Received: 26 February 2024 | Accepted: 18 June 2024 | Published online: 2 July 2024

DOI: 10.1111/opo.13359

OPO THE COLLEGE OF OPTOMETRISTS

ORIGINAL ARTICLE

Incidence of myopia in Swedish schoolchildren: A longitudinal study

Pelsin Demir[1] | **Karthikeyan Baskaran**[1] | **Pedro Lima Ramos**[2] | **Thomas Naduvilath**[3] | **Padmaja Sankaridurg**[3] | **Antonio Filipe Macedo**[1,4]

[1]Medicine and Optometry, Linnaeus University, Kalmar, Sweden

[2]EPIUnit - Institute of Public Health, University of Porto, Porto, Portugal

[3]Brien Holden Vision Institute, Sydney, New South Wales, Australia

[4]Department and Centre of Physics—Optometry and Vision Science, University of Minho, Braga, Portugal

Correspondence
Pelsin Demir, Medicine and Optometry, Linnaeus University, Kalmar, Sweden.
Email: pelsin.demir@lnu.se

Abstract

Purpose: The prevalence of myopia in Scandinavia tends to be lower than in other parts of the world. This study aimed to investigate the incidence of myopia and its predictors in Swedish children to characterise this trend.

Methods: A 2-year longitudinal study was conducted following a cohort of school-children aged 8–16 years. Myopia was defined as a spherical equivalent refraction (SER) ≤ −0.50 D. The study enrolled 128 participants, 70 (55%) females with a mean age of 12.0 years (SD = 2.4).

Results: The cumulative incidence of myopia during the follow-up period was 5.5%, and the incidence rate of myopia was 3.2 cases per 100 person-years. Participants with myopia at baseline exhibited a faster increase in refractive error during the follow-up period. Likewise, participants with two myopic parents exhibited a more marked change towards myopia, regardless of their initial refractive error.

Conclusion: In the current study, similar to prevalence, the incidence of myopia was low when compared with other parts of the world. These results lead us to formulate a new hypothesis that the normal emmetropisation process may be protected by low educational pressure practised in Sweden during early childhood. Further research is necessary to test this new hypothesis.

KEYWORDS
incidence, myopia, parental myopia, predictors, prevalence, refractive error

INTRODUCTION

The prevalence of myopia in Scandinavia is lower than in other parts of the world. A recent study from Denmark revealed a consistent prevalence of myopia over several decades, from 1882 to 2018, with rates among children 11–12 years of age ranging from 3.7% to 9.2%.[1] These findings are in line with other studies reporting a 13.4% (95% confidence intervals [CI 95] 8.7–18.3) myopia prevalence among adolescents in Norway[2] and 10.0% (CI 95 = 4.4–14.9) in Swedish children aged 8 to 16 years.[3] A further recent study from Sweden used data from glasses prescribed to children referred for eye examinations and examined the incidence of myopia among Swedish children aged 4–7 years.[4] This study reported that the incidence was stable between 2015 and 2020, ranging from 0.11% to 0.39%. This is in contrast with investigations from East Asia where the reported incidence was high, thereby resulting in the prevalence of myopia among children 6–18 years of age to be between 50.0% and 71.0%.[4–7] It remains unclear which factors can explain these contrasting prevalence findings.

Children with myopic parents seem more likely to develop myopia.[3,8–10] The odds ratio for the onset of myopia in children with two myopic parents is approximately three times higher compared with children without parental myopia.[11] In addition, myopic children with two myopic parents tend to have higher levels of myopia than those whose parents are not myopic.[3] However, genetics may be only part of the picture and genetic predisposition might be 'activated' or 'accelerated' when individuals are exposed to environmental risk factors.

There is a lack of information regarding the incidence and progression of myopia in Swedish children. Likewise, there are few studies investigating risk factors for myopia in this same population. This information is relevant to understand the progression of myopia in the Swedish population and to generate ideas to tackle the myopia epidemic around the globe.

This study characterised the incidence of myopia in Swedish school children. As the investigation was partially conducted during the COVID-19 pandemic, it also considers possible effects of the imposed restrictions on refractive error changes.

Key points

- The 2-year incidence of myopia among Swedish schoolchildren was low.
- The risk factors for refractive error changes were parental myopia and being already a myope at the start of the study.
- A new hypothesis is raised that low educational pressure in early childhood might protect Swedish children from abnormal emmetropisation leading to myopia.

METHODS

This study received ethics approval from the Regional Ethics Committee for Medical Research Ethics in Linköping (diary number 2018/423-31). The study protocol complied with the tenets of the Declaration of Helsinki and informed consent was obtained from the participants and their parents.

