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ABSTRACT

Aim To examine the demographic and social factors associated with myopia in schoolchildren in Ireland.

Methods Thirty-seven schools participated, representing a mix of urban and rural schools and schools in socioeconomically disadvantaged and non-disadvantaged areas in Ireland. Examination included cyclopleged autorefraction (1% cyclopentolate hydrochloride). Height and weight of participants were measured. Parents filled in a participant's lifestyle questionnaire, including questions on daily screen time use and daylight exposure. Myopia was defined as spherical equivalent ≤−0.50 D.

Results Data from 1626 participants (881 boys, 745 girls) in two age groups, 6–7 years (728) and 12–13 years (898), were examined. Myopia prevalence was significantly higher in children aged 12–13 years old (OR=7.7, 95% CI 5.1 to 11.6, p<0.001) and significantly associated with non-white ethnicity (OR=3.7, 95% CI 2.5 to 5.3, p<0.001). Controlling for age group and ethnicity, myopia prevalence was also significantly linked with height (p<0.001) and higher in participants in the following groups: using screens >3 hours per day (OR=3.7, 95% CI 2.1 to 6.3, p<0.001), obesity (OR=2.7, 95% CI 1.9 to 3.9, p<0.001), sedentary lifestyle (OR=2.9, 95% CI 1.9 to 4.4, p<0.001), frequently reading/writing (OR=2.2, 95% CI 1.4 to 3.5, p=0.001), less daylight exposure during summer time (OR=5.00, 95% CI 2.4 to 10.3, p<0.001), spring season births (OR=1.9, 95% CI 1.1 to 3.3, p=0.02), paternal history of myopia (OR=2.4, 95% CI 1.8 to 3.3, p<0.001) and bottle fed for the first three months of life (OR=1.7, 95% CI 1.3 to 2.5, p=0.02).

Conclusions The associations found between myopia prevalence in schoolchildren in Ireland and demographic and lifestyle factors suggest that longitudinal research investigating the associations between myopia prevalence and these factors may be beneficial in advising preventative public health programmes.

INTRODUCTION

While for many the presence of myopia is simply an optically corrected inconvenience,[1] for an ever-increasing minority, myopia is a factor leading to more serious vision disorders, such as an increased risk of retinal detachment, myopic maculopathy, choroidal neovascularisation, staphyloma, myopic retinoschisis, cataract, glaucoma and poor peripheral vision.[2,3] Myopia is a recognised growing health issue in East Asia in particular, where large-scale measurement and monitoring first began in the 1980s, with a very high prevalence (80%–90%) in school leavers.[4] The global myopia prevalence was estimated at two billion in 2010 and predicted to rise to five billion (half the projected world's population) by 2050.[5] As myopia onset and progression mainly occur during school years, there has been a tendency to associate myopia with near work.[6,7] Furthermore, urban living environment, primarily people living in congested conditions, in higher density population areas and smaller homes are statistically more likely to be myopic by age 6 years.[8]

Previous studies have found that myopia risk factors for schoolchildren include family history,[9] living environment,[7] outdoor activity,[9] urban dwelling,[8] ethnicity,[10] socioeconomic status,[7] obesity,[7] and body stature.[11] Children with myopia were reported to be late and light sleepers, as poor sleep quality and later bedtimes have been found to be significantly associated with high myopia.[12]

With regard to Ireland, between 5.3% and 10.1% of blindness (visual acuity ≤1.0 logarithm of the minimum angle of resolution, 6/60 Snellen) in adults was reported due to myopia.[13] Furthermore, the Ireland Eye Study (IES) reported myopia affecting one in five children aged 12–13 years old.[14] The Northern Ireland Childhood Errors of Refraction (NICER) study group estimated that myopia prevalence in children aged 10–16 years old in the UK has more than doubled over the last 50 years.[15] As myopia is more prevalent in non-white ethnic groups and an important risk factor for ocular diseases,[16] and given almost 10% of children in Ireland aged 5–15 years were non-white (2016 Ireland Census), Irish epidemiological studies are important to inform public health policy in Ireland on the implications of myopia prevalence. In this context, the relationship between myopia prevalence, the degree of myopia and ocular disease has financial implications as the cost of treating myopia and its associated comorbidities can be considerable.[17] Thus, to formulate targeted and effective policies to reduce myopia-related visual impairment, policymakers must first understand both the extent of the problem as well as its determinants.

The primary aim of this paper was to explore the relationships between IES refractive error data (for the period of June 2016–January 2018) and demographic and lifestyle variables, including the increasing use of digital media by schoolchildren. Digital media usage was less relevant to previous studies, as these earlier studies were carried out before the proliferation of digital media, mobile smartphones and other consumer electronic media devices. The secondary aim of this paper was to compare findings with previous studies, such as the NICER study—the closest comparator with a similar demographic profile, refractive error

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prevalence, and equivalent study protocols and methodology.[14 18] The NICER study data collection took place 10 years before the IES, between May 2006 and April 2008.[18]

