

## Review Article

# School vision screening, ages 5–16 years: the evidence-base for content, provision and efficacy

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### Abstract

The optometric profession in the UK has a major role in the detection, assessment and management of ocular anomalies in children between 5 and 16 years of age. The role complements a variety of associated screening services provided across several health care sectors. The review examines the evidence-base for the content, provision and efficacy of these screening services in terms of the prevalence of anomalies such as refractive error, amblyopia, binocular vision and colour vision and considers the consequences of their curtailment. Vision screening must focus on pre-school children if the aim of the screening is to detect and treat conditions that may lead to amblyopia, whereas if the aim is to detect and correct significant refractive errors (not likely to lead to amblyopia) then it would be expedient for the optometric profession to act as the major provider of refractive (and colour vision) screening at 5–6 years of age. Myopia is the refractive error most likely to develop during primary school presenting typically between 8 and 12 years of age, thus screening at entry to secondary school is warranted. Given the inevitable restriction on resources for health care, establishing screening at 5 and 11 years of age, with exclusion of any subsequent screening, is the preferred option.

**Keywords:** binocular vision, children, colour vision, refractive error, vision screening

### Introduction

Optimising the probability of early detection of eye disorders in children is crucial for successful clinical management. The implementation and nature of screening and surveillance has, however, to take full account of current Government health policy, the contribution of eye care professions allied to medicine and their integration with medical practitioners, the efficacy of screening procedures adopted, and general resource and organisational issues such as prerequisite professional training and appropriate financial provision. The optometric profession in the UK has a major role in the detection, assessment and management of ocular

anomalies in children between 5 and 16 years of age. The role complements a variety of associated screening services provided across several health care sectors. The review examines the evidence base for the content, provision and efficacy of these screening services in terms of the prevalence of anomalies such as refractive error, amblyopia, binocular vision and colour vision and considers the consequences of their curtailment. Reference is made to screening policies adopted in other countries and to the scope for extending the services currently offered by UK optometric practices. A number of suggestions are presented to attain cost-effective and appropriate delivery of phased screening and surveillance services for primary school entry, the transition between primary and secondary school and the secondary school period.

### *Multinational schemes*

The amelioration of childhood blindness and visual impairment is a stated priority of *Vision 2020 – The*

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*Right to Sight*, the global initiative, established by the World Health Organisation and the International Agency for Prevention of Blindness for elimination of avoidable blindness (WHO, 2000). It is only recently that uncorrected refractive error has achieved prominence as a major cause of functional blindness (in otherwise functional eyes) and significant impaired vision, and *Vision 2020* has identified the correction of refractive error as one of its major objectives. The initiative advocates vision screening in schools with the provision of affordable spectacles (Gilbert and Awan, 2003). In addition, a European Consortium of Research Excellence in Myopia (ECREM) has been proposed and comprises a network of excellence, which aims specifically to address child myopia by integrating resource and expertise across seven EU countries and around 50 scientists. The objective is by 2010 to instigate collaborative EU-funded ventures and to transfer to health professionals effective clinical protocols and treatment modalities for myopia, thus enhancing significantly the quality of life of the EU community (Gilmartin, 2002).

#### *Screening efficacy*

Screening has been defined as 'a public health service in which members of a defined population who do not necessarily perceive they are at risk of, or are already affected by a disease or its complication, are asked a question or offered a test, to identify those individuals who are more likely to be helped than harmed by further tests or treatment to reduce the risk of a disease or its complications' (see URL: <http://www.nsc.nhs.uk>). A National Health Service (NHS) review by Snowdon and Stewart-Brown (1997) has suggested that pre-school vision screening may not be beneficial as the conditions detected, such as amblyopia and uncorrected refractive error, are perceived as minor problems and the advantages of treating them have not been demonstrated. This report triggered a large debate and further research into amblyopia treatment (Moseley *et al.*, 1998; Harrad, 2000; Dorey *et al.*, 2001; Clarke *et al.*, 2003; Dutton and Cleary, 2003). For example, Clarke *et al.* (2003) have shown that treatment with glasses and/or patching improves vision significantly in severe anisometropic amblyopia. Other researchers have shown that amblyopia does not generally improve spontaneously and that patching is an effective treatment (Cleary, 2000; Dorey *et al.*, 2001). In the UK, although vision screening occurs nationwide with a variety of methods and programmes, little data is available on the discrepancies of these programmes. Recently controversy has arisen with the publication of the fourth edition of the guidance document 'Health for Children' (Hall and Elliman, 2003) which has recommended that vision screening should take place at age 4–5 years with no

further screening at primary school until secondary school (and only if undertaken by the school at the present time). If the scheme is implemented, not only will valuable information concerning the epidemiology of refractive error and visual problems between 5 and 16 years be unavailable, but more importantly, treatable and/or correctable visual problems may remain undetected.