This was a longitudinal study involving a cohort of 128 children conducted in southern Sweden from January 2019 to June 2021. Readers are referred to a previous paper on baseline characteristics and recruitment procedures for complete details about the cohort.[3] In brief, schoolchildren aged 8–16 years from Kalmar Län—a county in southern Sweden, were invited to participate in this study. Information about the study was spread through primary schools, social media, local media channels and national television broadcasts. According to Statistiska Central Byrån, there were 21,636 children aged 8–16 years living in this region of Sweden in 2018 (source: http://www.statistikdatabasen.scb.se/sq/89562). The sample size required to compute prevalence was determined using OpenEpi.[12] Based on a myopia prevalence of 11.7%,[13] the required sample size was 112 participants for a confidence level of 90%.

A 2-year follow-up period ensued with a total of four visits: baseline, 0.5, 1 and 2 years (the 1.5 years appointment was cancelled due to the COVID-19 pandemic). A comprehensive eye examination was repeated at every visit to determine changes in refractive error and other ocular parameters.[14] Each visit included measurements of distance visual acuity, axial length and corneal curvature with non-contact optical coherence biometry (IOLMaster 500, zeiss.com), height, weight and cycloplegic refraction[15] using the Shin-Nippon NVision-K 5001autorefractor (shin-nippon.jp/). Cycloplegic refraction was performed approximately 30 minutes after installation of two drops of cyclopentolate 1% (Cyclogyl, alcon.se/sv). Cycloplegic refraction findings were taken from the right eye only.

Questionnaires were used to obtain information regarding demographics, parental myopia, medical history, academic preferences, education, living conditions, time spent on near work, time spent on outdoor activities after school and reading habits (see Supporting Information). As part of assessing living conditions at home, parents were asked about the size of the room where their child spends most of their time doing near-work activities. The answer options were: a small room, less than or equal to 10 m^2; a medium room, less than or equal to 20 m^2 or a bigger room, bigger than 20 m^2. Parental myopia was confirmed by analysis of the parent's refractive prescription. The questionnaires were completed by the parents at the baseline and follow-up assessments.[3]

Definitions and statistical analysis

The definition of myopia was based on the cycloplegic spherical equivalent refraction (SER) of the right eye: SER = sphere + cylinder/2, with the cylinder expressed in minus cylinder format. A participant with a SER ≤ −0.50 dioptres (D) was considered to be myopic.[16] Hyperopia was defined as a SER ≥ +0.75 D.[3] Emmetropia was defined as a SER between −0.49 and +0.74 D. Defining hyperopia can be difficult, and most studies select a cut-off taking the participant's age into consideration. Considering the age range in the present study, a cut-off of +0.75 D was deemed appropriate, although this cut-off value is higher than the one used in an investigation of Norwegian adolescents[2] (+0.50 D), but lower than studies involving infants (+2.00 D).[17]

Cumulative incidence was computed by dividing the number of incident cases by the population at risk at baseline (comprising all initial participants) using the equation:

Cumulative incidence = new cases/population at risk.[18]

Incidence rate was computed using the equation:

Incidence rate = new cases during observation period/total person-time of observation while at risk during the study.[19]

Person-time was defined as the total amount of time participants were observed while at risk of developing the outcome of interest.

The effect of time, refractive state at baseline and parental myopia on SER was tested using linear mixed models (LMM) in SAS software PROC MIXED (sas.com). Normalised SER was computed by subtracting the baseline SER from all other measurements; this corresponds to a baseline SER of 0 for all participants in order to model SER progression. For this analysis, the normalised SER was defined as the 'dependent variable'. Participants were defined as 'random factors'. Explanatory or 'fixed factors' were: 'refractive state at baseline' (myopia, emmetropia, hyperopia) and 'parental myopia' (i.e., 0, 1 or 2 myopic parents) for the whole sample. Other factors and their two-way interaction with time were tested (sex, ethnicity and number of hours in near work or in outdoor time at baseline) but only the statistically significant effects were retained for the final model. *P*-values were adjusted for multiple comparisons using the Tukey–Kramer procedure. Mean values shown in the text and on graphs are the estimated means; these are the mean response for each factor adjusted for other variables in the model, and their standard errors for the specified factors. Statistical significance was set at $p<0.05$.

RESULTS

Sample characteristics

The cohort was formed of 70 (55%) females and 58 males (45%). During the course of the investigation, seven participants dropped out, meaning that 121 participants finished the study; 67 (55%) females and 54 (45%) males—the retention rate was 95% and the mean age at the end of the follow-up was 13.5 years (SD = 2.5). The sample was predominantly Caucasian (86.0%). Table 1 summarises the clinical and sociodemographic variables longitudinally.