METHODS

The methodology and study response rate for the IES have previously been described.[14] In summary, stratified random sampling was employed in the selection of participating schools. Schools were stratified by socially disadvantaged/non-disadvantaged status, urban/rural status, and by primary/postprimary status. Within each stratum, schools were randomly selected from a complete list (sampling frame) of schools provided on the website of the Irish Department of Education and Skills. The IES involved 1626 study participants from primary and post-primary schools in Ireland: 728 participants aged 6–7 years old (377 boys and 351 girls) and 898 participants aged 12–13 years old (504 boys and 394 girls). Children for whom informed consent and child assent were received were tested on school premises within school hours. In line with previous studies,[18 19] and as research has found no significant difference in refractive error classification and spherical equivalent refractive error parameters between cycloplegic autorefraction and cycloplegic subjective refraction,[20] the protocol for data collection included cycloplegic autorefraction (Dong Yang Rekto ORK-11 Auto Ref-Keratometer, Everview, Seoul, Korea) to determine refractive error. Cycloplegia was achieved, post instillation of one drop of topical anaesthetic (Minims Proxymetacaine Hydrochloride 0.5% w/v, Bausch & Lomb, UK), using one drop of cyclopentolate hydrochloride (Minims, 1% w/v, Bausch & Lomb). Non-white participants were administered two drops of cyclopentolate hydrochloride 5 min apart. Once it was established cycloplegia had been achieved, at least 20 min after instillation of the eye-drops, autorefraction was carried out. The representative value for spherical equivalent (SE)—sphere plus half the cylindrical value—was used in subsequent analysis. Height (in centimetres) was measured using the Leicester Height Measure MKII (Invicta Plastics, Leicester, England). Weight (in kilograms) was measured using digital scales seca 813 (Sönke Vogel, Geschäftsführer, Hamburg). Shoes were removed for both height and weight measurements.

Parents completed a participant and parental history and a participant's lifestyle questionnaire detailing inter alia birth history, daily screen time, daylight exposure and diet. The IES questionnaire was designed after a review of the NICER study questionnaire,[18] with input from epidemiology, dietetics and focus group user testing.

The study coordinator assessed participant ethnicity and confirmed using the parent/guardian self-report. Participants were categorised as either white (1290 participants), Traveller (156 participants) or non-white (black 80 participants, East Asian 51 participants, South Asian 49 participants). Although white, the Irish Traveller community was recognised as a minority ethnic group on 1 March 2017. The Irish state supports schools categorised as Delivering Equality of opportunity In School (DEIS). The IES categorised socioeconomic status by DEIS status: DEIS schools were defined as socioeconomically disadvantaged, other schools were advantaged. Areas were categorised as 'rural' if the population density was less than 10 persons per hectare (10 000 square metres), in line with the NICER study.[18]

Definitions used

All IES participants with SE ≤ -0.50 D in either eye were classified as myopic; high myopia was defined as SE ≤ -5.00 D.[5]

Statistical methodology

The SPSS V.24.0 statistics package was used for most analyses; the statistical programming language R (RStudio V.1.1.456, R Foundation for Statistical Computing, Vienna, Austria) was used to generate random numbers for the sampling procedure and also to provide prevalence data confidence intervals (CI).

It has been previously reported that myopia prevalence differed significantly between the two IES age groups.[14] All other reported risk factors associated with myopia in this paper were identified using multinomial logistic regression, controlling for age group and ethnicity, with emmetropic (SE $\leq$2.00 D and ≥ -0.50 D) participants as the reference group in all analyses. The 5% level of significance has been used throughout, without correction for multiple tests.

RESULTS

Table 1 provides a summary of the odds ratio (OR) associated with each significant risk factor of myopia controlling for age group and ethnicity in all analyses. Online supplementary table 1 displays all IES findings for associations between myopia prevalence and demographic, historical and lifestyle factors.

Myopia (in at least one eye) was found in 27 of 728 (3.7%, 95% CI 2.5 to 5.4) participating children aged 6–7 years old and 205 of 898 (22.8%, 95% CI 20.1 to 25.7) children aged 12–13 years old. High myopia was found in four children aged 12–13 years old (0.4%, 95% CI 0.1 to 1.2), two of whom were East Asian, one South Asian and one white. There were no children aged 6–7 years old with high myopia. Due to the very small numbers of participants with high myopia in the IES, risk factors associated with high myopia were hard to assess.

Demographic factors and myopia in the IES

The principal demographic factors in the IES were age group, ethnicity, urban/rural status, socioeconomic status and gender.

Multinomial regression analyses examining the relationship of myopia prevalence to these study demographic variables revealed that age group ($p<0.001$) and ethnicity ($p<0.001$) were highly significantly related to myopia prevalence, but that urban/rural status ($p=0.66$), socioeconomic status ($p=0.70$) and gender ($p=0.51$) were not.

There was no significant difference in myopia prevalence between the East Asian, South Asian and black participants (6–7 years, $p=0.69$; 12–13 years, $p=0.45$; overall, $p=0.49$). Myopia prevalence in East Asian participants (6–7 years, 14.3%; 12–13 years, 53.3%), South Asian participants (6–7 years, 8.3%; 12–13 years, 44.0%) and black participants (6–7 years, 16.1%; 12–13 years, 38.9%) was significantly higher than in white (6–7 years, 2.1%; 12–13 years, 20.2%; $p<0.001$) and Traveller participants (6–7 years, 7.1%; 12–13 years, 18.6%; $p<0.001$). Due to these findings, the relationships between other variables (lifestyle and so on) to myopia were investigated, controlling each time for the age group and ethnicity variables (but not the other demographic variables).

Table 2 displays the demographic and lifestyle factors stratified by age group and ethnicity. In summary, children aged 12–13 years old spent longer reading, writing and on screens and less time outdoors than children aged 6–7 years old (all $p<0.001$). Non-white participants spent more time reading, writing and on screens, less time outdoors, and less time engaged in after-school physical activities than white and Traveller participants (all $p<0.001$).