#### **Refractive error**

It is over 40 years since any significant study has examined the epidemiology of refractive error in the UK and in particular there is a clear need for a current comprehensive database on the epidemiology of refractive error in children. Access to such a database is central to our understanding of the nature of refractive error development, its management and its significance in education and the workplace. Informed decisions regarding a variety of clinical initiatives, research projects and strategic policy in health care and commerce often involve reference to the characteristics of ametropia across various sectors of the population. Such information is essential to support decisions on, for example, vision screening procedures and different treatment modalities including optical, surgical or pharmaceutical methods.

The issue is especially apposite to the child population where refractive error and its correction are crucial for education, ocular development and general well being. Several good mainland European sources of information [principally Scandinavian (Villarreal *et al.*, 2000)] have been published and these, together with USA (Kleinstejn *et al.*, 2003) and Australian sources (Jungmans *et al.*, 2002a), usually constitute the basis of estimates made for the UK. Despite some similarity with the UK these external samples are of limited value owing to, for example, population differences in distribution, mobility and cultural diversity. Logan *et al.* (2004a) have recently reported on a preliminary analysis of myopia development in children between 5 and 16 years supported by the UK College of Optometrists.

#### *Prevalence of refractive errors*

Estimates of prevalence depend on the definition of the disease or disorder, on the study population, especially with regard to ethnicity, and on the measurement methods. Consequently, study of the prevalence of refractive error reveals a wide variation in figures reported in the published literature. In refractive error research, in particular, the lack of standard definitions makes comparisons between different studies difficult. For example, hyperopia may be defined as greater than +2.00D in one study (Barnes *et al.*, 2001) whereas in

another a definition of greater than +0.50D may be used (Junghans *et al.*, 2002a). The refractive error data have been summarised in *Table 1*. Refractive error changes throughout the lifetime of an individual and these changes depend in part on age. In newborn infants refractive error has a wide distribution with myopia being present in approximately 19% of Caucasian infants and hyperopia in 74% (Cook and Glasscock, 1951; Banks, 1980; Hirsch and Weymouth, 1991). The high prevalence of hyperopia in infants is also accompanied by a high prevalence of astigmatism (Atkinson *et al.*, 1980; Fulton *et al.*, 1980; Gwiazda *et al.*, 1984). However, the distribution of the refractive status of the infant does not appear to differ significantly between races or different geographical locations (Fulton *et al.*, 1980; Edwards, 1991). As refractive error development depends, in part, on visual feedback (Smith and Hung, 1999), it is not surprising that there is little variation in infant refraction across races as generally there are no significant differences in the near world of the infant. The refractive error in premature infants differs from that of full-term infants, with a higher frequency and magnitude of myopia demonstrated in premature infants. A total of 39% of pre-term infants are myopic at birth compared with 17.5% of full-term infants (Dobson *et al.*, 1981; Saunders *et al.*, 2002). The mean spherical equivalent of pre-term infants has been found to be more myopic than full-term infants (Dobson *et al.*, 1981).

### Emmetropisation

The hyperopia seen in infants gradually decreases during infancy and early childhood (Mayer *et al.*, 2001). This relative myopic shift is presumed to reflect finely regulated eye growth and the processes involved are termed emmetropisation. In pre-school children

emmetropisation is thought to reduce the level of refractive error with the prevalence of myopia reducing from approximately 19 to 2–3% (for Caucasian children), but by the age of 6 years the prevalence of myopia rises to approximately 6% with approximately 45% of the children hyperopic (Robinson, 1999; Junghans *et al.*, 2002a; Zadnik *et al.*, 2002). The high prevalence of astigmatism that is seen in infants has been found to be greatly reduced or eliminated by 4 years of age (Gwiazda *et al.*, 1984). Myopia is the only type of refractive error that commonly develops during school age (Goss and Winkler, 1983). Therefore, by the time these Caucasian children become young adults approximately 25% will have developed myopia (Sperduto *et al.*, 1983). High levels of myopia (greater than 5D) in young children (less than 10 years of age) may indicate an associated systemic or ocular disorder, with myopia often being the first presenting symptom (Marr *et al.*, 2001; Logan *et al.* 2004a).

### Large-scale surveys: UK

In the UK it is over 40 years since comprehensive data on refractive error in children have been collected (Sorsby *et al.*, 1961) and the data for the prevalence of refractive error in the UK are extrapolated principally from the findings in the USA, Scandinavia and Australia. However, as part of an ongoing study in the UK the refractive error of 7600 children aged 7 years was obtained (Barnes *et al.*, 2001). The Avon Longitudinal Study of Parents and Children, based at Bristol University, enrolled 14 541 mothers during pregnancy in 1991–1992 and has monitored the medical history of the children and parents ever since. In this birth cohort of children aged 7 years a prevalence of 1.1% for myopia less than –1.00 D was found, whilst hyperopia greater than +2.00 D was found in 5.9% of the

