in five participants aged 6–7 years exceeded the World Health Organization recommended daily screentime (<2 h/day), which rose to one in three among socioeconomically disadvantaged participants. The present study identified target populations for initiatives designed to decrease screen-related sedentary behaviour. This is essential while managing myopia.

AUTHOR CONTRIBUTIONS

Síofra Christine Harrington: Conceptualization (lead); data curation (lead); formal analysis (lead); funding acquisition (equal); investigation (lead); methodology (equal); project administration (lead); resources (equal); supervision (supporting); validation (equal); visualization (equal); writing – original draft (lead); writing – review and editing (equal). **Veronica O'Dwyer:** Conceptualization (supporting); data curation (supporting); formal analysis (supporting); funding acquisition (equal); investigation (equal); methodology (equal); project administration (supporting); resources (equal); software (equal); supervision (lead); validation (equal); visualization (equal); writing – review and editing (equal).

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DATA AVAILABILITY STATEMENT

All data relevant to the study are included in the article or uploaded as supplementary information. The dataset that supports the findings of this study is available from the corresponding author upon reasonable request; restrictions apply to the availability of these data.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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