Table 1 Odds ratio of myopia, controlling for age group and ethnicity, for sociodemographic and lifestyle risk factors significantly related to myopia

Risk factor (response rate %)	Myopic (n)/ total (N)	(%)	OR (95% CI)	P value
Age group (100%)				
6–7 years	27/728	(3.7)	Ref	
12–13 years	205/898	(22.8)	7.7 (5.1 to 11.6)	**<0.001**
Ethnicity (100%)				
White	155/1290	(12.0)	0.3 (0.2 to 0.4)	**<0.001**
Traveller	20/151	(13.2)	0.3 (0.2 to 0.5)	**<0.001**
Non-white	57/185	(30.8)	Ref	
After-school activities (98.3%)				
Mainly on phone/screens (sedentary)	50/194	(25.8)	2.9 (1.9 to 4.4)	**<0.001**
Infrequent activity	41/345	(11.9)	1.7 (1.1 to 2.6)	**0.02**
Sporting activities ≤3 hours/per week	60/463	(13.0)	1.4 (1.0 to 2.1)	0.06
Sporting activities >3 hours per week	74/596	(12.4)	Ref	
Child's leisure time spent reading/writing (98.2%)				
Always/mostly reading/writing	7/36	(19.4)	3.0 (1.1 to 8.0)	**0.02**
Frequently reading/writing	87/551	(15.8)	2.2 (1.4 to 3.5)	**0.001**
Occasionally reading/writing	102/766	(13.3)	1.6 (1.0 to 2.5)	0.06
Seldom/never reading/writing	28/243	(11.5)	Ref	
Screen time (98.5%)				
Less than 1 hour per day	26/313	(8.3)	0.3 (0.2 to 0.5)	**<0.001**
1–3 hours per day	83/707	(11.7)	0.5 (0.3 to 0.8)	**0.001**
More than 3 hours per day	118/582	(20.3)	Ref	
Daylight exposure during summer (98.1%)				
Less than 1 hour per day	17/43	(39.5)	5.0 (2.4 to 10.3)	**<0.001**
1–2 hours per day	47/185	(25.4)	2.7 (1.8 to 4.1)	**<0.001**
2–4 hours per day	97/640	(15.2)	1.6 (1.1 to 2.3)	**0.01**
More than 4 hours per day	65/735	(8.8)	Ref	
Birth season (100%)				
Spring	62/400	(15.5)	1.9 (1.1 to 3.2)	**0.015**
Summer	64/434	(14.7)	1.5 (0.9 to 2.6)	0.12
Autumn	67/442	(15.2)	1.6 (1.0 to 2.8)	0.07
Winter	39/350	(11.1)	Ref	
Child factors (98%)				
Breast fed only for the first 3 months	98/620	(15.8)	0.9 (0.6 to 1.3)	0.6
Bottle fed only for the first 3 months	66/651	(10.1)	0.5 (0.4 to 0.8)	**0.002**
Combined breast and bottle fed for the first 3 months	54/314	(17.2)	Ref	
BMI group (99.9%)				
Non-overweight	139/1193	(11.6)	0.4 (0.3 to 0.5)	**<0.001**
Overweight	45/249	(18.1)	0.6 (0.4 to 1.0)	**0.04**
Obese	48/136	(35.3)	Ref	
Parental factors (93%)				
Parental myopia				
Father myopic	84/382	(22.0)	2.4 (1.8 to 3.3)	**<0.001**
Father not myopic	117/1130	(10.4)	Ref	

Significant P values highlighted in bold
BMI, body mass index; CI, confidence interval; N, total number of participants; OR, Odds ratio; Ref, reference category; n, number of participants.

Myopia and anthropometry

Controlling for age and ethnicity, myopia prevalence was significantly associated with the following continuous variables: participant height (cm) ($p=0.008$), and body mass index (BMI) (kg/m^2) ($p=0.001$), but not weight (kg) ($p=0.053$), the odds for myopia being greater in taller participants and those with higher BMI measurements.

The relationship between myopia prevalence and BMI categories was also examined. For this analysis, as per the Childhood Obesity Working Group of the International Obesity Taskforce with cut-offs at half yearly intervals for boys and girls, BMI was divided into three groups: non-overweight (including underweight), overweight and obese.[21] These cut-offs were chosen because of their application in the Growing Up in Ireland[22] and the NICER[18] studies.

In the IES being overweight or obese was associated with the following factors:

- Age group: 19.1% of children aged 6–7 years old and 32.7% of children aged 12–13 years old were overweight or obese ($p<0.001$).
- Socioeconomic disadvantage: 27.1% of socioeconomically disadvantaged participants aged 6–7 years old and 52.9% of those aged 12–13 years old were overweight or obese—the corresponding number for advantaged participants was 14.9% and 30.2%, respectively ($p<0.001$).
- Non-white ethnicity: 17.2% of white, 21.5% of Traveller and 30.9% of non-white children aged 6–7 years old were overweight or obese—the corresponding percentage for those aged 12–13 years old was 23.3%, 40.0% and 56.7%, respectively ($p<0.001$).
- Female gender: 16.4% of boys aged 6–7 years old and 30.8% of those aged 12–13 years old were overweight or obese, and the corresponding percentage for girls was 21.9% and 35.5%, respectively ($p=0.03$).

Among children aged 6–7 years old, 3.2% of the non-overweight subgroup were myopic; this increased to 3.5% of the overweight participants and 9.4% among the clinically obese participants. This pattern was repeated in children aged 12–13 years old; among the non-overweight subgroup, 20.0% were myopic, and this increased to 25.8% of the overweight participants and 32.8% among the clinically obese participants. Figure 1 displays the relationship between myopia prevalence and BMI in IES participants. Multinomial logistic regression analysis, controlling for age and ethnicity, demonstrated that the relationship between myopia prevalence and BMI category was statistically significant ($p<0.001$). Thus, despite the strong connections of obesity with both age and ethnicity, the statistical evidence from the IES was that myopia prevalence was still significantly associated with obesity, controlling for age and ethnicity.

