Refractive error and visual impairment in school children in Northern Ireland

L O'Donoghue, J F McClelland, N S Logan, et al.

Br J Ophthalmol published online May 21, 2010
doi: 10.1136/bjo.2009.176040

BJO Online First, published on May 21, 2010 as 10.1136/bjo.2009.176040

Refractive error and visual impairment in school children in Northern Ireland

L O'Donoghue,[1] J F McClelland,[1] N S Logan,[2] A R Rudnicka,[3] C G Owen,[3] K J Saunders[1]

[1]School of Biomedical Sciences, University of Ulster, Coleraine, UK
[2]Aston University, Ophthalmic Research Group, Birmingham, UK
[3]St George's, University of London, London, UK

Correspondence to
Dr Lisa O'Donoghue, School of Biomedical Sciences, University of Ulster, Cromore Road, Coleraine, BT52 1SA, UK; l.odonoghue@ulster.ac.uk

Accepted 6 March 2010

ABSTRACT

Aims To describe the prevalence of refractive error (myopia and hyperopia) and visual impairment in a representative sample of white school children.

Methods The Northern Ireland Childhood Errors of Refraction study, a population-based cross-sectional study, examined 661 white 12–13-year-old and 392 white 6–7-year-old children between 2006 and 2008. Procedures included assessment of monocular logarithm of the minimum angle of resolution (logMAR), visual acuity (unaided and presenting) and binocular open-field cycloplegic (1% cyclopentolate) autorefraction. Myopia was defined as −0.50DS or more myopic spherical equivalent refraction (SER) in either eye, hyperopia as ≥+2.00DS SER in either eye if not previously classified as myopic. Visual impairment was defined as >0.30 logMAR units (equivalent to 6/12).

Results Levels of myopia were 2.8% (95% CI 1.3% to 4.3%) in younger and 17.7% (95% CI 13.2% to 22.2%) in older children: corresponding levels of hyperopia were 26% (95% CI 20% to 33%) and 14.7% (95% CI 9.9% to 19.4%). The prevalence of presenting visual impairment in the better eye was 3.6% in 12–13-year-old children compared with 1.5% in 6–7-year-old children. Almost one in four children fails to bring their spectacles to school.

Conclusions This study is the first to provide robust population-based data on the prevalence of refractive error and visual impairment in Northern Irish school children. Strategies to improve compliance with spectacle wear are required.

Refractive errors such as myopia and hyperopia are common ocular conditions with high costs associated with their correction. They have been identified as a cause of public health and economic concern.[1] Although there is an obvious need for appropriate allocation of healthcare resources, to date studies in the UK have been limited due either to lack of random sampling to obtain a representative population[2 3] or to reliance on non-cycloplegic measurements of ocular refraction.[4 5]

The WHO's "Vision 2020: The Right to Sight" initiative included the correction of refractive errors as one of the target areas to eliminate avoidable causes of visual impairment.[6] Uncorrected refractive error is the most common cause of visual impairment in school-age children in both industrialised and developing countries.[7] Although the Refractive Error Study in Children (RESC) surveys[8] and the Sydney Myopia Study (SMS)[9] have provided valuable population-based data on refractive error and visual impairment in children, there are no current robust data on the prevalence of potentially correctable visual impairment in children in the UK where not only are childhood vision screening programs in place but eye examinations and spectacle correction are also available free of charge to all children under 16 years of age.

The following report describes the prevalence of refractive error (myopia and hyperopia) in school children aged 6–7 and 12–13 years in Northern Ireland, UK and documents the extent to which uncorrected refractive error results in visual impairment in these children.

METHODS

Methodology

The Northern Ireland Childhood Errors of Refraction (NICER) study is an epidemiological study of refractive error among school-aged children in Northern Ireland and is a sister study of the Aston Eye Study, examining refractive error in a multiethnic urban population.[10] Another paper within this issue describes the NICER study methodology in detail.[11] In brief, stratified random-cluster sampling was used to identify potential participants aged 6–7 and 12–13 years. The protocol for data collection included measurement of logMAR monocular distance visual acuity (unaided and with spectacles if worn) and cycloplegic autorefraction (1% cyclopentolate hydrochloride) using a binocular open-field autorefractor. Participants were tested within school premises during the school day, between May 2006 and March 2008.