**Table 1.** Prevalence of refractive error in children in different races and ages

Country	Age (years)	Prevalence of myopia (%)	Prevalence of hyperopia (%)	Criteria	Method to assess refractive error
USA CLEERE ( <i>n</i> = 2523) (Kleinstejn <i>et al.</i> , 2003)	6–14	9.2	12.8	M ≤ –0.75 D; H ≥ +1.25 D	Cycloplegic autorefraction
Australia ( <i>n</i> = 2490) (Junghans <i>et al.</i> , 2002b)	3–12	5.3	7.7	M ≤ –0.50 D; H ≥ +1.50 D	Non-cycloplegic retinoscopy
UK ( <i>n</i> = 7600) (Barnes <i>et al.</i> , 2001)	7	1.1	5.9	M ≤ –1.00 D; H > +2.00 D	Autorefraction (corrected against cyclo ret)
Sweden ( <i>n</i> = 1045) (Villarreal <i>et al.</i> , 2000)	12–13	44.9	8.4	M ≤ –0.50 D; H ≥ +1.00 D	Cycloplegic retinoscopy
Singapore ( <i>n</i> = 1453) (Saw <i>et al.</i> , 2002a)	7–9	29–53.1	Not reported	M < –0.50 D	Cycloplegic autorefraction
India ( <i>n</i> = 6447) (Murthy <i>et al.</i> , 2002)	5–15	4.9–10.8	15.6–3.9	M ≤ –0.50 D; H ≥ +2.00 D	Cycloplegic autorefraction
Hong Kong ( <i>n</i> = 7560) (Fan <i>et al.</i> , 2004)	5–16	36.7	4.0	M ≤ –0.50 D; H ≥ +2.00 D	Cycloplegic autorefraction

children. Of note was the finding that 13.4% of the myopic children and 28.9% of the hyperopes did not have spectacles. In a survey of a birth cohort in one health district of the UK, 5.1% of the children were diagnosed, between the ages of 2 and 5 years, as having an ocular and/or vision defect (Stayte *et al.*, 1993). The vision defect in 2.1% of these children was attributable to refractive error, which required correction with spectacles. In a retrospective study to examine the number of children referred with ocular defects to a hospital orthoptic service, an ocular or visual defect was found in 8.9% of 6-year-old children (Kendall *et al.*, 1989). The prevalence of refractive error was 6.5% with the majority being hyperopic (5.7%) and only a few were myopic (0.8%). However, the criteria used to define myopia and hyperopia were not reported.

#### *Large-scale surveys: Australia*

A study in Australia has investigated the incidence of functional vision problems in 2697 unselected children aged 3–12 years (Junghans *et al.*, 2002b). Although the children were drawn from a variety of ethnic backgrounds, because of study constraints ethnicity was not determined for each child. The majority of the children, 89%, had a spherical component for the refractive error between 0 and +1.50 D. Hyperopia more than +1.50 D was present in 7.7% of eyes; however, only 2% had hyperopia greater than +2.00 D. Myopia greater than or equal to -0.50 D was found in 5.3% of the children with only 1.1% having myopia greater than or equal to -2.00 D. Although one in every 14 children already wore a refractive correction, the researchers found that one in five of these children required a change in spectacle refraction. As part of this study the prevalence of myopia and hyperopia was analysed according to age (Junghans *et al.*, 2002a). There was an overall trend towards myopia with age though this was not statistically significant. Myopia (greater than -0.50 D) was present in 2.8% of 5-year-old children rising to 8.7% in 12-year-old children, and hyperopia (greater than +0.50 D) was found in 46.1% of 5-year-old children with only 24.1% of 12-year-old children hyperopic. Another Australian study examined the prevalence of undetected ocular conditions in a pilot sample of school children ( $n = 131$ ) aged 5–18 years of age (Rose *et al.*, 2003). A significant refractive error was found in 27.5% of the children. The criteria to define myopia depended on the age of the child, -1.00 D or more in children over 12 years of age or -0.75 D or more for younger children. Similarly hyperopia was defined as +1.00 D or greater in children older than 12 years of age or +1.50 D or greater in younger children. Only 28% of the children with a significant refractive error were found to have

spectacles and 50% of these required a change in prescription.

#### *Large-scale surveys: Sweden and USA*

In Sweden, a comprehensive nationwide screening program for both ocular disease and visual dysfunction has been in operation for over 20 years, and as such they have detailed information on the prevalence of refractive error and other visual dysfunctions in children. In 12–13-year-old Swedish children a prevalence of 45% for myopia (i.e. -0.50 D or more) was recorded with hyperopia (+1 D or more) in 8.4% of the 1045 children (Villarreal *et al.*, 2000). However, the high prevalence of myopia found in this study may not indicate the true prevalence level because of the fact that the participation rate was only 67%. In extrapolating this data to the UK it must be noted that Sweden has much less ethnic variation than the UK.