Incidence and prevalence

At baseline, the prevalence (CI 95) of myopia ($n=13$) was 10.0% (4.4–14.9). Corresponding values for hyperopia ($n=61$) and emmetropia ($n=54$) were 48.0% (38.8–56.7) and 42.0% (33.5–51.2), respectively. The *cumulative incidence* of myopia during the 2-year follow-up was 5.5% (2.2–10.9) while the *incidence rate* of myopia was 3.2 cases per 100 person-years (0.8–5.6).

Results from the questionnaire

The average age for beginning reading and writing was 6.0 years (SD = 1.0). Within the questionnaire, participants or their parents were asked to indicate if they liked activities such as sports, travel and outdoor play (outdoor person), or preferred activities such as computer games, reading and writing (indoor person). A total of 52 (42%) participants were classified as outdoor persons, 50 (39%) as indoor persons and 24 (19%) had no specific preference. Furthermore, 99 (78.0%) participants lived in houses and 28 (22.0%) in apartments.

Regarding the room size at home, determined by parents, where the participants spent most of their time engaged in near-work activities, 22 (18%), 85 (68%) and 17 (14%) reported rooms measuring ≤10, ≤20 or >20 m^2, respectively. None of these factors contributed significantly to the incidence of myopia and have been omitted from the discussion.

Longitudinal changes in SER and associated factors

There was a significant effect of time on SER, F (3, 250) = 16.3, $p<0.001$. Table 2 summarises the pairwise comparisons with adjusted p-values of SER between different time points. There was a significant interaction between refractive state at baseline X time, F (2, 122) = 6.36, $p=0.002$; these results are summarised in Table 3 and Figure 1. There was a significant interaction of time X parental myopia, F (2, 122) = 6.16, $p=0.003$; these results are summarised in Table 3 and Figure 1. A summary of

TABLE 1 Summary of the key variables at baseline (0), 0.5, 1 and 2 years; the '*n*' changed between visits which affected direct comparisons between time points.

	Baseline (*n* = 128)	0.5 year (*n* = 126)	1 year (*n* = 114)	2 years (*n* = 121)
Age (years)	12.0 (SD = 2.5) 12.0 (IQR = 5.0)	12.0 (SD = 2.5) 12.5 (IQR = 4.0)	12.5 (SD = 2.5) 13.0 (IQR = 4.0)	13.5 (SD = 2.5) 14.0 (IQR = 4.0)
Spherical equivalent refraction (dioptres)	+0.65 (SD = 1.2) +0.70 (IQR = 1.0)	+0.70 (SD = 1.3) +0.78 (IQR = 1.1)	+0.66 (SD = 1.2) +0.67 (IQR = 1.1S)	+0.51 (SD = 1.5) +0.64 (IQR = 1.0)
Axial length (millimetres)	**23.16 (SD = 0.86)** **23.17 (IQR = 1.1)**	**23.19 (SD = 0.87)** **23.17 (IQR = 1.1)**	**23.20 (SD = 0.87)** **23.21 (IQR = 1.2)**	**23.28 (SD = 0.89)** **23.31 (IQR = 1.1)**
Near work (hours/day)	5.3 (SD = 3.1) 4.6 (IQR = 3.3)	4.8 (SD = 2.6) 4.4 (IQR = 3.2)	2.5 (SD = 1.6) 2.2 (IQR = 2.1)	2.9 (SD = 1.8) 2.7 (IQR = 2.4)
Outdoor time (hours/day)	2.6 (SD = 2.2) 1.9 (IQR = 2.1)	2.4 (SD = 1.7) 1.8 (IQR = 2.0)	1.6 (SD = 1.0) 1.4 (IQR = 1.3)	1.6 (SD = 1.2) 1.3 (IQR = 1.6)

Note: The first and second numbers in each box indicate the Mean (SD) and the Median (IQR), respectively. Values in bold font indicated the variable was normally distributed.

Abbreviations: IQR, interquartile range; SD, standard deviation.

TABLE 2 Summary of pairwise comparisons of spherical equivalent refractive error (SER) between time points, that is, at baseline (0), 0.5, 1 and 2 years.

Time (years)	0	0.5	1
0.5	$M = 0.004$ D (SE = 0.04), $p = 0.06$	—	—
1	**$M = -0.16$ D (SE = 0.05), $p = 0.005$**	**$M = -0.15$ D (SE = 0.05), $p = 0.006$**	—
2	**$M = -0.27$ D (SE = 0.04), $p < 0.001$**	**$M = -0.26$ D (SE = 0.04), $p < 0.001$**	$M = -0.11$ D (SE = 0.04), $p = 0.06$

Note: The mean difference (*M*) was computed by subtracting the SER at baseline. *p*-Values were adjusted for multiple comparisons using the Tukey–Kramer procedure. The bold font indicates a statistically significant difference.