Ethics

Approval for the study was obtained from the University of Ulster's Research Ethics Committee. The research adhered to the principles of the Declaration of Helsinki.

Definitions

For prevalence data, the refractive status of both eyes was assessed. In keeping with the RESC protocol, a subject was classified as myopic if either eye was myopic and hyperopic if either eye was hyperopic and they had not been previously classified as myopic.[12] Myopia is defined as −0.50DS or more myopic spherical equivalent refraction (SER) and hyperopia as ≥+2.00DS SER. To further examine the effect of hyperopia on visual acuity, significant hyperopia was defined as SER ≥+3.00D.[9] Myopia prevalence is also presented using a criterion of at least −0.75D in each principal meridian.[13]

Visual impairment was defined as acuity poorer than 0.30 logMAR units (equivalent to 6/12),[8] and

in keeping with convention, the prevalence of visual impairment is presented in two ways: "better eye" and "either eye". WHO definitions of "uncorrected visual impairment" as the unaided visual acuity and "presenting visual impairment" as the visual acuity with spectacles, if available, have been employed.[8] When examining the relationship between refractive error and visual acuity, data from the right eye were analysed.

Assessment of economic Status

A Geographical Information Systems approach, using unit postcode address information and the Northern Ireland multiple deprivation measure, was applied to assign an area-based rank measure of economic deprivation to each child.[14] The measure, calculated at the small-scale census Output Area level, is based on three weighted domains of deprivation: income (41.7%), employment (41.7%) and proximity to services (16.6%).

Data handling and statistical analysis

All statistical analyses were carried out using Intercooled Stata 9.2 software (StataCorp LP, College Station, Texas, USA). CIs for prevalence rates have been adjusted for the cluster design. Throughout, 95% CIs have been used. Mean visual acuity measures are reported with their standard deviations.

RESULTS

Study population

Of the children invited to participate in the study, parental consent was obtained from 65% of 12–13-year-olds and 62% of 6–7-year-olds. Reflective of the Northern Irish population, 98.7% of participants were white, and this report presents data from 661 white children aged 12–13 years (50.5% male) and 392 white children aged 6–7 years (49.5% male). The mean ages of the two study groups were 13.1 (0.38) and 7.1 (0.37) years, respectively. There was no statistically significant gender difference in the age of the subjects within each group (t test, both p>0.08).

Refractive data

Refractive data are complete for 100% of the 12–13-year-old participants. Of 6–7-year-old children, 99.7% cooperated fully with data collection: one child consented to instillation of the eye drops into the left eye only, so refractive data of this participant have been analysed for the left eye only.

Table 1 describes the prevalence of myopia and hyperopia in both age groups. When a criterion of myopia of at least −0.75D in each principal meridian is employed, the prevalence of myopia adjusts to 0.5% (numbers too small to calculate CIs) and 12.4% (8.4% to 16.4%) in the younger and older children, respectively.

Visual acuity

Uncorrected visual acuity was assessed in 100% of 12–13-year-old children and 390 of 392 (99.5%) younger children. One of the younger children failed to co-operate with any form of visual acuity testing, and one child with high hyperopia failed to co-operate with unaided visual acuity testing. Uncorrected visual acuity was correlated between the two eyes (r=0.90, p<0.0001 in 12–13-year-olds; r=0.59, p<0.0001 in 6–7-year-olds). Visual acuity data are presented in table 2.