Photorefractive data from 14 000 US primary-school children (aged 3–8 years) was analysed, of which 4.6% displayed significant anomalies consisting of hyperopia  $\geq 2.5$  D, myopia  $\geq 1.0$  D, anisometropia  $\geq 1.0$  D, media opacity and ocular misalignment  $\geq 10$  prism dioptres (Morgan and Kennemer, 1997). Another 6.7% had findings that were possibly significant, that is the anomaly was present but the amount just missed a significant level. The most common refractive error was myopia, seen in 4.5% of the children, with 2.9% of the children hyperopic.

#### *Variation of refractive errors with ethnicity*

Ethnicity is a factor likely to affect the ocular characteristics within various populations. The prevalence of refractive error varies considerably with race, this is most evident in the data for the prevalence of myopia, with much higher values reported for Chinese (Lam *et al.*, 2002), Japanese (Matsumura and Hirai, 1999) and Singaporean (Saw *et al.*, 2002a) populations. For example, the prevalence of myopia in Hong Kong for 6-year-old children is 30% (Lam and Goh, 1991) compared with a prevalence of myopia of 4% for a similar age group in San Francisco (Zadnik *et al.*, 1993). In Asian populations, the prevalence of myopia increases rapidly with age; 30% of 6–7-year-old Chinese children and up to 70% of 16–17-year-old males are myopic (Lam and Goh, 1991). Similarly, 15–20% of Japanese 7-year-old children are myopic and a prevalence of 66% for 17-year-old has been reported in Japanese (Matsumura and Hirai, 1999). Other Chinese population studies have also recorded a high prevalence of myopia; values of 11.8% for 6-year-old Taiwanese children have been reported (Lin *et al.*, 1996), and this prevalence was found to increase to 55.5% by the age of 12 and to 75.9% at

15 years of age. In Taiwanese medical students, aged 18–21 years, 92.8% were myopic ( $\geq 0.25$  D).

A recent study has examined the prevalence of refractive error using non-cycloplegic refraction in 946 Singapore adolescents aged 15–19 years (Quek *et al.*, 2004). Whereas the prevalence of myopia (spherical equivalent of  $-0.50$  D or more) reported was high at 73.9%, the prevalence of hyperopia (spherical equivalent of  $\geq +0.50$  D) was found to be only 1.5%; that of anisometropia to be 11.2% for a spherical error difference of at least 1 D and 2.7% for a spherical error difference of at least 2 D. In contrast anisometropia  $\geq 2$  D in Caucasian populations has a prevalence of around 1.5% (Logan *et al.* 2004a). However, not all Asian populations have a high prevalence of myopia: in Tibet and Melanesia the prevalence of myopia in children has been found to be much lower than that in Hong Kong, Japan and Taiwan. In Tibetan children aged 6–16 years, a prevalence of myopia of 3.9% has been reported (Garner *et al.*, 1995), with a similar finding in Melanesian children (Garner *et al.*, 1985). Epidemiological studies on remote populations in Arctic regions have revealed an inordinately high increase in myopia prevalence in the present generation compared to previous generations (Johnson, 1988), with a prevalence of myopia of approximately 45% (van Rens and Arkell, 1991). Both a change to a more Westernised diet and the introduction of more formal schooling have been implicated as causative in the increased prevalence of myopia (Cordain *et al.*, 2002).

#### *Ocular biometry: age, gender and ethnicity*

Refractive error and ocular components in a large group of US children aged 6–14 years have been described as a function of age and gender (Zadnik *et al.*, 1993). Of these 2583 children, 10.1% were myopic ( $-0.75$  D or more in both meridians) and 8.6% were hyperopic ( $+1.25$  D or more in both meridians). No significant difference in mean refractive error between boys and girls was found. As expected, the authors found a significant effect of age on refractive error with the younger children being more hyperopic than the older children; similar findings were reported in the Australian study on epidemiology of myopia (Junghans *et al.*, 2002a). The most rapid changes in the ocular components were found to take place between 6 and 9 years of age. Additionally this study, on US school children, investigated racial variations in refractive error (Kleinstein *et al.*, 2003). The study conducted was a multi-centre, longitudinal, observational study of refractive error and ocular development in children from four ethnic groups. The study population included 2523 children, of which 534 were African American, 491 Asian, 463 Hispanic and 1035 white: all were aged

5–17 years. Myopia was defined as  $-0.75$  D or more and hyperopia as  $+1.25$  D or more in each principal meridian and the refractive error was assessed by cycloplegic refraction. As expected, Asians had the highest prevalence of myopia (18.5%) followed by Hispanics (13.2%). Whites had the lowest prevalence of myopia (4.4%), which was not significantly different from African Americans (6.6%). Whites had the highest prevalence of hyperopia (19.3%), followed by Hispanics (12.7%). Asians had the lowest prevalence of hyperopia (6.3%), which was not significantly different from African Americans (6.4%). These studies indicate that the increasingly cosmopolitan nature of cities in the UK must be taken into account in determining prevalence levels for refractive error.