Abbreviation: SE, standard error.

the statistical analysis of axial length is given in the 'Supporting Information'. These findings reflect the SER and are in line with previous reports.[20] Only those findings related to the SER are discussed here.

DISCUSSION

This was a unique cohort study conducted in Sweden that characterised the incidence of myopia in a sample of schoolchildren. Factors associated with myopia, such as development and progression, were also investigated. With this cohort, it was possible to show that the refractive state at baseline and parental myopia affected the SER progression over time.

The 2-year cumulative incidence of myopia and the incidence rate in the current study were consistent with a low prevalence of myopia.[3] These findings are consistent with analyses from other Scandinavian countries.[1,2,21–23] For example, a Danish investigation compiled myopia data from 29 studies between 1882 and 2018, and revealed that the prevalence remained stable over that period, with rates ranging from 0.0% to 8.9% in children up to 10 years of age.[1] A study conducted in Portugal examined the prevalence and incidence of myopia among children aged 6–13 years, yielding results consistent with those of the current study.[24] In contrast with the present findings, evaluations conducted in East Asia with samples of a similar age have reported a significantly higher incidence of myopia.[4,25,26] For instance, a cumulative incidence of myopia between 33.6% and 54% has been reported,[5] while others have noted an annual incidence rate from 30[26] to 31.7 cases per 100-person years.[27] When comparing similar age groups, the incidence of myopia tends to be higher in children of East Asian ethnicity than for European Caucasians. This suggests that factors beyond age, such as genetics and environment, play a significant role for the incidence and prevalence of myopia in different regions. This has been observed in the United Kingdom, where the prevalence of myopia was higher among British children with South Asian ethnicity compared with British children with Caucasian ethncitiy.[28] The incidence of myopia in the current investigation was markedly lower than that found in East Asia and consistent with current and past analyses conducted in Scandinavia.

In the present cohort, the incidence of myopia was low. The sample was formed mostly of Caucasian children, which can partially explain the low incidence; however, we speculate that other factors might be involved. Our hypothesis is that the low educational pressure in early childhood that is practised in Sweden, where formal schooling starts at 7 years of age, contributes to a more natural development of the eye. This may facilitate a normal emmetropisation process, potentially leading to a lower incidence and prevalence of myopia. This is contrast to the high educational pressure found in East Asian countries where the prevalence of myopia is very high.[29,30] In China, children start primary school at 6 years of age and spend about 7 h per day there.[31] In Sweden, children start primary school at 7 years of age, which comprises, on average, 4.5 h per day. Also, in the early years of education, Swedish schools offer a high quantity of outdoor time, irrespective of the weather and season.[32–34] We speculate that the Swedish educational curriculum is protecting, in part, the Swedish children from developing myopia.[35]

The longitudinal analysis of changes in SER showed the expected trend in children, that is, a change towards myopia. The progression was influenced by the refractive state at baseline and parental myopia. In the current study, the mean change in SER was −0.30 D, that is, approximately − 0.15 D per year. Reports from East Asia show a typical progression of −0.60 D per year,[36,37] that is four times the progression rate observed here. The slow change seen in the current investigation explains the low incidence of myopia in Sweden, when compared with East Asian studies. These findings revealed that participants with myopia at baseline exhibited a significantly faster change in SER. This result is in agreement with a recent evaluation of refractive progression in European children with myopia.[22]

Another independent factor associated with the progression of SER was parental myopia. This finding is also in line with previous studies reporting that children with two myopic parents had a faster change towards myopia than the other two parental categories, irrespective of their refractive state at baseline.[23,38]

The SER change between years 1 and 2 was not statistically significant. However, year 1 was during the peak of the COVID-19 pandemic. This implies no detectable effects of the pandemic constraints on SER in

TABLE 3 Summary of pairwise comparison of spherical equivalent refraction (SER) changes between categories of refractive state on the left-hand side and parental myopia on the right-hand side at different time points, that is, baseline (0), 0.5, 1 and 2 years of follow-up.