History of spectacle wear

Although the proportion of 12–13-year-old children who reported spectacle wear was higher (25% CI 22% to 28%, n=167) compared with 6–7-year-old children (12.8%, CI 9.0% to 16.5%, n=50), a similar proportion in both age groups did not have their spectacles at school (n=39, 23% of 12–13-year-olds and n=12, 24% of 6–7-year-olds). Parental reporting of children's spectacle wear and child self-reporting of spectacle wear showed substantial agreement (κ=0.80, p<0.0001) in older children and almost perfect agreement (κ=0.84, p<0.0001) in younger children.[15] Within both age groups, children who wore spectacles had a statistically significantly poorer (t test, all p<0.0001) uncorrected visual acuity in both eyes compared with children who did not wear spectacles.

Of the 128 older children who had their spectacles available at school, 10 (7.8%, 1.5% of sample) were classified as emmetropic. However, of these, five were wearing a low myopic correction which improved visual acuity. Of the 38 younger children who had their spectacles available at school, one (0.26% of the sample) had no significant refractive error.

Table 1 The prevalence of refractive error and visual impairment

	N	6–7-year-olds % (CIs)	N	12–13-year-olds % (CIs)
Prevalence				
Myopia≤−0.50DS	11	2.8 (1.3–4.3)* †	117	17.7 (13.2–22.2)*
Hyperopia≥+2.00DS	103	26 (20–33)* †	97	14.7 (9.9–19.4)*
Uncorrected visual impairment (better eye)	11	2.8 (0.9–4.7)*	85	12.9 (10.3–15.4)*
Presenting visual impairment (better eye)	6	1.5 (0.2–2.9)	21	3.2 (1.2–5.1)
Uncorrected visual impairment (either eye)	39	9.9 (6.5–13.4)*	124	19 (14–23)*
Presenting visual impairment (either eye)	28	7.2 (4.2–10.1)	51	7.7 (6.5–13.4)

*Statistically significant difference between the two age-groups.
†Statistically no significant gender difference.

Visual acuity and refractive data

In the two age groups, children with myopia and significant hyperopia have statistically significantly poorer uncorrected and presenting visual acuity than children without ametropia (table 2)

Although uncorrected visual impairment in the better eye was not associated with economic status in 6–7-year-old children (logistic regression, p=0.88), 12–13-year-old children from higher economic backgrounds were more likely to have uncorrected visual impairment (logistic regression, p=0.001).

Of the 21 12–13-year-old children with presenting visual impairment in the better eye, six did not wear spectacles, five of whom were myopic, and eight did not have their spectacles at school. In this age group, presenting visual impairment in either eye was not statistically significantly associated with economic status (logistic regression, p=0.59).

Of the six younger children with presenting visual impairment in the better eye, three did not wear spectacles, and one did not have their spectacles at school.

The majority of presenting visual impairment in at least one eye was due to myopia (69%) in 12–13-year-old children and hyperopia (55%) in 6–7-year-old children.

DISCUSSION

This present paper presents, for the first time in the UK, population-based data describing the prevalence of cycloplegic measures of myopia and hyperopia in childhood.

The prevalence of myopia (≤−0.50DS SER) in 6–7-year-old children is low (2.8%). Similar findings in young children have been reported by other studies: the SMS has reported a prevalence of myopia of 1.4% in the right eyes of 6-year-old children, with a lower prevalence of 0.8% in white 6-year-olds of European

Table 2 Visual acuity (uncorrected and presenting)

	6–7-year-olds		12–13-year-olds	
VA (uncorrected)	**Number**	**Mean logMAR (SD)**	**Number**	**Mean logMAR (SD)**
Right				
All	390	0.12 (0.12)*	661	0.09 (0.30)*
Boys	193	0.12 (0.12)†	334	0.07 (0.27)‡
Girls	197	0.12 (0.12)†	327	0.12 (0.33)‡
Left				
All	390	0.12 (0.15)*	661	0.09 (0.31)*
Boys	193	0.12 (0.16)†	334	0.06 (0.28)‡
Girls	197	0.12 (0.15)†	327	0.13 (0.34)‡
Right				
No refractive error	295	0.09 (0.09)	484	−0.02 (0.15)
Myopia≤−0.50DS	8	0.27 (0.24)§	99	0.58 (0.40)§
Hyperopia≥+2.00DS and <+3.00DS	49	0.13 (0.11)¶	29	0.04 (0.13)¶
Hyperopia≥+3.00DS	38	0.25 (0.19)§	49	0.21 (0.26)§
VA (presenting)				
Right				
No refractive error	295	0.09 (0.08)	484	−0.02 (0.14)
Myopia≤−0.50DS	8	0.27 (0.24)§	99	0.16 (0.22)§
Hyperopia≥+2.00DS and <+3.00DS	49	0.12 (0.6)¶	29	0.02 (0.12)¶
Hyperopia≥+3.00DS	38	0.20 (0.12)§	49	0.10 (0.17)§