#### **Binocular vision problems**

Amblyopia is a disorder of reduced visual function, in the absence of ocular disease, as a result of interruption of normal visual development during the sensitive period in childhood. Amblyopia is the one of leading causes of defective vision in childhood (Mulvihill *et al.*, 1997) with a prevalence of 1–4% (von Noorden, 1967; Ohlsson *et al.*, 2001). Prevalence varies, however, with the level of visual acuity selected and the methodology used to measure amblyopia. Strabismus, anisometropia, visual deprivation and bilateral ametropia occurring alone or in combination may be factors in causing amblyopia. Amblyopia is amenable to treatment, but only in the sensitive period of visual maturation, which ceases at approximately 8 years of age. Current opinion advocates detection of amblyopia at a young age as the earlier the treatment is started the better the visual outcome. Early detection and treatment of amblyogenic conditions such as high refractive error and anisometropia can clearly help prevent the development of amblyopia (Kvarnström *et al.*, 2001). However, the recent studies (Clarke *et al.*, 2003; Pediatric Eye Disease Investigator Group, 2003a,b) have shown an improvement in amblyopia for children across an age range of 3–7 years, with no age effect in treatment outcome.

#### *Prevalence of amblyopia*

In Sweden and Israel, the prevalence and severity of amblyopia have both been reduced significantly where screening programmes are in place (Eibschitz-Tsimhoni *et al.*, 2000; Kvarnström *et al.*, 2001). In Sweden, a comprehensive screening programme for both eye disease and visual dysfunction has been operating for over 20 years. The vision screening is nationwide and consists of at least five ocular examinations at Child Health Care Centres up to the age of 4 years. Visual acuity is measured at 4 years of age, and again between 7 and

10 years of age. The research has shown that the prevalence of deep amblyopia (i.e. visual acuity  $< 0.3$  log MAR) has been reduced from 2 to 0.2% as a result of diagnosis and treatment of amblyopia following detection via screening (Kvarnström *et al.*, 2001). Amblyopia resulting in acuity  $\leq 0.5$  log MAR was found in 1.1% of 12–13-year-old Swedish children (sample size: 1045) (Ohlsson *et al.*, 2001). The same prevalence was found for 5–13-year-old Swedish children in a previous larger study of 8769 children (Jensen and Goldschmidt, 1986). In the city of Haifa, Israel, children between the ages of 1 and  $2\frac{1}{2}$  years have been systematically screened since 1968 for amblyopia and amblyogenic risk factors (Eibschitz-Tsimhoni *et al.*, 2000). The prevalence of amblyopia in a cohort of 8-year-old children from Haifa was compared with that found in a group of 8-year-old children from the city of Hadera where the early screening programme was not conducted. A prevalence of amblyopia of 1.0% was found in 808 children who were screened as infants compared to a prevalence of 2.6% found in 782 previously unscreened children. With comprehensive screening, the research has shown that the prevalence of amblyopia is reduced as a result of appropriate diagnosis and treatment following detection of amblyopia via screening.

#### *Prevalence of strabismus*

Strabismus is a misalignment of the eyes, whereby one eye is turned in, out, up or down, some or all of the time. The prevalence of strabismus within a general Scandinavian population is considered to be 2.5–4% (Frandsen, 1960; Kvarnström *et al.*, 2001). The most common forms of strabismus in children include infantile esotropia, with a prevalence of 1–2% and accommodative esotropia, with a prevalence of 2–2.5% and an age of onset between 2 and 3 years (Ingram and Walker, 1979). The longer the strabismus is present without treatment increases the risk of developing more severe sensory anomalies, such as amblyopia, and additionally decreases the likelihood of a functional or cosmetic improvement (Flom and Bedell, 1985). However, currently there is a debate whether surgery for strabismus should be performed early or late, but this has not as yet been resolved. A prevalence of 1.7% for misalignment of the eyes was found by off-axis photorefractometry on 14 075 US primary school children (Morgan and Kennemer, 1997). A much lower prevalence of amblyopia (0.3%) was reported in the Australian functional vision screening study (Junghans *et al.*, 2002b). The discrepancy in prevalence values in these two studies may have arisen from the use of clinical judgement rather than strict adherence to study protocol in the Australian study. The researchers suggest that if the children had misalignment

of the visual axis (demonstrated by cover test) but had stereopsis of 100" arc or better then they may not have been classed as strabismic.

#### *Stereoacuity*

Poor stereoacuity is usually seen in conjunction with amblyopia. The Australian functional vision screening study measured stereopsis in 2697 children with either the Titmus Fly or Randot Stereo Test (Junghans *et al.*, 2002b). The median value for stereopsis was 40" with a range of 20–800", children with strabismus being excluded from the binocular vision analysis. A total of 73.1% of the children showed stereopsis of 70" or better, which is generally considered to be normal (Simons, 1986; Lam *et al.*, 1996). One of the categories for inadequate functional vision was stereopsis of 80" arc or more, and 13.3% of the children fell into this category.