Refractive state	Time	0	0.5	1	Myopic parents	Time	0	0.5	1
Myopia	0.5	$M = -0.10$ D (SE = 0.10), $p = 0.29$	—	—	None	0.5	$M = -0.03$ D (SE = 0.07), $p > 0.99$	—	—
	1	**$M = -0.30$ D (SE = 0.12), $p = 0.01$***	$M = -0.20$ D (SE = 0.12), $p = 0.09$	—		1	$M = 0.02$ D (SE = 0.10), $p > 0.99$	$M = 0.05$ D (SE = 0.01), $p > 0.99$	—
	2	**$M = -0.56$ D (SE = 0.11), $p < 0.001$***	**$M = -0.46$ D (SE = 0.10), $p < 0.001$***	$M = -0.26$ D (SE = 0.11), $p = 0.37$		2	$M = -0.11$ D (SE = 0.08), $p = 0.97$	$M = -0.10$ D (SE = 0.07), $p = 0.99$	$M = -0.13$ D (SE = 0.07), $p = 0.86$
Hyperopia	0.5	$M = 0.004$ D (SE = 0.05), $p = 0.95$	—	—	1	0.5	$M = 0.11$ D (SE = 0.06), $p = 0.87$	—	—
	1	$M = -0.10$ D (SE = 0.06), $p = 0.93$	$M = -0.10$ D (SE = 0.06), $p = 0.95$	—		1	$M = -0.14$ D (SE = 0.07), $p = 0.75$	**$M = -0.24$ D (SE = 0.07), $p = 0.03$***	—
	2	$M = -0.16$ D (SE = 0.06), $p = 0.24$	$M = -0.16$ D (SE = 0.05), $p = 0.15$	$M = -0.07$ D (SE = 0.06), $p = 0.99$		2	$M = -0.23$ D (SE = 0.07), $p = 0.08$	**$M = -0.33$ D (SE = 0.07), $p < 0.001$***	$M = -0.09$ D (SE = 0.07), $p = 0.96$
Emmetropia	0.5	**$M = 0.09$ D (SE = 0.05), $p = 0.046$***	—	—	2	0.5	$M = -0.10$ D (SE = 0.08), $p = 0.99$	—	—
	1	$M = -0.08$ D (SE = 0.05), $p = 0.94$	**$M = -0.18$ D (SE = 0.05), $p = 0.001$***	—		1	**$M = -0.37$ D (SE = 0.10), $p = 0.006$***	$M = -0.28$ D (SE = 0.10), $p = 0.11$	—
	2	$M = -0.08$ D (SE = 0.05), $p = 0.96$	**$M = -0.17$ D (SE = 0.05), $p = 0.02$***	$M = -0.01$ D (SE = 0.05), $p > 0.99$		2	**$M = -0.47$ D (SE = 0.09), $p < 0.001$***	**$M = -0.38$ D (SE = 0.08), $p < 0.001$***	$M = -0.10$ D (SE = 0.08), $p = 0.99$

Note: The mean difference (*M*) was computed by subtracting SER for the time in the column 'Time' from SER for the time in the first row. *p*-Values were adjusted for multiple comparisons using the Tukey–Kramer procedure.

Abbreviations: D, dioptre; SE, standard error.

*Statistically significant difference.

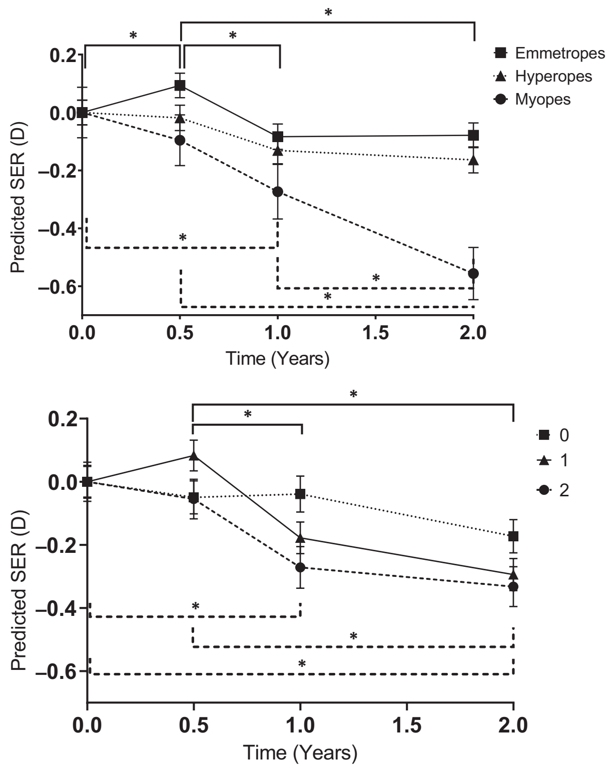

FIGURE 1 Results of the linear mixed model analysis. On the *y*-axis is the predicted change in the spherical equivalent refraction (SER), whereas the *x*-axis indicates time in years with measurements performed at baseline (0 years), 0.5, 1 and 2 years. Top: Progression of SER according to the refractive state at baseline. Bottom: The progression of the SER was examined based on parental myopia status (Zero, one or two myopic parents) across all participants, regardless of the refractive state at baseline. The mean values in the graphs are the estimated means (mean response for each factor, adjusted for any other variables in the model) and error bars represent the standard error of the mean. *Statistically significant difference.

