Br Ir Orthopt J 2008; **5:** 15–21

Hypermetropia in childhood: a review of research relating to clinical management

ANNA R. O'CONNOR PhD BMedSci (Hons)

Division of Orthoptics, University of Liverpool, Liverpool

Abstract

Aim: **There are numerous questions regarding the management of children with hypermetropia, such as what level of hypermetropia should be prescribed. The aim of this review is to evaluate the findings reported in the literature and to determine the areas where further research is required.**
Methods: **A literature search of databases was performed, focusing on publications from the last 10 years.**
Results: **The reported prevalence of hypermetropia in children ranges from 0.9% to 12.8%, depending on the age at test and definition of hypermetropia. There is no consensus on when to prescribe for hypermetropia but there is evidence to suggest that early correction results in fewer cases of amblyopia and strabismus. In addition hypermetropia has been shown to be associated with poorer reading and writing skills. The process of emmetropisation is affected by a number of factors, including preterm birth and strabismus, but the pattern of eye growth varies according to the type of strabismus present. Results of refractive surgery have been very successful only in relatively low degrees of hypermetropia.**
Conclusion: **Although there is considerable variation in the opinion on when to prescribe, the evidence suggests that early identification and correction of hypermetropia of 4 dioptres or above is probably beneficial in terms of preventing cases of amblyopia and strabismus, and improving performance in many areas of development. There is still debate concerning the correction of lower amounts of hypermetropia and on the optimum method of identification and treatment.**

Key words: Emmetropisation, Hypermetropia, Low birth weight, Refractive surgery, Strabismus

Introduction

Hypermetropia is the most common type of refractive error but there are many aspects of its development and subsequent impact on its management in childhood that are poorly understood. This lack of knowledge has resulted in considerable variation in clinical care. The lack of evidence means that decisions regarding correction of hypermetropia are based on opinion, formed from personal experience and the experience of others. This review is not intended to be fully comprehensive but rather focuses on key clinical issues such as:

- How is 'high' or 'clinically significant' hypermetropia defined?
- Do glasses prevent emmetropisation?
- How does preterm birth affect refractive development?
- At what level of hypermetropia should a correction be prescribed?
- Are alternative treatments, such as laser surgery, applicable to children?

Although there are no definitive answers for many of these questions, this review will endeavour to discuss the relevant evidence.

A search of scientific literature databases, including Pubmed and Web of Knowledge, was performed using the key words stated above. After identification of relevant articles the references from those articles were reviewed. Also a forward citation search of articles greater than 5 years old was performed using Web of Knowledge, which identifies articles published subsequently that reference the original article.

Epidemiology of hypermetropia

A wide range of factors contribute to the development of hypermetropia, including ethnicity and socio-economic development. This review was restricted to reports from the developed world to avoid introducing many confounding factors.

First, there is a need to define 'high' or 'clinically significant' hypermetropia. Table 1 summarises the reported prevalence rates of hypermetropia in children. It is evident that there is a lack of consensus on the definition of hypermetropia across studies; the amount varies by up to 2 dioptres, so unsurprisingly the prevalence varies by more than 10% between studies.

The large disparity between studies may not be solely attributable to the definitions used by the authors of each study. The additional information provided in Table 1 may also account for some of the differences. For example, it would be expected that the prevalence would reduce with reducing age, as it is known that the average spherical equivalent reduces from +2.20 D (±1.60

Correspondence and offprint requests to: Dr Anna O'Connor, Division of Orthoptics, Thompson Yates Building, Brownlow Hill, Liverpool, L69 3GB. e-mail: annaoc@liv.ac.uk

Table 1. A summary of reported prevalence rates of hypermetropia in children

Reference	Sample size	Age (years)	Definition of hypermetropia	Prevalence (%)
Gronlund[1]	35	4–6	≥+2D MSE	5%
	42	7–9		4%
	35	10–12		1%
	31	13–15		3%
Junghans[2]	3690 eyes	3–12	>+1.5 DS	7.7% of eyes
			>+2.00 DS	2% of eyes
Ip[3]	2353	11–14	≥+2.00D MSE	3.5%
Larsson[4]	217	10	>+3D MSE	0.9%
Kleinstein[5]	2523	5–17	≥+1.25 D in each meridian	12.8%
Williams[6]	7538	7	+1.00 D	10%
Ingram[7]	296 eyes	1	≥+2.00 DS	11% of eyes
		3.5		12.2% of eyes
Williams[8]	1298	8	>+3 DS	3.2%
Atkinson[9]	3166	7–9 months	≥3.5 DS	5.7%
Brody[10]	507	3–5	≥4 DS	7.5%

D, dioptres; DS, dioptres sphere; MSE, mean spherical equivalent.

standard deviation) at 1 month of age to +1.13 D (±0.85) at 48 months old.[11] This reduction in hypermetropia continues with age but at a slower rate, with a reduction of approximately half a dioptre over a period of 9 years (age 3–12 years)[2] and the average spherical equivalent becoming myopic in teenagers (–0.46 ± 2.18 at 14 years).[12] However, there are numerous other factors, including ethnicity,[5] social class[6] and the use of cycloplegia and its type,[13] that affect refractive development and therefore the prevalence of hypermetropia.