#### *Visual defects in UK children*

In the UK, the City University Vision Screener for Schools was used to determine the prevalence of visual defects among 245 school children aged between 5 and 8 years in a school in Aylesbury (Thomson and Evans, 1999). Some form of visual defect (i.e. a visual acuity of less than 0.2 log MAR in one or both eyes or a Risk Index exceeding a predetermined threshold but excluding colour deficiencies) was found in 19.6% of the children. Of special note was that two-thirds of these children were unaware of their visual problem although the remaining one-third was already under professional care. In addition, a questionnaire completed by the children's parents revealed that 47.3% of the children had never had an eye examination by an optometrist.

#### **Colour vision**

Total colour blindness is rare and congenital colour vision deficiency affects the ability of predominantly boys to recognise and interpret reds and greens. The consensus is that colour vision deficiencies affect approximately 8% of males and 0.5% of females. However, a number of studies assessing children directly have found a lower prevalence of colour deficiency in boys. The prevalence of colour deficiency has been found to be approximately 6.6% in boys and 0.4% in girls in a group of 513 children between 3 and 11 years of age, from a London primary school (Birch and Platts, 1993). Colour vision has been assessed as part of the Australian functional vision screening study (Junghans *et al.*, 2002b) where 7.68% of the children were found to fail more than two colour plates on the Ishihara Test,

however, no data on the gender of these children was given. In an Australian study to determine the prevalence of undetected ocular conditions in a pilot sample of school children the prevalence of colour vision defects was 5.3% (Rose *et al.*, 2003). This value represented seven children, six of whom were boys. A large-scale study, on 32 322 males aged 11–14 years of age, conducted in southern Italy using Ishihara plates found that 4.8% had a colour deficiency (Gallo *et al.*, 2003). Additionally, this study investigated the psychological aspects of colour defective vision at school, the authors inferred from the results that children with defective colour vision could develop actual social limitations.

### **Curtailement of vision screening: impacts and consequences**

In the UK, vision screening occurs from birth to puberty in a variety of forms with both programmes and methodology varying across the country. The main aim of vision screening is principally to identify children with amblyopia, strabismus and refractive errors. Vision assessment at school entry is undertaken in the majority of districts in the UK although there is great diversity in the methodology and the personnel who perform the screening (Snowdon and Stewart-Brown, 1997). The advantage of school screening is that the screening criteria of 100% coverage can conceivably be attained, given that normally a very high percentage of all children attend school. At pre-school vision screening the attendance has been lower: in the UK values of 67 and 79.3% have been reported for attendance at pre-school vision screening (Newman *et al.*, 1996; Williams *et al.*, 2003).

#### *The impact of curtailment on school performance and quality of life*

The role of vision screening after school entry remains controversial, as there is a paucity of evidence to support the benefits of screening in this age group. The degree of disability caused, at this age, by uncorrected refractive errors is unknown. Children with hyperopia require increased accommodative effort in order to see clearly at near. Consequently they may experience transient blurring, fatigue and symptoms of asthenopia (Motsch and Muhlendyck, 2001), particularly if anisohyperopic. High, uncorrected hyperopia has been linked with reading difficulties and is often a causative factor in the development of esotropia (Simons and Glasser, 1988). It has not been statistically proven that academic underachievement is attributable to uncorrected refractive error though anecdotal evidence does support an argument that blurred vision can adversely affect a child's learning progress.

#### *The effect of undetected amblyopia*

Amblyopia may impair the ability of a child to carry out visually demanding tasks as it is associated with poor stereoacuity and, therefore, may affect both the child's academic progress and sporting ability. Career choices may also be influenced (Adams and Karas, 1999) and additionally amblyopia significantly increases the risk of visual impairment (VA < 6/18) or blindness (VA < 6/60) if the vision in the non-amblyopic eye is affected (Rahi *et al.*, 2002). Screening for amblyopia in early childhood is conducted in many countries to ensure that affected children are detected and treated within the critical period (i.e. as early as possible in childhood), and also achieve a level of vision in their amblyopic eye that would be useful should they lose vision in their other eye later in life. However, considerable international debate surrounds the value of screening for amblyopia (Snowdon and Stewart-Brown, 1997; Ciner *et al.*, 1998; Williams *et al.*, 2003). One of the arguments for screening preschool children for amblyopia is that treatment of amblyopia is less successful with increased age. This has been attributed to both reduced compliance and reduced cortical plasticity in older children (Daw, 1998; Simons and Preslan, 1999). A study by the US-based Paediatric Eye Disease Investigator Group investigated the response to treatment of moderate amblyopia in children from 3 to 7 years of age (Paediatric Eye Disease Investigator Group, 2002). Surprisingly, they found no difference in response to amblyopia treatment between the younger and older age groups suggesting that the age of initiation of amblyopia treatment does not affect the outcome for children under 7 years of age. Other studies have found similar results (Clarke *et al.*, 2003; Paediatric Eye Disease Investigator Group, 2003a). The US Amblyopia Treatment Study has demonstrated that more than 75% of amblyopic children less than 7 years of age can have a significant improvement in visual acuity in the amblyopic eye (i.e. to 6/9 or better) as a result of treatment (Paediatric Eye Disease Investigator Group, 2002). The efficacy of treating amblyopia versus no treatment has been investigated in children aged 3–5 years, the researchers found that the effects were related to the initial visual acuity; full treatment showed a significant effect in the moderately amblyopic group (6/36–6/18 at recruitment) compared to the mild amblyopes (6/12–6/9 at recruitment)(Clarke *et al.*, 2003).