the current cohort. It should be noted that the restrictions in Sweden did not include complete lockdowns. Temporary closure of individual schools or classes occurred in response to outbreaks, but there was no nationwide lockdown. Therefore, this is likely to explain differences between the current results and the effects of the lockdowns compiled in a recent systematic review and meta-analysis.[39] The review points to the detrimental effect of the pandemic, with faster than normal myopia development. It is noteworthy that the present investigation was designed and began before the onset of the pandemic, and was not specifically targeted to detect the impact of COVID-19 on refractive error development.

The current study has two major strengths; firstly its longitudinal design and secondly the low dropout rate. A limitation was the poor quality of the information reported in the questionnaire. We observed a lack of reliability due to variations in the wording of questionnaires between the first two and the last two visits, which made the self-reporting inconsistent. Therefore, variables such as time spent in near work have to be considered with caution. The sample size limited the statistical power to find associations between environmental factors and myopia. Nevertheless, these findings are in line with recent studies conducted, for example, in Japan using significantly larger samples.[29,30,38,39]

CONCLUSION

The incidence of myopia in Swedish children was low when compared with other parts of the world. Myopic children at baseline and children with two myopic parents (or both) showed a significantly faster-paced refractive error change over time. These results show that parental myopia remains a critical confounder to consider when planning clinical trials for myopia control interventions. The findings lead us to speculate that the normal emmetropisation process may be safeguarded by low educational pressure during early childhood. Further studies are necessary to clarify how educational pressure early in life affects the incidence of myopia among different ethnicities. Understanding these influences is crucial for developing effective public health strategies aimed at reducing myopia prevalence.

AUTHOR CONTRIBUTIONS

Pelsin Demir: Conceptualization (equal); data curation (equal); formal analysis (equal); funding acquisition (lead); investigation (equal); methodology (lead); project administration (lead); resources (lead); validation (equal); visualization (equal); writing – original draft (equal); writing – review and editing (equal). **Karthikeyan Baskaran:** Conceptualization (equal); data curation (equal); formal analysis (equal); investigation (equal); supervision (equal); validation (equal); visualization (equal); writing – original draft (equal); writing – review and editing (equal). **Pedro Lima Ramos:** Formal analysis (supporting). **Thomas Naduvilath:** Data curation (supporting); formal analysis (supporting); writing – review and editing (supporting). **Padmaja Sankaridurg:** Conceptualization (supporting); resources (supporting); writing – review and editing (supporting). **Antonio Filipe Macedo:** Conceptualization (equal); data curation (equal); formal analysis (equal); investigation (equal); supervision (equal); validation (equal); visualization (equal); writing – original draft (equal); writing – review and editing (equal).

ACKNOWLEDGEMENTS

This study was supported by Specsavers Sweden AB, the faculty of Health and Life Sciences, Linnaeus University and the Brien Holden Vision Institute.

FUNDING INFORMATION

This article received no specific funding. The first author's PhD and this article were supported by Specsavers and the faculty.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

ORCID

Pelsin Demir https://orcid.org/0000-0002-9970-3237
Karthikeyan Baskaran https://orcid.org/0000-0002-3745-0035
Pedro Lima Ramos https://orcid.org/0000-0003-1280-9854
Thomas Naduvilath https://orcid.org/0000-0001-8813-2048
Padmaja Sankaridurg https://orcid.org/0000-0001-5537-6193
Antonio Filipe Macedo https://orcid.org/0000-0003-3436-2010