Myopia and after-school leisure activities

Among children aged 6–7 years old, 8.1% with sedentary lifestyles were myopic. This percentage decreased consistently with increased physical activity and dropped to just 3.1% for participants mainly involved in after-school physical activities. Hence, myopia prevalence was inversely related to the amount of time engaged in after-school physical activity. This pattern was repeated among those aged 12–13 years old, where 35.2% of participants with sedentary lifestyles were myopic; this decreased to 14.4% among participants involved in regular after-school physical activities. These differences in myopia prevalence were statistically significant ($p=0.01$, logistic regression controlling for age and ethnicity). Figure 2 displays the relationship between myopia prevalence and after-school activities. The very slight increase in myopia prevalence found among children aged 6–7 years old in the moderate physical activity subgroup when compared with the light physical activity subgroup was difficult to assess due to the very small numbers in these subgroups.

Obesity was significantly related to physical activity in the IES. However, fitting a logistic regression model relating myopia prevalence to the obesity and physical activity categories, jointly and controlling for age and ethnicity, revealed that both obesity

Table 2 Relationship between risk factors associated with myopia stratified by age group and ethnicity

Weekly activities	White		Traveller		Non-white‡	
After-school physical activity*†	6–7 years n (%)	12–13 years n (%)	6–7 years n (%)	12–13 years n (%)	6–7 years n (%)	12–13 years n (%)
Mainly on phone/screens (sedentary)§	42 (7.3)	73 (10.5)	5 (7.7)	10 (11.8)	27 (34.6)	37 (37.0)
Infrequent activity	166 (28.2)	96 (13.9)	26 (40)	12 (14.1)	27 (34.6)	18 (18.0)
Sporting activities ≤3 hours/per week	202 (34.9)	179 (25.9)	19 (29.2)	20 (23.5)	15 (19.2)	28 (28.0)
Sporting activities >3 hours per week	168 (29.1)	344 (49.7)	15 (23.1)	43 (50.6)	9 (11.5)	917 (17.0)
Child's leisure time spent reading/writing *†						
Always/mostly reading/writing§	16 (2.8)	12 (1.7)	1 (1.6)	1 (1.2)	2 (2.6)	4 (3.9)
Frequently reading/writing	241 (41.9)	216 (31.2)	21 (33.3)	19 (22.2)	22 (28.2)	32 (31.4)
Occasionally reading/writing	272 (47.3)	328 (47.4)	28 (44.4)	35 (40.7)	45 (57.7)	58 (56.9)
Seldom/never reading/writing	46 (8.0)	136 (19.7)	13 (20.6)	31 (36.0)	9 (11.5)	8 (7.8)
Screen time *†						
Less than 1 hour per day§	182 (31.6)	67 (9.7)	21 (32.3)	16 (18.6)	19 (24.1)	8 (7.8)
1–3 hours per day	379 (65.8)	543 (78.4)	40 (61.5)	61 (70.9)	53 (67.1)	68 (66.0)
More than 3 hours per day	15 (2.6)	83 (12.0)	4 (6.2)	9 (10.5)	7 (8.9)	27 (26.2)
Daylight exposure during summer *†						
Less than 1 hour per day§	6 (1.0)	17 (2.5)	3 (4.7)	5 (5.8)	5 (6.2)	7 (6.7)
1–2 hours per day	37 (6.4)	85 (12.3)	7 (10.9)	9 (10.5)	19 (23.5)	28 (26.9)
2–4 hours per day	222 (38.5)	286 (41.3)	18 (28.1)	31 (36.0)	38 (46.9)	45 (43.3)
More than 4 hours per day	311 (54.0)	304 (43.9)	36 (56.3)	41 (47.7)	19 (23.5)	4 (23.1)
Birth season						
Spring§	142 (24.4)	176 (24.9)	11 (16.9)	18 (20.9)	25 (30.9)	28 (26.9)
Summer	150 (25.8)	196 (27.7)	10 (15.4)	26 (30.2)	24 (29.6)	28 (26.9)
Autumn	160 (28.5)	184 (62.0)	22 (33.8)	23 (26.7)	18 (22.2)	29 (27.9)
Winter	124 (21.3)	152 (21.5)	22 (33.8)	19 (22.1)	14 (17.3)	19 (18.3)
Child factors *						
Breast fed only for first 3 months§	199 (34.6)	290 (42.2)	16 (25.4)	27 (31.8)	34 (45.3)	54 (54.0)
Bottle fed only for first 3 months	262 (45.6)	267 (38.9)	41 (65.1)	46 (54.1)	19 (25.3)	16 (16.0)
Combined breast and bottle fed	114 (19.8)	130 (18.9)	6 (9.5)	12 (14.1)	22 (29.3)	30 (30.0)
BMI group *†						
Non-overweight§	492 (82.8)	507 (71.6)	51 (78.5)	51 (59.3)	56 (69.1)	45 (43.3)
Overweight	64 (11.0)	117 (16.5)	11 (16.9)	17 (19.8)	11 (13.6)	29 (27.9)
Obese	36 (6.2)	84 (11.9)	3 (4.6)	17 (19.9)	14 (17.3)	30 (28.8)
Parental myopia						
Father myopic§	105 (19.0)	203 (30.9)	14 (23.0)	23 (27.1)	8 (12.3)	29 (32.2)
Father not myopic	449 (81.0)	454 (69.1)	47 (77.0)	62 (72.9)	57 (87.7)	61 (67.8)

*Significant difference with ethnicity.
†Significant difference between children aged 6–7 years old and those aged 12–13 years old.
‡East Asian, South Asian and black participants combined.
§Reference category.
BMI, body mass index; n, number of participants.