Emmetropisation

The topic of emmetropisation is extensive and will not be considered in this review in its entirety. However, those aspects that are integral to the management of hypermetropia in childhood, in particular how strabismus and preterm birth affect emmetropisation, will be discussed.

There are three recognised mechanisms of emmetropisation that will affect eye growth and the resultant refractive error.[14] These are:

1. passive, where the eye grows due to predetermined genetic factors;
2. active, where a blurred visual input results in a change in eye growth towards emmetropia;
3. in response to excessive accommodation.

In hypermetropia one of the key questions is whether prescribing glasses will prevent emmetropisation, as the glasses will remove the blur signal and/or affect accommodation. The potential result would be to leave the child needing glasses permanently. Ingram *et al.*[15] reported that in children with a refractive error of at least +5.25 D in one eye at age 6 months who wore their glasses, emmetropisation was significantly impeded, but not halted, compared with those who did not wear their glasses. Therefore it has been suggested that an undercorrection of hypermetropia is a sensible compromise. Theoretically, by leaving a degree of hypermetropia the signals to emmetropise remain and the eye continues to grow. A longitudinal randomised control trial study by Atkinson *et al.*[16,17] addressed this issue by evaluating the outcome of treated (undercorrected by 1 dioptre at 9 months of age) versus children with hypermetropia who were not treated. Evaluation between 9 and 36 months of age showed no significant difference between the groups. However, while the majority of subjects followed this pattern there was considerable individual variation, which could not be accounted for. In addition, in the study by Atkinson *et al.* the range of hypermetropia prescribed was +3.5 to <+6 D, making comparison with Ingram *et al.*'s[15] findings difficult. Thus, while the overall findings suggest that an undercorrection has no impact on emmetropisation, further work is required.

Studies of refractive development have demonstrated that the majority of change in refractive error occurs during the first year of life,[18] with the change in axial length being the most influential factor in emmetropisation.[19] This implies there would be no adverse effect to prescribing glasses after 1 year of age. Therefore age could be the best determinate of whether prescribing glasses will affect emmetropisation. Unfortunately, due to factors including strabismus and preterm birth, the impact on developmental age alone does not predict outcome.

Emmetropisation and preterm birth

Emmetropisation requires normal development of the ocular structures. However, this might not occur following premature birth, an increasingly common event.[20] Reports of myopia in association with retinopathy of prematurity (ROP) and/or preterm birth alone are relatively common.[21–26] There are cases of myopia secondary to severe ROP[27,28] ranging from low to high myopia, which is probably related to the disease process. However, no direct link has been found between ROP and hypermetropia. Despite this lack of association with ROP, the prevalence of hypermetropia is higher in low birth weight children,[29,30] with the prevalence of high hypermetropia being inversely proportional to the birth weight.[31] Population-based studies of low birth weight children have reported levels of hypermetropia of 4.2%[4] with more than +3.0 D at 10 years, and 6.6%[28] with +3.0 D or more at 10–12 years – higher than all the rates of hypermetropia greater than +3.0 D reported in Table 1 and more than 4 times the rate reported by Larsson *et al.*[4]

To determine whether a child is at high risk of developing a number of ophthalmic conditions, factors such as neurological deficits and medical complications have been evaluated. Some factors have been shown to be associated with certain measures of outcome; for example, there is a known link between intraventricular haemorrhage and poor visual outcome,[32] but no factors have yet been shown to be related to the development of hypermetropia.

It has been found that the disruption to development following preterm birth,[33] even in the absence of ROP,[34] affects ocular growth from a very early age. At 40 weeks the ocular dimensions of the preterm infants were significantly different from children born at term, with shorter axial lengths, shallower anterior chambers and more highly curved corneas.[34] A similar pattern was found in ex-preterm children at 10–12 years of age[28] but there is a lack of longitudinal data. As the growth of the eye is abnormal from such an early age it is not possible to use early measures of eye size to determine long-term refractive error.

