• Review Article •

Visual problems: a review of prevalence studies on visual impairment in school-age children

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Abstract

• Childhood visual impairment (VI) have a significant impact on the educational achievement, career choices and social life of affected individual, and in children, is mainly due to either preventable or treatable causes. Reliable data on the prevalence and causes of VI in children will guide the development of a systematic vision screening program for its early detection and successful treatment of possible causes. The purpose of this literature review is to summarize the available data on prevalence and causes of VI in school-age children from various regions globally. A discussion on the major findings highlighting the definition criteria, classifications and limitations for further studies is also presented.

• **KEYWORDS:** visual impairment; school-age children; vision screening; school performance

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INTRODUCTION

Visual impairment (VI) has a considerable impact on the lives of the affected individuals as well as their families and society. Its effect on development and learning is more significant when it is present at birth or shortly afterwards compared to when it is acquired later in life. Loss of vision in children influences their academic opportunities, career choices, and social life, with defective near vision influencing their ability to perform a variety of tasks that involve reading[1-2]. As more than 85% of what a child learns in school is through visual presentation, their ability to perform optimally will be affected[3-4]. Visual field deficits also affect the child's ability to accomplish tasks that require ambulation in challenging environments or the application of peripheral vision[1]. In addition, approximately 90% of visually impaired children are not receiving adequate education due to factors that include discrimination, stigmatisation and lack of access to appropriate schools[5-6].

Reports suggests that in both developed and developing countries, the majority of VI is either preventable or treatable[7-8]. Early detection and effective treatment of underlying causes at the 'sensitive' period of visual development therefore remains an important approach for preventing VI[9-11]. Reliable data on the prevalence and causes of VI in children are necessary for developing a systematic vision screening program with valid and reliable test protocols. Such data will help to direct the application of available resources and efforts for early detection to people who are at risk, thereby reducing the high short- and long-term costs to the health system and society. The purpose of this literature review is to document the prevalence and causes of VI in school-age children from various regions globally. A discussion on the major findings highlighting the definition criteria, classifications and limitations for further studies is also presented.

METHODS

The online databases of PubMed, Medline, OVID, Google Scholar, Science Direct and Embase were explored for the keywords, and VI (prevalence and causes) in school children. The search was restricted to primary research published in the English language and in peer-reviewed journals. Only epidemiological studies with stated the measures of prevalence and causes of VI among school-age children between 5-18y of age were included. However, two studies on VI among Nigerian children with participants in the age groups 4-24y[12] and 9-21y[13] were included due to insufficient data on visual anomalies in these age groups in Nigeria.

In this narrative review, a summary of each study that met the outlined criteria is presented first and then evaluated in relation to other studies. Parameters of interests for review included: sample size and sampling method; participant characteristics, including gender and age; prevalence rates and causes of VI; information on diagnostic criteria and measurement techniques. The studies were compared according to geographic regions or ethnicity.

Table 1 Prevalence of childhood visual impairment across various countries

Study	Country	Age (y)	Sample size (*n*)	VA threshold	Prevalence (%)		
					Uncorrected VA	Presenting VA	Best corrected VA
Abdull *et al*[14]	Nigeria	10-15	5371	<6/12	Not reported	Not reported	1.2
Ajaiyeoba *et al*[12]	Osun, Nigeria	4-24	1144	Not reported	Not reported	1.5	Not reported
Megbelayin and Asana[13]	Calabar, Nigeria	9-21	1175	≤6/9	Not reported	6.9	Not reported
Kumah *et al*[18]	Ghana	12-15	2435	≤6/12	3.7	3.5	0.4
Naidoo *et al*[17]	South Africa	5-15	4238	≤6/12	1.4	1.4	0.32
Taylor *et al*[26]	Australia	5-15	1694	<6/12	Not reported	Not reported	1.7
Robaei *et al*[27]	Sydney, Australia	6	1740	<6/12	4.1	Not reported	Not reported
Murthy *et al*[21]	India (urban)	5-15	6447	≤6/12	6.4	4.9	0.81
Dandona *et al*[22]	India (rural)	7-15	4074	≤6/12	2.7	2.6	0.78
Paudel *et al*[19]	Vietnam	12-15	2238	≤6/12	19.4	12.2	Not reported
Goh *et al*[20]	Malaysia	7-15	4634	≤6/12	17.1	10.1	1.4
Salomao *et al*[23]	Brazil	11-14	2441	≤6/12	4.8	2.7	0.41
O'Donoghue *et al*[24]	United Kingdom	6-7	392	<6/12	Not reported	1.5	Not reported
		12-13	661			3.6	
Sauer *et al*[25]	Peru	5-18	380	≤6/9	Not reported	8.9	Not reported

VA: Visual acuity.