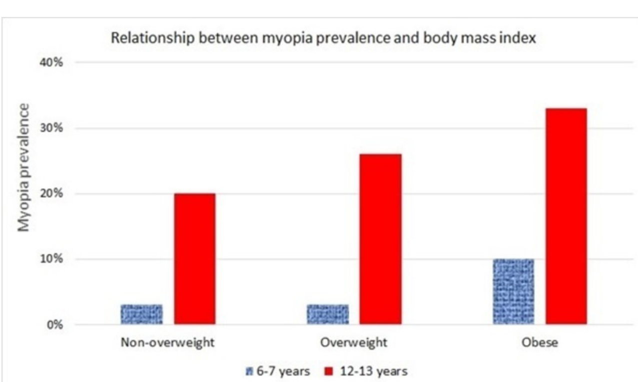

Figure 1 Relationship between myopia prevalence (y-axis) and body mass index category (x-axis) in Ireland Eye Study participants aged 6–7 years and 12–13 years.

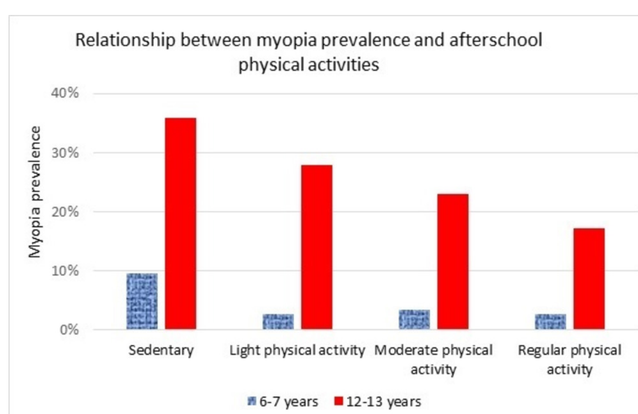

Figure 2 Relationship between myopia prevalence (y-axis) and after-school activities categories (x-axis) in Ireland Eye Study participants aged 6–7 years and 12–13 years.

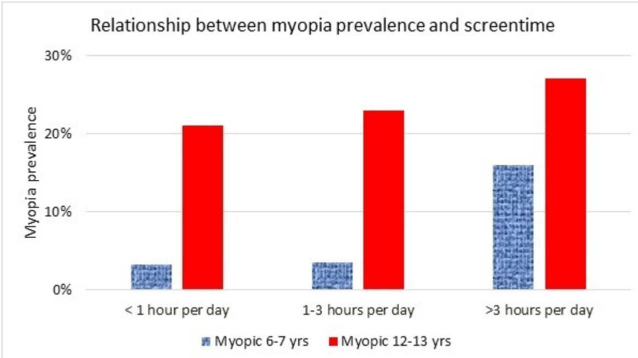

Figure 3 Relationship between myopia prevalence (y-axis) and screen time categories (x-axis) in Ireland Eye Study participants aged 6–7 years and 12–13 years.

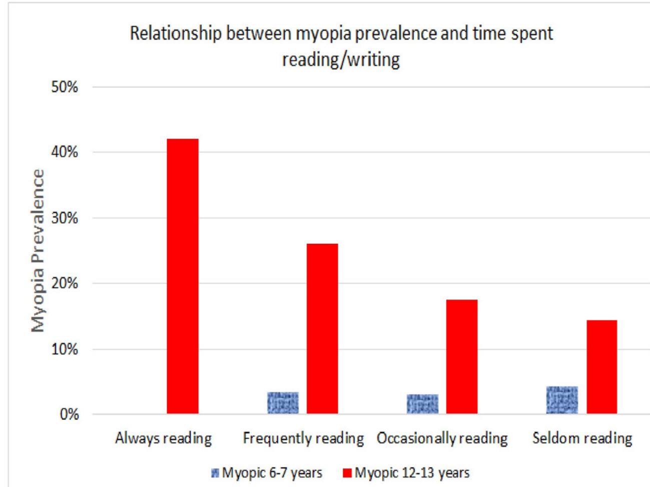

Figure 4 Relationship between myopia prevalence (y-axis) and time spent reading/writing (x-axis) in Ireland Eye Study participants aged 6–7 years and 12–13 years.

and physical activity remained statistically significant, after controlling for the other. Therefore, in the IES, both obesity and physical activity variables were related to the prevalence of myopia over and above what can be explained by the relationship of these two variables to each other.

Myopia and screen time

Myopia prevalence in the IES increased with increased time engaged in screen technologies in both age groups (p<0.001). Among children aged 6–7 years old, myopia prevalence increased fivefold (3.0% in the <1 hour screen time group, 15.5% in the >3 hours screen time group). Although the differences were not as pronounced, the myopia prevalence increase was still significant among children aged 12–13 years old, where myopia prevalence increased from 21.0% among participants who spent less than 1 hour per day on screens, to 27.0% among those who spent greater than 3 hours per day on screens. Figure 3 displays the relationship between myopia prevalence and time engaged in screen technologies.