REFERENCES

1. Hansen MH, Hvid-Hansen A, Jacobsen N, Kessel L. Myopia prevalence in Denmark—a review of 140 years of myopia research. *Acta Ophthalmol*. 2021;99:118–27.
2. Hagen LA, Gjelle JVB, Arnegard S, Pedersen HR, Gilson SJ, Baraas RC. Prevalence and possible factors of myopia in Norwegian adolescents. *Sci Rep*. 2018;8:13479. https://doi.org/10.1038/s41598-018-31790-y
3. Demir P, Baskaran K, Theagarayan B, Gierow P, Sankaridurg P, Macedo AF. Refractive error, axial length, environmental and hereditary factors associated with myopia in Swedish children. *Clin Exp Optom*. 2021;104:595–601.
4. Guo Y, Duan JL, Liu LJ, Sun Y, Tang P, Lv YY, et al. High myopia in greater Beijing school children in 2016. *PLoS One*. 2017;12:e0187396. https://doi.org/10.1371/journal.pone.0187396
5. Li L, Zhong H, Li J, Li CR, Pan CW. Incidence of myopia and biometric characteristics of premyopic eyes among Chinese children and adolescents. *BMC Ophthalmol*. 2018;18:178. https://doi.org/10.1186/s12886-018-0836-9
6. Nakao SY, Miyake M, Hosoda Y, Nakano E, Mori Y, Takahashi A, et al. Myopia prevalence and ocular biometry features in a general Japanese population: the Nagahama Study. *Ophthalmology*. 2021;128:522–31.
7. Li Y, Liu J, Qi P. The increasing prevalence of myopia in junior high school students in the Haidian District of Beijing, China: a 10-year population-based survey. *BMC Ophthalmol*. 2017;17:88. https://doi.org/10.1186/s12886-017-0483-6
8. Kurtz D, Hyman L, Gwiazda JE, Manny R, Dong LM, Wang Y, et al. Role of parental myopia in the progression of myopia and its interaction with treatment in COMET children. *Invest Ophthalmol Vis Sci*. 2007;48:562–70.
9. Tang SM, Kam KW, French AN, Yu M, Chen LJ, Young AL, et al. Independent influence of parental myopia on childhood myopia in a dose-related manner in 2,055 trios: the Hong Kong Children Eye Study. *Am J Ophthalmol*. 2020;218:199–207.
10. Mutti DO, Mitchell GL, Moeschberger ML, Jones LA, Zadnik K. Parental myopia, near work, school achievement, and children's refractive error. *Invest Ophthalmol Vis Sci*. 2002;43:3633–40.
11. Lim LT, Gong Y, Ah-Kee EY, Xiao G, Zhang X, Yu S. Impact of parental history of myopia on the development of myopia in mainland China school-aged children. *Ophthalmol Eye Dis*. 2014;6:31–5.
12. Dean A. OpenEpi: open source epidemiologic statistics for public health, version 2.3.1. 2010. [cited 2024 June 30]; Available from: http://www.openepi.com
13. Hashemi H, Fotouhi A, Yekta A, Pakzad R, Ostadimoghaddam H, Khabazkhoob M. Global and regional estimates of prevalence of refractive errors: systematic review and meta-analysis. *J Curr Ophthalmol*. 2018;30:3–22.
14. Demir P, Hovsepian N, Pagels P, Petersson V, Baskaran K, Macedo AF. All retinas are not created equal: fovea-to-macula thickness ratio and foveal microvasculature in healthy young children. *Ophthalmic Physiol Opt*. 2022;42:644–52.
15. Demir P, Macedo AF, Chakraborty R, Baskaran K. Comparison of an open view autorefractor with an open view aberrometer in determining peripheral refraction in children. *J Optom*. 2023;16:20–9.
16. Sankaridurg P, Berntsen DA, Bullimore MA, Cho P, Flitcroft I, Gawne TJ, et al. IMI 2023 digest. *Invest Ophthalmol Vis Sci*. 2023;64:ARVO E-Abstract 7.
17. Jiang X, Tarczy-Hornoch K, Stram D, Katz J, Friedman DS, Tielsch JM, et al. Prevalence, characteristics, and risk factors of moderate or high hyperopia among multiethnic children 6 to 72 months of age: a pooled analysis of individual participant data. *Ophthalmology*. 2019;126:989–99.
18. Saw SM, Tong L, Chua WH, Chia KS, Koh D, Tan DTH, et al. Incidence and progression of myopia in Singaporean school children. *Invest Ophthalmol Vis Sci*. 2005;46:51–7.
19. Jacobsen N, Jensen H, Goldschmidt E. Does the level of physical activity in university students influence development and progression of myopia?—A 2-year prospective cohort study. *Invest Ophthalmol Vis Sci*. 2008;49:1322–7.
20. Bullimore MA, Brennan NA. Juvenile-onset myopia-who to treat and how to evaluate success. *Eye (Lond)*. 2024;38:450–4.
21. Pärssinen O, Kauppinen M, Viljanen A. The progression of myopia from its onset at age 8–12 to adulthood and the influence of heredity and external factors on myopic progression. A 23-year follow-up study. *Acta Ophthalmol*. 2014;92:730–9.
22. Polling JR, Klaver C, Tideman JW. Myopia progression from wearing first glasses to adult age: the DREAM Study. *Br J Ophthalmol*. 2021;106:820–4.
23. Pärssinen O, Kauppinen M. Associations of near work time, watching TV, outdoors time, and parents' myopia with myopia among school children based on 38-year-old historical data. *Acta Ophthalmol*. 2022;100:e430–e438.
24. Gonzalez-Meijome JM, Macedo-de-Araújo RJ, Amorim-de-Sousa AI, Fernandes P, Queiros A. Change in myopia prevalence over 24 months in a school population from 6 to 13 years of age in Portugal. *Invest Ophthalmol Vis Sci*. 2018;59:ARVO E-Abstract 3384.
25. Zhang J, Li Z, Ren J, Wang W, Dai J, Li C, et al. Prevalence of myopia: a large-scale population-based study among children and adolescents in Weifang, China. *Front Public Health*. 2022;10:924566. https://doi.org/10.3389/fpubh.2022.924566
26. Wang SK, Guo Y, Liao C, Chen Y, Su G, Zhang G, et al. Incidence of and factors associated with myopia and high myopia in Chinese children, based on refraction without cycloplegia. *JAMA Ophthalmol*. 2018;136:1017–24.
27. Tsai DC, Fang SY, Huang N, Hsu CC, Chen SY, Chiu AWH, et al. Myopia development among young schoolchildren: the Myopia Investigation Study in Taipei. *Invest Ophthalmol Vis Sci*. 2016;57:6852–60.
28. Rudnicka AR, Owen CG, Nightingale CM, Cook DG, Whincup PH. Ethnic differences in the prevalence of myopia and ocular biometry in 10- and 11-year-old children: the Child Heart and Health Study in England (CHASE). *Invest Ophthalmol Vis Sci*. 2010;51:6270–6.
29. Takeuchi M, Meguro A, Yoshida M, Yamane T, Yatsu K, Okada E, et al. Longitudinal analysis of 5-year refractive changes in a large Japanese population. *Sci Rep*. 2022;12:2879. https://doi.org/10.1038/s41598-022-06898-x
30. Ding X, Morgan IG, Hu Y, Yuan Z, He M. Exposure to the life of a school child rather than age determines myopic shifts in refraction in school children. *Invest Ophthalmol Vis Sci*. 2022;63:ARVO E-Abstract 15.
31. Ren H, Zhou Z, Liu WK, Wang X, Yin Z. Excessive homework, inadequate sleep, physical inactivity and screen viewing time