Individuals with amblyopia are debarred from a wide range of occupations, which increases with the severity of amblyopia, because they fail the required visual standards (Adams and Karas, 1999). These occupations include the fire brigade, civilian police force and the military services. Additionally, they may not be able to hold a class II professional driving licence. Therefore,

every effort must be made to achieve the best possible acuity in children with amblyopia so as to allow them the widest choice of occupation in adult life, not limited by visual disability.

#### *Risk of visual loss*

It has been shown that the risk of visual loss in the normal eye for individuals with one amblyopic eye is greater than previously assumed (Rahi *et al.*, 2002). The study investigated the risk, causes and outcomes of visual impairment attributable to loss of vision in the non-amblyopic eye among people who had monocular amblyopia. National surveillance was done to identify all individuals in the UK with unilateral amblyopia (with corrected acuity worse than 6/12) who had newly acquired visual loss in the non-amblyopic eye. Of 370 eligible individuals (age range 1–95 years), 28% had socially significant visual loss (classed as VA between 6/12 and 6/18, or any acuity with visual field less than 120° horizontally and 20° vertically but not eligible to be classed as visual impairment), 49% had visual impairment, and 23% severe visual impairment or blindness, according to World Health Organisation criteria. The minimum risk of permanent visual impairment by age 95 years was 33 per 100 000 total population. The projected lifetime risk of vision loss for an individual with amblyopia was at least 1.2%. Only 35% of people previously in paid employment were able to continue work. The study shows that in addition to any direct benefits of improved visual function in the amblyopic eye, effective treatment of amblyopia during childhood, to achieve a good level of functional vision in the amblyopic eye, remains a potentially valuable strategy against incapacitating vision loss later in life. Rahi *et al.*'s (2002) findings emphasise an important benefit of detection and treatment of children with amblyopia and strengthen the need for effective screening programmes to detect amblyopia in early childhood.

#### *'Health for All Children' 2003*

An efficient vision screening system in both primary and secondary schools would give all children an equal opportunity for good eyesight. The guidelines from the new edition of 'Health for All Children' (Hall and Elliman, 2003) are likely to increase nationwide discrepancies. Typically, visual problems develop gradually in children so that the child may be unaware of the problem until it is quite advanced, especially if the visual problem is monocular. Although any child (under 16 years of age) can have a full eye examination with an optometrist which is paid for by the NHS, many parents do not take advantage of this opportunity and some eye problems are likely to remain undetected,

particularly, in children from areas of high social disadvantage. Adolescents may tend to self-present to optometrists if reduced visual acuity is perceived to be problematic, though not all may be willing to admit difficulty with vision. Importantly, an optometrist is in a position to suggest an eye examination for children if there is a known family history of visual problems.

#### *Colour vision deficiencies*

As congenital colour vision deficiencies are non-progressive and untreatable there is little evidence to suggest that screening for colour vision is beneficial to children of any age. However, detection of a colour vision deficiency would identify a genetic anomaly and would warrant colour vision screening in all male members of the family. Perceived benefits of colour vision screening may be that children with a degree of colour defective vision may be disadvantaged in the educational environment if colour-coded materials are used for teaching purposes. In addition, as certain careers require normal colour vision, individuals with colour deficiencies could make informed career choices. This would advocate screening for colour vision, particularly in boys, at the start of secondary school education (Gordon, 1998).

The 4th edition of 'Health for All Children' (Hall and Elliman, 2003) suggests that children's vision should be screened on school entry, but does not advocate any screening thereafter. It states that if screening in secondary schools already occurs then this should continue, but only on a single occasion, and no new screening should be introduced. This will lead to a decreased service with no vision screening at all after the age of five in most primary and junior schools and, at best, only one vision screening in senior schools.