Myopia and reading/writing

Myopia was closely associated with increased time engaged with reading/writing (p=0.01). Among those aged 12–13 years old, 41.2% of participants who spent most of their leisure time reading or writing were myopic, compared with 25.7% of those who frequently spent time reading/writing, 17.6% in the group who occasionally engaged with reading/writing and only 14.4% of those who seldom spent their leisure time reading/writing. Figure 4 displays the relationship between myopia and time spent reading/writing in both age cohorts. The very small differences in myopia prevalence found in the participants aged 6–7 years were difficult to assess due to the very small numbers in these subgroups.

As screen time and time engaged in reading are inherently linked, a logistic regression model relating myopia prevalence to the reading/writing and screen time categories, jointly (controlling for age and ethnicity), was fitted which revealed that both reading/writing and screen time remained statistically significant, after controlling for the other. Hence, in the IES, both screen time and reading/writing variables were related to the prevalence of myopia over and above what can be explained by the relationship of these two variables to each other.

Myopia and time spent outdoors during daylight

Myopia in the IES was also significantly associated with summer daylight exposure. Myopia prevalence was higher in those spending <2 hours per day outdoors during summer time (p<0.001). Winter daylight exposure was not found to be significantly associated with myopia (p=0.87).

Participants born in spring were more likely to be myopic; 14.9% of participants with myopia were born in spring compared with 12.9% in both autumn and summer and 9.4% born in winter (p=0.02).

Parental risk factors for myopia

Compared with participants without parents with myopia, IES participants with fathers with myopia were twice as likely to be myopic (22.0% vs 10.4%, p<0.001); however, the relationship between maternal myopia history and myopia in the child was not statistically significant (p=0.27). Controlling for age and ethnicity, myopia prevalence was not associated with either father's educational level (p=0.62) or mother's educational level (p=0.21).

DISCUSSION

While epidemiological studies such as the IES can demonstrate a statistical association, they do not determine causation.[23] Risk factors associated with childhood myopia in the IES were as follows:

Anthropometry

The association, in the IES, between myopia prevalence and subject height while controlling for age and ethnicity concurs with a recent study of 7681 rural Chinese participants aged 5–15 years-old.[24]

The association, in the IES, between obesity and myopia prevalence is similar to that found in the Netherlands, where myopia was associated with a higher BMI.[7] In the IES this relationship remained after controlling for lifestyle. With regard to BMI in Ireland, the Growing Up in Ireland study reported one in four children aged 9 years old (26%) as overweight or obese,[22] which is similar to the IES (one in five children aged 6–7 years old, and one in three children aged 12–13 years old).

Conversely, no association was found between myopia prevalence and BMI in Southern Californian subjects aged 5–19 years[25]; however, this retrospective study involved a clinical sample and not a randomly selected population-based sample. Interestingly, the myopia prevalence among IES participants aged 12–13 years old who had their eyes examined within the 12 months before IES data collection was 46.4%, which was broadly in line with that reported in Southern Californians aged 11–13 years old (49.4%).[25] Hence children with myopia may be more likely to have their eyes tested.

As BMI in the IES was significantly related to a range of other study variables, the relationship found in the IES between myopia and obesity may be due, in part, to the relationships between BMI and these other variables. Nevertheless, when age, ethnicity and after-school physical activity were controlled for in the analysis, the significant relationship between BMI and myopia persisted.

Myopia and light exposure

The higher myopia prevalence in IES participants born in spring aligns with one Korean study but contrasts with a study of 276 911 Israeli participants which reported higher myopia prevalence within study participants born in summer.[26 27] Whether increasing myopia prevalence is to do with less daylight exposure or due to activities pursued indoors is a matter for speculation.[28]

The association between reduced myopia in IES participants spending increased time outdoors during the summer time concurs with a previous study in Boston,[29] which is of interest since daylight time varies significantly throughout the year in New England as it does in Ireland. Notably, time outdoors >2.5 hours per day, during daylight, has been reported to postpone the onset of myopia and slow the myopic shift in refractive error[30]; however, results regarding the effects of daylight exposure on myopia progression are equivocal.[30 31] The mechanisms underpinning daylight exposure's protective effect against myopia are unclear; increased depth of focus plus low accommodative demand associated with time spent outdoors have been proposed as possible biological mechanisms associated with this reduction of myopia.[31] Whether this is entirely due to the flat dioptric topography of the visual field outdoors, which appears to be a strong signal to slow eye growth, or due to increased light levels outdoors is inconclusive.[23]

As higher light levels have been shown to postpone myopia onset, there is likely to be a minimum desired indoor light level for myopia prevention.[32]

The close link found between circadian rhythms and eye growth[23 33] and decreased sleep quality with later bedtimes in children with high myopia[12] further reinforces the part light exposure plays in refractive error development in children. Therefore, circadian timing and time of day of school hours may be important factors to consider when addressing myopia control at a public health level.

The lack of any relationship between myopia prevalence and outdoor activities during the winter months is unremarkable in Ireland at a time of year when daylight hours are limited to 7/8 hours. In Ireland, the school day is between 5 and 7 hours, which coincide with daylight hours. Hence, it was challenging to assess the influence of daylight exposure on refractive status during the winter months.

After-school leisure activities

Similar to the Generation R study in Rotterdam (the Netherlands), IES participants who engaged in increased after-school physical activities were found to be significantly less likely to be myopic than those with sedentary lifestyles.[34] Furthermore, this significance remained after controlling for BMI in the IES. Consequently, longitudinal research on whether engaging in after-school physical activities or not engaging in screen-based activities to prevent myopia progression is crucial.