*No statistically significant difference between the two age-groups.
†No statistically significant gender differences.
‡Statistically significant gender differences.
§Statistically significant difference in VA compared to children with no refractive error.
¶No statistically significant difference in VA compared to children with no refractive error.

descent.[16] Robinson[17] defined myopia as at least −0.25DS (measured by non-cycloplegic refraction) in the horizontal meridian (ie, within 20° of the horizontal axis) and reported a prevalence of 6% in 6-year-old children in Canada with the prevalence dropping to 1.8% if the definition of myopia was amended to at least −1.00DS in the horizontal meridian. However, the ethnicity of participants was not described. The Avon Longitudinal Study of Parents and Children (ALSPAC) in the UK used a definition of "likely to be myopic" as equivalent to a non-cycloplegic refractive error of ≤−1.50DS to report a prevalence of myopia of 1.5% in 7-year-old white children.[4] By contrast, the prevalence of myopia (≤−0.50DS SER), using similar protocols and methodology to the present study, in 7-year-old children in Singapore is 28%.[18]

The prevalence of myopia (≤−0.50DS SER) in white 12–13-year-old children in Northern Ireland is 17.7%, statistically significantly different from the prevalence in 6–7-year-old children. It is not possible to ascertain if this is a real difference or a cohort effect, as the two age-groups may have been exposed to different environmental influences. Although in the present study the environmental differences experienced by the two age groups are likely to be minimal, to fully examine differences in prevalence with age, prospective studies are required, and future review of the present study's participants is under way.

The prevalence of myopia in white 12–13-year-old children in Northern Ireland is higher than the prevalence of a similarly aged group in Sydney, Australia, where the prevalence of myopia was only 4.6% in white children.[19] The study population in Northern Ireland is slightly older than that of the Australian study (mean age: 13.1 vs 12.7 years, respectively), but this difference is unlikely to fully explain the disparity in reported prevalences. A lower prevalence of myopia (11% in 13-year-old children) has also been reported in Poland, with 1% tropicamide used as the cycloplegic agent.[20] By contrast, the prevalence of myopia in Northern Ireland is markedly lower at 12–13 years than the 45% reported in Swedish children of the same age.[21] However, the latter study used 0.5% tropicamide rather than the more effective cycloplegic agent, cyclopentolate hydrochloride 1%, which may have falsely inflated the reported prevalence.[22]

The use of SER to classify myopia results in an over-estimation of prevalence in populations with significant levels of astigmatism. For example, a subject with refractive error: +1.00/−3.00 has a SER of −0.50DS and is therefore classified as myopic, although their refractive error is primarily astigmatic in nature. Despite the limitations of SER, it has been used in the current study to facilitate comparisons with other epidemiological studies of refractive error. The Orinda Longitudinal Study of Myopia (OLSM) in the USA, whose study population is largely white, used 1% tropicamide and a criterion of myopia of at least −0.75D in both meridians to report a prevalence of myopia of 20% in the right eyes of 13-year-old children.[23] This definition of myopia overcomes some of the limitations of SER, and using the same definition, the prevalence of myopia (in either eye) in Northern Ireland falls to 12% in 12–13-year-old children. Kleinstein[13] reported a prevalence of 4.4% in white children in the Collaborative Longitudinal Evaluation of Ethnicity and Refractive Error study (a follow-on study of the OLSM) in the USA, using the same definition of at least −0.75D in each meridian. However, as the quoted prevalence rate of the latter study covered the entire study population between the ages of 5 and 17 years, comparisons with the current study are problematic.