The reasons for the lack of emmetropisation in the preterm population are unclear. Reduced axial lengths would suggest an increase in hypermetropia, but the mean axial length of children with myopia has been found to be less than the normative data from full-term subjects.[28] The increase in high hypermetropia in the preterm population, combined with the lack of predictability based on early measures, poses questions regarding the long-term ophthalmic care of these children and whether they need additional follow-up.

Emmetropisation and strabismus

The presence of strabismus with hypermetropia adds another dimension to the decision to treat hypermetropia. Defective emmetropisation has been reported in children with strabismus[35] and causally linked to the development of strabismus because the lack of emmetropisation was found before the onset of strabismus. Ingram *et al.* reported defective emmetropisation in both eyes of more than 80% of children with either a microtropia or heterotropia, regardless of their early refractive status.[35] However, the age at follow-up was during the period of eye growth when emmetropisation is incomplete. Therefore it is not known whether the strabismus resulted in a slower/delayed development of the eye growth or whether the effect on emmetropisation would persist in the long term. In a case report[36] a normal pattern of development of the ocular components was demonstrated up to the onset of strabismus, which suggests a number of different growth patterns can be associated with strabismus. Unfortunately, therefore, measuring ocular components is not effective in predicting the development of strabismus.

Although Ingram *et al.*'s[35] data showed that emmetropisation was impeded when glasses were worn in early childhood, in patients with strabismus emmetropisation did not occur irrespective of refractive correction.[15] These results are difficult to interpret because all cases of microtropia and heterotropia were grouped together, which prevents understanding of the impact of a precise diagnosis, and the level of binocular vision or visual acuity, on emmetropisation. If these findings could be applied to all cases of strabismus it would suggest that full corrections should be given in all cases of strabismus. However, Abrahamsson *et al.*[37] analysed cases of esotropia and exotropia separately and found a significant difference between the two groups. In esotropia there was an increase in the refractive error before the onset of the strabismus, whereas there was no relationship between refractive error changes and the development of an exotropia. In cases of accommodative esotropia it has been reported that the presence of anisometropia is an important factor, as in conjunction with the hypermetropia it increases the risk of developing strabismus by almost a factor of 8 compared with children with just hypermetropia.[38] Further work in this area is essential, particularly in exploring the impact of different types of esotropia on emmetropisation.

Prescribing patterns in childhood hypermetropia

Many factors influence the decision to prescribe a hypermetropic correction, for example the alignment of the eyes or even social factors, as children wearing glasses can be victimised by their peers.[39] Also deficits of accommodation, for example in children with Down's syndrome,[40,41] will affect the decision of when to prescribe. Ultimately, it is a balance between obtaining the optimum visual function (encompassing both visual acuity and binocular vision) while not impeding emmetropisation.

In the child without a manifest deviation there is much variation in the opinion of ophthalmic professionals in terms of when to prescribe. Some of this variation will be attributable to the influence of the personal opinions of the tutors when training, from continuing education courses and clinical experience[42,43] because of the lack of evidence on which to base decisions. A survey of optometrists demonstrated considerable variability in prescribing plus lenses in adults but they found the most important factor in the decision-making process was the presence of symptoms.[44] Unfortunately, in paediatric practice symptoms may or may not be present and the patient may either not be aware of the problem or unable to describe the symptoms accurately. Therefore, in children decisions need to be made in the absence of subjective information. A survey of members of the American Association for Pediatric Ophthalmology and Strabismus[45] established considerable variability in opinions on when to prescribe, with 50% giving glasses for 4 dioptres or more of hypermetropia in children over the age of 2 years.

Although it is recognised that one set of rules cannot fit all, treatment guidelines based on evidence can be helpful. There are a number of published guidelines available from around the world but they vary considerably in the level of detail provided and are not entirely evidence-based. The Royal College of Ophthalmologists guidelines[46] state: 'In children without strabismus the precise indication for treatment of spherical errors is ill defined and will depend on the age of the child and the magnitude of the error'. One example given is that it is advisable to give some refractive correction when the error is about +4.00 even when the acuity is normal. The American Academy of Ophthalmology, however, is more prescriptive in its guidance.[47] They recommend that glasses should be prescribed for hypermetropia without a deviation when the refractive error is greater than or equal to +6.00 for children up to the age of 1 year, +5.00 for those aged 1–2 years and +4.50 for those aged 2–3 years. However, it is important to highlight that the guidelines state they 'were generated by consensus and are based solely on professional experience and clinical impressions'. In contrast to the American approach, the published guidelines from Thailand[48] are very vague, saying that 'young children with low to moderate hyperopia generally require no treatment', without defining young, low or moderate.