Near work activities

Researchers have consistently reported an association between time engaged in near work activities and myopia, which aligns with the IES study.[6 7] However, investigation of the use of screen-based technologies within the classroom and after school is new, and its effect on the progression of refractive error is an open question. In the Netherlands, myopia was significantly associated with time spent watching television but not with computer use.[34] As smartphone use has increased from 75% to 97% in Irish people aged <25 years,[35] researching the effects of these portable screens on the growing eye is now essential. Children are increasingly less likely to use desktop computers or televisions, with most accessing online media and entertainment content via screens that are more easily transportable.[36] For example, mobile media use in Americans aged 2–4 years old increased from 34% in 2011 to 80% in 2013; in the UK 51% of infants aged 6–11 months use touch screens daily.[36] Screen-based technologies are not responsible for the myopia epidemic in East Asia, which began in the 1980s prior to the advent of smartphones[4]; however, the ubiquitous use of smartphones and other media devices may increase the time children engage in near work, thereby reducing the time spent outdoors during daylight. The relationship between increased time engaged in screens and increased myopia prevalence in the IES may be due to several confounding factors. The relatively high accommodative demand associated with using smartphones at short working distances, cumulative blue light exposure,[37] coupled with dim lighting resulting in dilated pupils and the consequent increased peripheral image defocus,[23] plus the reduced time outdoors, may lead to increased risk of myopia onset or progression in susceptible children.

The lack of any relationship between myopia and urban living in Ireland is unsurprising, as there is little difference in living conditions between urban and rural dwelling when compared with Asia, where crowded living conditions and constricted living space were reported risk factors for myopia development and progression.[8]

Likewise, the association between socioeconomic status and myopia found in a Singaporean study was not mirrored in the IES.[6] However, in line with Saw *et al.*,[6] the IES found time engaged in near work to be associated with myopia, possibly highlighting the differences in socioeconomic advantage/disadvantage globally.[38] In Ireland, all children have access to books and publicly funded education, which may not be the case in some countries.[39]

Family history

The IES association between participants with myopia and parental myopia is in agreement with previous studies.[7 9] However, myopia prevalence in the IES was strongly associated with myopia in the father and not with myopia in the mother; this merits further investigation. Parental history of myopia was self-reported via the IES questionnaire. Hence the question as to the accuracy of self-reported refractive error category ought to be considered, although the self-reported reason for the use of optical correction was reported accurate for myopia (89.1%).[40]

As family history of myopia was found to be associated with early-onset myopia in Chinese preschool participants (aged <72 months), genetic factors may play a more important role than environmental factors in early-onset myopia.[9] Conversely, the very low myopia prevalence found in IES participants aged 6–7 years (3.7%) and the scarcity of high myopia in the IES (0.2%) suggest that genetic factors may play less of a role in myopia prevalence in Ireland.

SUMMARY AND CONCLUSION

In summary, the IES results demonstrate that obesity, more time spent on screens and near visual tasks coupled with less time spent engaged in physical activities may increase the risk of myopia in schoolchildren. In agreement with other studies, reduced time spent outdoors was associated with myopia. In addition, the pattern of activities of participants aged 12–13 years old was more myopigenic than of those aged 6–7 years old; non-white participants, in particular, reported spending less time outdoors and more time doing near work than white and Traveller participants.

However, many of the environmental risk factors associated with myopia in the IES may be inter-related. Moreover, the statistical adjustment may not completely remove the influence of one risk factor over another. Furthermore, in considering the IES results, it is important to stress the cross-sectional nature of the data; the analysis is therefore descriptive addressing association and not causal pathways. Notwithstanding these caveats, one clear message from the IES findings is that public health education programmes addressing the importance of daily outdoor activities, managing children's screen time and sleep time may be beneficial to eye health of schoolchildren in Ireland. More research, including longitudinal studies, examining the broader consequences of the ubiquitous media environment, in which children are growing up today, and in particular the effect this digital age may have on their health and vision, ought to be considered.

Trends in these dynamic and evolving factors need to be monitored over time to identify any changing impact on the progression or reduction in the myopia condition.