No significant gender difference in the prevalence of myopia or hyperopia was found in either age group in the current study. By contrast, the SMS has reported a higher prevalence of myopia in 12-year-old girls compared with 12-year-old boys (14% vs 10%). This gender difference is often attributed either to girls undertaking more near-work than boys or to gender differences

in the age of onset of puberty. The SMS has not reported whether this gender difference varies with ethnicity, which may explain the variance with the current study.[19] Often, studies reporting higher prevalence of myopia in female subjects predominantly involve older subjects.[24] The children in the present study may be too young to demonstrate these differences, and future review will provide an opportunity to evaluate whether they follow the anticipated pattern with increasing age.

Although populations with a high prevalence of myopia generally have a relatively low prevalence of hyperopia,[19] there is a higher prevalence of both myopia (≤−0.50DS) and hyperopia (≥+2.00DS) in children aged 12–13 years old in Northern Ireland compared with white children in Australia, where the prevalence of hyperopia in this age group is 4.4%. The high prevalence of hyperopia in the current population is of some concern from a clinical perspective as hyperopia is associated with poor visual outcome, such as amblyopia and strabismus. Children with significant hyperopic refractive errors also have a consistently poorer performance on a range of visuocognitive and visuomotor tests compared with children without significant refractive errors,[25] with subsequent implications for general development and educational attainment. In Northern Ireland, the prevalence of hyperopia of at least +2.00DS is closer to that reported for Polish children (11.8% in 13-year-olds and 19.2% in 7-year-olds).[20] The ALSPAC reported a prevalence of hyperopia (≥+2.00DS) of 5% in white children,[26] but the lack of cycloplegic assessment may explain the low prevalence reported.

It is unclear from the current study whether the increased prevalence of myopia in childhood in Northern Ireland compared with Australia is due to environmental or genetic influences. The SMS has recently reported a higher prevalence of myopia for children who reside in urban compared to suburban areas[27] and has also shown that lower amounts of outdoor activity is a risk factor for myopia.[28] Future papers will investigate whether these environmental factors impact on the prevalence of myopia in Northern Irish school children.

The present study provides valuable population-based normative values for visual acuity in white children in the UK, similar to the mean values reported by the SMS (20/20 Snellen equivalent acuity in 12-year-old children,[29] and 0.1 logMAR acuity in 6-year-olds children[9]). Although the SMS reported better visual acuity in boys compared with girls in both age groups, the current study found a significant gender difference only in the older age group. The increased prevalence of uncorrected visual impairment in children from higher economic backgrounds reflects an increased prevalence of myopia among these children.

Across both age groups, our study found that almost one in four children who had been prescribed spectacles did not have them available at school. Although the reasons for and impact of this failure to wear prescribed spectacles were not addressed, many of the children who did not have their spectacles available had ametropia and/or uncorrected visual impairment, both of which are likely to impact on visual comfort and school performance. Future research should be directed at identifying reasons for non-compliance with spectacle wear with a view to implementation of strategies to boost compliance. The proportion of children who wear spectacles but have no refractive error is low (1.5% of 12–13-year-olds, 0.26% of 6–7-year-olds). Overprescribing of spectacles does not appear to be a significant problem in Northern Ireland.

Data from the 1970 British Cohort Study reported a prevalence of distance vision of 6/12 or worse of 4.4% at age 10–11 years and 11.4% at age 15–16 years[30] compared to 12.9% in 12–13-year-olds in the current study. However, in the current study, the prevalence of presenting visual impairment is much lower (3.2%), suggesting that most cases of uncorrected visual impairment are detected and treated. In 6–7-year-old children, there is a low prevalence of both uncorrected (2.8%) and presenting (1.5%) visual impairment. In the SMS, the prevalence of presenting visual impairment worse than 0.30 logMAR is even lower (1.1% in 12–13-year-old children[29]: 0.9% in 6–7-year-old children).[9] The RESC studies have shown wide variation between populations in the prevalence of presenting visual impairment, ranging from 10.3% in Guangzhou, China to 1.2% in Rural Nepal,[12] reflecting wide inter-population variations in the prevalence of myopia and equality of access to eye care services.