The differences in prescribing patterns exist not only between countries but also between groups of professionals. Lyons *et al.*[49] found considerable variation between ophthalmologists and optometrists: approximately one-third of optometrists prescribed +3.00 to +4.00 DS in infants 6 months old, but less than 5% of ophthalmologists reported that they would prescribe in this scenario. Reiter *et al.*[50] made a comparison between the prescribing habits of different professionals and the same professionals in different countries. There was a variation in the prescribing patterns between German and American ophthalmologists, but the German ophthalmologists had similar prescribing regimes to US optometrists. Overall, from both reports, the US ophthalmologists were less likely to prescribe for lower amounts of hypermetropia. This difference was attributed to factors such as the varying structures of the health care systems; for example, they may be seeing different population types due to the referral systems. Ultimately, though, there are no evidence-based guidelines to support either prescribing philosophy. However, it would seem that most reports advocate prescribing glasses in a young child when the level of hypermetropia is approximately +4 DS, irrespective of the level of vision.

As children have large amplitudes of accommodation[51] it could be argued that low to moderate levels of hypermetropia do not need to be prescribed, in the absence of strabismus or amblyopia, with no resultant detriment to the child. This is supported by evidence from the study by Helveston *et al.*[52] who found no relationship between visual functions and measures of academic performance, but they did not assess the relationship between academic performance and refractive error. However, there is more recent evidence to the contrary, with reports specifically of hypermetropia being associated with a range of deficits such as poorer performance on visual and literacy tasks,[53] reduced reading and writing skills[5] and lower IQ.[54] To ensure these deficits were not related to the increased amblyopia and strabismus found in children with moderate hypermetropia, a study that found deficits in the visuocognitive and visuomotor domains repeated the analysis.[55] Their conclusions remained the same even after exclusion of the cases of strabismus and amblyopia. One recent report suggests that refractive error is also associated with headaches;[56] however, due to the multifactorial nature of headaches it is difficult to determine the impact directly attributable to the refractive error.

The findings on prescribing patterns are predominantly focused on the general population. However, as discussed previously low birth weight children are at increased risk of developing high hypermetropia with the added complication of an increased risk of a range of cognitive disorders found in this population.[57–59] The visual deficits in this population have been reported to be associated with increased cognitive deficits,[60–62] although a precise causal link with hypermetropia specifically has not been made. However, it could be argued that as these children have many learning difficulties they should be assessed and given glasses to maximise their vision and minimise any impact on learning.[63]

Based on this evidence a refractive error of greater than +4.00 D in a child over the age of 1 year, especially if they were a low birth weight child, should be prescribed glasses to prevent a range of deficits.

Implications for vision screening

There are many issues surrounding vision screening that have been evaluated.[64] These include what test to use, when to test, who to test[62] and who should carry out the test.[65] Refractive errors as a whole are one of the target conditions aimed to be identified, but the current UK guidelines given in the Hall report[66] do not include any direct assessment of the refractive error, relying instead on the visual acuity test to detect any resultant deficit. As the recommended visual acuity assessment is at distance only, and variations exist in referral criteria depending on the age and test, it could potentially miss those with moderate hypermetropia who are able to accommodate sufficiently for a distance test. Therefore the question is whether additional testing should be incorporated to detect moderate hypermetropia and if so what that test should be.

Auto-refractors give accurate and reliable results in children[67] following cycloplegia but without cycloplegia are less reliable.[68,69] Alternatively a photoscreener[70] could be used, as the aim of screening is to detect children at high risk of having the condition, not to diagnose or determine the exact refractive error. The second Cambridge infant vision screening program[17,71,72] used an isotropic videorefractor, without cycloplegia, at 7–9 months; referrals were made based on the findings and follow-up acuity measures were taken at 3 and 5 years of age. Children reported to be borderline for hypermetropia ($\geq$+3.00 D but <+4.00 D) or who were found to be hypermetropic on subsequent retinoscopy, but not given spectacles, all had normal acuity. The authors therefore concluded that this method would be suitable for detecting hypermetropia, which results in visual deficit. The overall sensitivity and specificity for detecting a refractive or orthoptic condition were 0.67 and 0.96, respectively.

Although the results from the Cambridge study[9] would support an early assessment this would necessitate increased funding. However, it could be argued that by detecting hypermetropia before the onset of amblyopia there will be a reduction in children requiring treatment, and therefore a reduction in cost.[73] Again this argument requires agreement on what is classified as a 'significant' degree of hypermetropia, which as discussed earlier is very difficult. This highlights another area where further research is required.