#### *Non-UK studies and recommendations*

Several countries have reviewed their existing vision screening programs and evaluated their efficacy (Lennerstrand *et al.*, 1995; Ciner *et al.*, 1998; Juttman, 2001). All studies have made recommendations to improve the screening system in terms of detection of visual dysfunction and for a consistent nationwide approach to screening. The American Association for Paediatric Ophthalmology and Strabismus (AAPOS) Vision Screening Committee has suggested a set of risk factors for amblyopia (see *Table 2*), based on a review of the literature, that should be detected with pre-school vision screening (Donahue *et al.*, 2003). None of these studies has suggested curtailing nationwide vision screening unlike the model proposed for the UK.

This review demonstrates that there is a high rate of undetected significant visual defects in school-age children. Vision screening at school age, both at entry and

**Table 2.** Amblyogenic risk factors for pre-school vision screening (Donahue *et al.*, 2003)

Risk factor	Magnitude
Anisometropia	>1.50 D (sphere or cylinder)
Strabismus	Any manifest
Hyperopia	>3.50 D (any meridian)
Myopia	<-3.00 D (any meridian)
Astigmatism	>1.50 D orthogonal axis >1.00 D oblique axis
Media opacity	>1 mm in size
Ptosis	Upper-lid margin $\leq$ 1 mm above corneal reflex
Visual acuity	Per age appropriate standards

again at a later age, would detect refractive errors and other visual defects which otherwise would go uncorrected. The future of pre-school vision screening in the UK was reviewed by Rahi and Dezateux (1997) who concluded that at the time of the review there was a paucity of evidence supporting the benefits of an existing service and no evidence to verify that vision screening is ineffective or detrimental.

### Recommendations for visual screening

#### *Neonatal period, early infancy and infancy to primary school age*

Whereas the review is concerned principally with the age range of 5–16 years it is common for children younger than this to attend optometric practice for an eye examination, either directly or as an adjunct to an adult consultation. Optometrists are well aware of their role in screening young children (Harvey and Gilmartin, 2004) and increasingly complement orthoptic and health visitor primary screening. Importantly optometrists also act as a channel of communication for parental concern over a child's eyes. Both these functions pertain to the vital pre-school primary filter and have yet to be quantified formally; their significance in screening of the pre-school child probably being significantly underestimated. Of value would be an activity-based analysis of the contribution of the optometrist to screening of the pre-school child.

#### *Primary school entry*

If the aim of the vision screening is to detect and treat conditions that may lead to amblyopia then clearly the screening programme must focus on pre-school children. However, if the aim is to detect and correct significant refractive errors (not likely to lead to amblyopia) then it would be expedient for the optometric profession to act as the major provider of refractive

(and colour vision) screening at 5–6 years of age. This second filter is also valuable as a 'fail safe' for those children who have not been detected at the primary filter stage. Optometrists commonly report cases of children between 5 and 6 years of age and above who present with undetected amblyopia because of anisometropia or high astigmatism and to a lesser extent because of strabismus. It seems appropriate, therefore, that optometrists should be encouraged to participate in formal vision screening of children on school entry. However, a significant problem associated with optometrists providing visual screening is that currently there is no structure in place to provide financial support for the service. Furthermore, the onus is on parents to arrange for child visual screening to take place in general optometric practice and, although evidence is lacking, differences in socio-economic status may affect substantially the ability parents have to make appropriate arrangements. It seems likely that participation rates in child visual screening would be significantly increased if optometrists were to offer a service, sufficiently reimbursed, within the school environment. All screening programmes should be properly audited for sensitivity and specificity. Additionally an audit of children presenting to the optometrist with undetected amblyopia after 5 years of age would be valuable.

#### *Primary: secondary school transition*

The transition between primary and secondary school is important for the child in educational, emotional and social terms. The unremitting development in information and computer technology will expose secondary school children to complex visual environments in both educational and leisure pursuits. The ability to engage effectively with these environments will require optimum ocular and visual performance and hence visual screening at 11 years of age represents a significant return on investment. Myopia is the refractive error most likely to develop during primary school presenting typically between 8 and 12 years of age but a third level screening filter would also identify residual amblyopic children. Early detection of myopia would also be of advantage should current trials on pharmaceutical agents (Siatkowski *et al.*, 2003; Tan *et al.*, 2003) for treating myopia prove beneficial. The greater level of compliance and health awareness (for both child and parent) at secondary school level would facilitate the use of cost-effective automated screening protocols and devices, again appropriately provided by the optometric profession, either within school or practice. More frequent screening would be ideal but at the very least visual screening should take place to support the transition between primary and secondary school i.e. circa 11 years of age. The use of automated screening devices and protocols

supervised by optometrists would constitute a cost effective and efficient mode of delivery.

### Secondary school

An effective substitute for formal vision screening during secondary school is the provision of effective educational materials on eye safety and ocular well being, especially as they relate to career options and modes of refractive correction. Given the inevitable restriction on resources for health care, establishing screening at 4–5 and 11 years of age, with exclusion of any subsequent screening, is the better option. The optometric profession might place more emphasis on designing educational materials for the secondary school age groups and making them more accessible via school educational talks and demonstrations.

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