are major contributors to high paediatric obesity. *Acta Paediatr*. 2017;106:120–7.
32. Mikaels J. Becoming-place: a rhizomatic exploration of friluftsliv in the Swedish school curriculum. *Curric Perspect*. 2019;39:85–9.
33. Borge AIH, Nordhagen R, Lie KK. Children in the environment: forest day-care centers: modern day care with historical antecedents. *History Family*. 2003;8:605–18.
34. Ulset V, Vitaro F, Brendgen M, Bekkhus M, Borge AIH. Time spent outdoors during preschool: links with children's cognitive and behavioral development. *J Environ Psychol*. 2017;52:69–80.
35. He M, Xiang F, Zeng Y, Mai J, Chen Q, Zhang J, et al. Effect of time spent outdoors at school on the development of myopia among children in China: a randomized clinical trial. *JAMA*. 2015;314:1142–8.
36. Fan DS, Lam DS, Lam RF, Lau JTF, Chong KS, Cheung EYY, et al. Prevalence, incidence, and progression of myopia of school children in Hong Kong. *Invest Ophthalmol Vis Sci*. 2004;45:1071–5.
37. Tong L, Huang XL, Koh AL, Zhang X, Tan DTH, Chua W-H. Atropine for the treatment of childhood myopia: effect on myopia progression after cessation of atropine. *Ophthalmology*. 2009;116:572–9.
38. Jones-Jordan LA, Sinnott LT, Chu RH, Cotter SA, Kleinstein RN, Manny RE, et al. Myopia progression as a function of sex, age, and ethnicity. *Invest Ophthalmol Vis Sci*. 2021;62:36. https://doi.org/10.1167/iovs.62.10.36
39. Verkicharla PK, Kammari P, Das AV. Myopia progression varies with age and severity of myopia. *PLoS One*. 2020;15:e0241759. https://doi.org/10.1371/journal.pone.0241759

SUPPORTING INFORMATION

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

How to cite this article: Demir P, Baskaran K, Ramos PL, Naduvilath T, Sankaridurg P, Macedo AF. Incidence of myopia in Swedish schoolchildren: A longitudinal study. *Ophthalmic Physiol Opt*. 2024;44:1301–1308. https://doi.org/10.1111/opo.13359