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REFERENCES

1 McCrann S, Flitcroft I, Lalor K, *et al*. Parental attitudes to myopia: a key agent of change for myopia control? *Ophthalmic Physiol Opt* 2018;38:298–308.
2 Wong TY, Ferreira A, Hughes R, *et al*. Epidemiology and disease burden of pathologic myopia and myopic choroidal neovascularization: an evidence-based systematic review. *Am J Ophthalmol* 2014;157:9–25.
3 Nagra M, Gilmartin B, Logan NS, *et al*. The effects of severe myopia on the properties of sampling units in peripheral retina. *Optom Vis Sci* 2018;95:399–404.
4 Seet B, Wong TY, Tan DT, *et al*. Myopia in Singapore: taking a public health approach. *Br J Ophthalmol* 2001;85:521–6.
5 Holden BA, Fricke TR, Wilson DA, *et al*. Global prevalence of myopia and high myopia and temporal trends from 2000 through 2050. *Ophthalmology* 2016;123:1036–42.
6 Saw SM, Chua WH, Hong CY, *et al*. Nearwork in early-onset myopia. *Invest Ophthalmol Vis Sci* 2002;43:332–9.
7 Tideman JWL, Polling JR, Hofman A, *et al*. Environmental factors explain socioeconomic prevalence differences in myopia in 6-year-old children. *Br J Ophthalmol* 2018;102:243–7.
8 Choi KY, Yu WY, Lam CHI, *et al*. Childhood exposure to constricted living space: a possible environmental threat for myopia development. *Ophthalmic Physiol Opt* 2017;37:568–75.
9 Low W, Dirani M, Gazzard G, *et al*. Family history, near work, outdoor activity, and myopia in Singapore Chinese preschool children. *Br J Ophthalmol* 2010;94:1012–6.
10 Saw SM, Goh PP, Cheng A, *et al*. Ethnicity-specific prevalences of refractive errors vary in Asian children in neighbouring Malaysia and Singapore. *Br J Ophthalmol* 2006;90:1230–5.
11 Dirani M, Islam A, Baird PN. Body stature and myopia-The genes in myopia (GEM) twin study. *Ophthalmic Epidemiol* 2008;15:135–9.
12 Ayaki M, Torii H, Tsubota K, *et al*. Decreased sleep quality in high myopia children. *Sci Rep* 2016;6:1–9.
13 Munier A, Gunning T, Kenny D, *et al*. Causes of blindness in the adult population of the Republic of Ireland. *Br J Ophthalmol* 1998;82:630–3.
14 Harrington SC, Stack J, Saunders K, *et al*. Refractive error and visual impairment in Ireland schoolchildren. *Br J Ophthalmol* 2018.
15 McCullough SJ, O'Donoghue L, Saunders KJ. Six year refractive change among white children and young adults: evidence for significant increase in myopia among white UK Children. *PLoS One* 2016;11.
16 Saw S-M. How blinding is pathological myopia? *Br J Ophthalmol* 2006;90:525–6.
17 Zheng Y-F, Pan C-W, Chay J, *et al*. The economic cost of myopia in adults aged over 40 years in Singapore. *Invest Ophthalmol Vis Sci* 2013;54.
18 O'Donoghue L, Kapetanankis VV, McClelland JF, *et al*. Risk factors for childhood myopia: findings from the NICER study. *Invest Ophthalmol Vis Sci* 2015;56:1524–30.
19 French AN, Morgan IG, Mitchell P, *et al*. Patterns of myopigenic activities with age, gender and ethnicity in Sydney schoolchildren. *Ophthalmic Physiol Opt* 2013;33:318–28.
20 Choong YF, Chen AH, Goh PP. A comparison of autorefraction and subjective refraction with and without cycloplegia in primary school children. *Am J Ophthalmol* 2006;142:68–74.
21 Cole TJ, Bellizzi MC, Flegal KM, *et al*. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ* 2000;320:1240.
22 Walsh B, Cullinan J. Decomposing socioeconomic inequalities in childhood obesity: evidence from Ireland. *Economics & Human Biology* 2015;16:60–72.
23 Flitcroft DI. The complex interactions of retinal, optical and environmental factors in myopia aetiology. *Prog Retin Eye Res* 2012;31:622–60.
24 Qian DJ, Zhong H, Li J, *et al*. Myopia among school students in rural China (Yunnan). *Ophthalmic Physiol Opt* 2016;36:381–7.
25 Theophanous C, Modjtahedi BS, Batech M, *et al*. Myopia prevalence and risk factors in children. *Clin Ophthalmol* 2018;12:1581–7.
26 Lee DC, Lee SY, Kim YC. An epidemiological study of the risk factors associated with myopia in young adult men in Korea. *Sci Rep* 2018;8.
27 Mandel Y, Grotto I, El-Yaniv R, *et al*. Season of birth, natural light, and myopia. *Ophthalmology* 2008;115:686–92.
28 Ngo C, Saw S-M, Dharani R, *et al*. Does sunlight (bright lights) explain the protective effects of outdoor activity against myopia? *Ophthalmic Physiol Opt* 2013;33:368–72.
29 Gwiazda J, Deng L, Manny R, *et al*. Seasonal variations in the progression of myopia in children enrolled in the correction of myopia evaluation trial. *Invest Ophthalmol Vis Sci* 2014;55.
30 Wu PC, Chen CT, Lin KK, *et al*. Myopia prevention and outdoor light intensity in a school-based cluster randomized trial. *Ophthalmology* 2018;125:1239–50.
31 Xiong S, Sankaridurg P, Naduvilath T, *et al*. Time spent in outdoor activities in relation to myopia prevention and control: a meta-analysis and systematic review. *Acta Ophthalmol* 2017;95:551–66.
32 Zhou Z, Chen T, Wang M, *et al*. Pilot study of a novel classroom designed to prevent myopia by increasing children's exposure to outdoor light. *PLoS One* 2017;12:e0181772.
33 Nickla DL. Ocular diurnal rhythms and eye growth regulation: where we are 50 years after Lauber. *Exp Eye Res* 2013;114:25–34.
34 Tideman JWL, Polling JR, Jaddoe VWV, *et al*. Environmental risk factors can reduce axial length elongation and myopia incidence in 6- to 9-year-old children. *Ophthalmology* 2019;126:127–36.
35 There's no place like phone | Deloitte Ireland | About Deloitte, 2018. Available: https://www2.deloitte.com/ie/en/pages/about-deloitte/articles/Theres-no-place-like-phone.html [Accessed 17 Feb 2018].
36 Ponti M, Bélanger S, Grimes R, *et al*. Screen time and young children: promoting health and development in a digital world. *Paediatr Child Health* 2017;22:461–8.
37 Oh JH, Yoo H, Park HK, *et al*. Analysis of circadian properties and healthy levels of blue light from smartphones at night. *Sci Rep* 2015;5:11325.
38 Galobardes B, Lynch J, Smith GD. Measuring socioeconomic position in health research. *Br Med Bull* 2007;81-82:21–37.
39 Rosner M, Ortiz-Ospina E, 2018. Global rise of education. Available: https://ourworldindata.org/global-rise-of-education [Accessed 22 Dec 2018].
40 Cumberland PM, Chianca A, Rahi JS, *et al*. Accuracy and utility of self-report of refractive error. *JAMA Ophthalmol* 2016;134:794.