While better eye data suggest presenting visual impairment is not a major problem in the UK, the high prevalence (7.2%) of presenting visual impairment in either eye of 6–7-year-olds is of some concern as inter-ocular difference in visual acuity is well recognised as a risk factor for amblyopia. The majority of presenting visual impairment in at least one eye was due to hyperopia in the younger age group and myopia in the older age group.

Strengths and Limitations

The refractive data from the NICER study is supported by ocular biometric data, the findings of which will be presented in future publications. However, due to the limited data available for the UK, it is unclear whether the prevalence of childhood myopia and hyperopia in Northern Ireland is representative of the white UK population as a whole. Future comparisons with data from white subjects in the Aston Eye Study will be made to address this issue.

CONCLUSION

The NICER study is the first to provide robust population-based data on the prevalence of refractive error and visual impairment in white school children in the UK. Although the prevalence of uncorrected and presenting visual impairment in the better eye is low, the high prevalence of monocular presenting visual impairment needs to be addressed. Strategies to improve the compliance of spectacle wear in children in this population are also urgently required.

Acknowledgements The authors are grateful to the College of Optometrists, who provided a research scholarship to Lisa O'Donoghue, and to the Northern Ireland Optometric Society who provided funding for the portable digital fundus camera.

Funding College of Optometrists, 42 Craven Street, London WC2N 5NG;Northern Ireland Optometric Society, PO Box 28, Dromore BT25 1YH.

Competing interests None.

Ethics approval This study was conducted with the approval of the University of Ulster Research Ethics Committee.

Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES

1. **Hyman L.** Myopic and hyperopic refractive error in adults: an overview. *Ophthalmic Epidemiol*. 2007;**14**:192–7.
2. **Sorsby A,** Benjamin B, Sheridan M. Refraction and its components during the growth of the eye from the age of three. *Memo Med Res Council* 1961;**301**:1–67.
3. **Donnelly UM,** Stewart NM, Hollinger M. Prevalence and outcomes of childhood visual disorders. *Ophthalmic Epidemiol* 2005;**12**:243–50.
4. **Williams C,** Miller LL, Gazzard G, *et al*. A comparison of measures of reading and intelligence as risk factors for the development of myopia in a UK cohort of children. *Br J Ophthalmol* 2008;**92**:1117–21.
5. **Williams C,** Miller L, Northstone K, *et al*. The use of non-cycloplegic autorefraction data in general studies of children's development. *Br J Ophthalmol* 2008;**92**:723–4.
6. **Resnikoff S,** Pararajasegaram R. Blindness prevention programmes: past, present, and future. *Bull World Health Organ* 2001;**79**:222–6.