Other treatment options

It was proven over 100 years ago that the refractive error of the eye could be changed by reshaping the cornea using thermal burns.[74] Since then many techniques have been used with considerable success with the development of new instrumentation,[75] particularly in regard to the correction of myopia. However, the correction of hypermetropia is technically more difficult and has not been evaluated to the same degree as myopia. As stated by the National Institute for Clinical Excellence,[76] 'the evidence on the treatment of myopia suggests that LASIK is efficacious whereas the evidence is weaker for its efficacy in patients with hypermetropia'.

There are currently a variety of methods used to correct hypermetropia surgically with the most common being photorefractive keratectomy (PRK) and more recently laser-assisted *in situ* keratomileusis (LASIK).[74] A Cochrane review[77] evaluated the published evidence on the outcomes of these methods for myopia and found their effectiveness to be comparable but that LASIK gives a faster visual recovery. Both PRK[78] and LASIK[79] have also been shown to be effective treatment methods for hypermetropia, but a comparison study showed that, as with myopia, LASIK was associated with a faster refractive stability.[80]

Long-term follow-up data for correction of high myopia with LASIK are available over a period of 10 years.[81] In contrast only 5-year follow-up data were found for treatment of hypermetropia.[82] The best outcomes after 5 years were found in the low hypermetropia group, with only 50–67% of those whose initial refraction was greater than +4 D being within 1 dioptre of emmetropia,[82,83] together with lower rates of good acuity in the high hypermetropia group. In addition a regression of the hypermetropia over a 5-year period was described by Jaycock *et al.*,[84] particularly for the higher degrees of hypermetropia. An alternative procedure, conductive keratoplasty, which uses radio waves to reshape the cornea, has also been found to be effective in low to moderate degrees of hypermetropia[85] and is non-invasive. No reports were found of high success rates of any treatment in subjects with hypermetropia greater than +3.5 DS.

There are alternative surgical options, for example a clear lens extraction with an intra-ocular lens implantation; however, a published debate between ophthalmologists[86] favoured this procedure only in older adults with presbyopia.

Most publications on the outcome of surgical treatment for hypermetropia are from the adult population; however, there are some proponents for the correction of hypermetropia in children. Positive outcomes have been reported using both PRK[87] and LASIK[88] but these reports are still in the minority as refractive surgery is not advocated as a primary treatment for hypermetropia alone.

Refractive surgery in patients with strabismus

Although there are few reports on the use of refractive surgery for hypermetropia alone, there are an increasing number of studies evaluating its potential use in adults who have hypermetropia with strabismus and/or amblyopia. While refractive surgery can result in symptoms such as diplopia and decompensating strabismus,[89–91] which have been attributed in part to a lack of pre-operative orthoptic assessment and careful selection of patients, strabismus need not be a barrier to refractive surgery.[92] Refractive surgery has been advocated in patients with fully accommodative esotropia. A few small studies have reported positive outcomes following PRK and LASIK with no manifest deviation post-operatively.[93–95] However, in one study that treated children,[93] almost half (47%) required enhancement following the original surgery due to under-correction of the hypermetropia, which left the majority of subjects with diplopia.

One report evaluated the use of PRK in combination with strabismus surgery for partly accommodative esotropia.[96] The PRK was successful in treating the hypermetropia (up to +4.25 D) but it was found that basing the amount of strabismus surgery on standard surgical tables resulted in a uniform undercorrection of the deviation. To try to prevent the undercorrection the authors recommended basing the amount of surgery on the near angle, instead of the distance angle which they used.

The use of laser refractive surgery has been evaluated in cases of amblyopia, but predominantly those associated with myopia.[97] One report suggested it could be used in patients with severe anisometropia, and resultant amblyopia, as an alternative to conventional treatment when the patient was non-compliant.[98] The three children with hypermetropia in this report were aged 5, 8 and 13 years old and all in the high hypermetropia group (>+4.00 D). At 30 months after PRK the outcome of these three children was mixed, with one refractive error being reduced by only half. A more positive outcome was reported by Dvali *et al.*[88]: 38% of their patients experienced a reduction in the amblyopia and in 32% the amblyopia was completely corrected by the LASIK.

Overall this evidence suggests that refractive surgery may have a role in the correction of hypermetropia, particularly in those with less than 4 dioptres. In addition there is a potential use as an alternative to optical correction for reducing the visual acuity loss due to amblyopia. However, in patients with strabismus care must be taken, as it cannot be assumed that surgical techniques applied previously are appropriate in cases following refractive surgery.

Summary

Although the evidence discussed here has identified considerable variation in opinion on matters such as when to prescribe, it does suggest that early identification and treatment for children with high hypermetropia would be beneficial. This would potentially prevent cases of amblyopia and strabismus, and improve performance in many areas of development. However, it is still not known whether this is achieved.

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