7. **Robaei D,** Kifley A, Rose KA, *et al*. Refractive error and patterns of spectacle use in 12-year-old Australian children. *Ophthalmology* 2006;**113**:1567—73.
8. **Gilbert CE,** Ellwein LB. Refractive Error Study in Children Study Group. Prevalence and causes of functional low vision in school-age children: results from standardized population surveys in Asia, Africa, and Latin America. *Invest Ophthalmol Vis Sci* 2008;**49**:877—81.
9. **Robaei D,** Rose K, Ojaimi E, *et al*. Visual acuity and the causes of visual loss in a population-based sample of 6-year-old Australian children. *Ophthalmology* 2005;**112**:1275—82.
10. **Logan NS,** Rudnicka AR, Shah P, *et al*. Ethnic differences in ocular refraction and biometry in UK children: evidence from the Aston Eye Study. *Invest Ophthalmol Vis Sci* 2008;**49**:2602.
11. **O'Donoghue L,** Saunders KJ, McClelland JF. Sampling and measurement methods for a study of childhood refractive error in a United Kingdom population. *Br J Ophthalmol* in press.
12. **He M,** Zeng J, Liu Y, *et al*. Refractive error and visual impairment in urban children in southern china. *Invest Ophthalmol Vis Sci* 2004;**45**:793—99.
13. **Kleinstein RN,** Jones LA, Hullett S, *et al*. Refractive error and ethnicity in children. *Arch Ophthalmol* 2003;**121**:1141—7.
14. **Northern Ireland Statistic and Research Agency.** Northern Ireland multiple deprivation measures 2005 http://www.nisra.gov.uk/archive/deprivation/NIMDM2005 FullReport.pdf (accessed 29 March 2009).
15. **Landis JR,** Koch GG. The measurement of observer agreement for categorical data. *Biometrics*. 1977;**33**:159—74.
16. **Ojaimi E,** Rose KA, Morgan IG, *et al*. Distribution of ocular biometric parameters and refraction in a population-based study of Australian children. *Invest Ophthalmol Vis Sci* 2005;**46**:2748—54.
17. **Robinson BE.** Factors associated with the prevalence of myopia in 6-year-olds. *Optom Vis Sci* 1999;**76**:266—71.
18. **Saw SM,** Zhang MZ, Hong RZ, *et al*. Near-work activity, night-lights, and myopia in the Singapore-China study. *Arch Ophthalmol* 2002;**120**:620—27.
19. **Ip JM,** Huynh SC, Robaei D, *et al*. Ethnic differences in refraction and ocular biometry in a population-based sample of 11-15-year-old Australian children. *Eye (Lond)* 2008;**22**:649—56.
20. **Czepita D,** Zejmo M, Mojsa A. Prevalence of myopia and hyperopia in a population of Polish schoolchildren. *Ophthalmic Physiol Opt* 2007;**27**:60—5.
21. **Villarreal MG,** Ohlsson J, Abrahamsson M, *et al*. Myopisation: the refractive tendency in teenagers. prevalence of myopia among young teenagers in Sweden. *Acta Ophthalmol Scand* 2000;**78**:177—81.
22. **Egashira SM,** Kish LL, Twelker JD, *et al*. Comparison of cyclopentolate versus tropicamide cycloplegia in children. *Optom Vis Sci* 1993;**70**:1019—26.
23. **Zadnik K,** Mutti DO, Friedman NE, *et al*. Initial cross-sectional results from the orinda longitudinal study of myopia. *Optom Vis Sci* 1993;**70**:750—8.
24. **Kempen JH,** Mitchell P, Lee KE, *et al*. The prevalence of refractive errors among adults in the United States, Western Europe, and Australia. *Arch Ophthalmol* 2004;**122**:495—505.
25. **Atkinson J,** Anker S, Nardini M, *et al*. Infant vision screening predicts failures on motor and cognitive tests up to school age. *Strabismus* 2002;**10**:187—98.
26. **Williams C,** Northstone K, Howard M, *et al*. Prevalence and risk factors for common vision problems in children: data from the ALSPAC study. *Br J Ophthalmol* 2008;**92**:959—64.
27. **Ip JM,** Rose K, Morgan I, *et al*. Myopia and the urban environment: findings for a sample of 12-year old Australian school children. *Invest Ophthalmol Vis Sci* 2008;**49**:3858—63.
28. **Rose KA,** Morgan IG, Ip J, *et al*. Outdoor activity reduces the prevalence of myopia in children. *Ophthalmology* 2008;**115**:1279—85.
29. **Robaei D,** Huynh SC, Kifley A, *et al*. Correctable and non-correctable visual impairment in a population-based sample of 12-year-old Australian children. *Am J Ophthalmol* 2006;**142**:112—18.
30. **Rudnicka AR,** Owen CG, Richards M, *et al*. Effect of breastfeeding and sociodemographic factors on visual outcome in childhood and adolescence. *Am J Clin Nutr* 2008;**87**:1392—99.