Table 2 Causes of childhood visual impairment across various countries

Study	Percentage of participants (%)						
	Refractive error	Amblyopia	Corneal opacity	Retinal disorder	Cataract	Other causes	Unexplained causes
Ajaiyeoba *et al*[12]	58.8	5.9	11.8	0	11.8	11.8	-
Megbelayin and Asana[13]	61.1	0.3	0.2	0.7	0	0.6	-
Kumah *et al*[18]	71.7	9.9	4.6	5.9	0	1.88	-
Naidoo *et al*[17]	63.6	7.3	3.7	9.9	0	3.1	12.0
Murthy *et al*[21]	81.7	4.4	-	4.7	-	3.3	5.9
Dandona *et al*[22]	61.0	12.0	-	-	-	15.0	13.0
Paudel *et al*[19]	92.7	2.2	0	0.4	0.7	1.5	2.6
Goh *et al*[20]	87.0	2.0	0	0	0	0.6	10.4
Salomao *et al*[23]	76.8	11.4	0	5.9	0	2.7	7.7
Taylor *et al*[26]	47.0	19.0	0	0	0	0	34.0
Robaei *et al*[27]	69.0	-	-	-	-	-	-

Studies on School-Age Children

African region Table 1 shows the various studies that have reported on prevalence and causes of VI in paediatric populations in Africa and elsewhere, while Table 2 presents the major causes of VI for these studies, where available. The exact prevalence and causes of childhood VI and blindness are difficult to establish due to the infrequent occurrence of relevant pediatric eye conditions and the lack of well-designed epidemiological studies, particularly in developing countries. For instance, in Nigeria, a national survey[14] on blindness and VI conducted between 2005 and 2007 reported only on the causes of VI in an adult population. In addition, the study was constrained by the sampling method used to identify the paediatric population, which limits the generalization of findings, as the school-age children were invited to participate only if they were living in a family of at least one eligible adult[14-16]. In the study, blindness was defined as presenting visual acuity (VA) of 6/120 or worse in the better eye, while VI was defined as presenting VA of less than 6/12 in the better eye. Of the 5371 children who were examined, the prevalence of blindness was 0.6%, with a higher prevalence in females (0.89%) than males (0.33%). The study also reported that the prevalence of mild, moderate and severe VI was much lower than that of blindness[14-16].

Two cross-sectional studies[15-16] were reported in some Nigerian cities, although with an older population than the studies included in this review. The studies were limited by poor diagnostic criteria, with that by Megbelayin and Asana[13] defining VI as presenting VA of 6/9 or less in one or both eyes and reported a prevalence of VI of 6.9%. The definition criteria they adopted has the potential of overestimating the prevalence of VI in the study sample. In the earlier study by

Ajaiyeoba *et al*[12], the prevalence of VI was estimated to be 1.5%, but it provided no clearly defined criteria. However, in both studies[12-13], refractive error (RE) was the major cause of VI.

In a large-scale Refractive Error Study in Children (RESC) study in a South African population, Naidoo *et al*[17] reported on the prevalence of uncorrected (1.4%), presenting (1.2%) and best corrected VA of ≤6/12 (0.32%) in children 5-15y of age in the Durban area. A geographically defined cluster sampling design and a door-to-door enumeration survey was applied to recruit the participants. RE (63.6%) was the major cause of VI, with only 12 (19.0%) of those affected wearing spectacles during examination. A more recent school-based RESC study was conducted in the Ashanti Region of Ghana[18] on children whose ages ranged from 12-15y. Reliable VA testing was possible in all but one of the 2454 children examined for VI and RE, with 119 children having VI in one or both eyes. Approximately, 3.7%, 3.5%, and 0.4% had uncorrected, presenting and best VA of 6/12 or worse in the better eye respectively, with RE being the major cause of reduced vision.

Asian region The prevalence of VI and RE in school children 12-15y of age was studied in Ba Ria, Vung Tau Province, Vietnam[19]. The authors examined each subject with a standardized test protocol and found that 87.8% of 2258 children had normal or near normal vision (≥6/9.5) in the better eye. A total of 434 (19.4%) children had uncorrected VA of ≤6/12 in both eyes, with 71 (3.2%) being blind, while the prevalence of VI (presenting vision ≤6/12 in the better eye) was 12.2%, including six blind children. However, with best-corrected VA, no children were found to be blind. RE was the major cause of VI in 92.7% of the vision-impaired children, and amblyopia was responsible for 2.2%. A comparatively similar result was obtained by Goh *et al*[20] in multi-ethnic population, including Malay (70.3%), Chinese (16.5%), Indian (8.9%) and others (4.3%) in Malaysia. The prevalence of uncorrected, presenting, and best-corrected VI (VA≤20/40) in the better eye was 17.1%, 10.1%, and 1.4%, respectively. In eyes with reduced vision, RE was the cause in 87.0%, amblyopia in 2.0%, other causes in 0.6%, and unexplained causes, suspected to be amblyopia, accounted for another 10.4%.

In India, a population-based study involving a random selection and door-to-door enumeration of children aged 5-15y from 22 geographically defined clusters found that RE (81.7%) was a major contributor to the cause of VI in children in New Delhi. The prevalence of uncorrected, presenting, and best corrected VA of 6/12 or worse in the better eye was 6.4%, 4.9%, and 0.81%, respectively[21]. A similar study with children aged 7-15y from rural India found a lower prevalence of uncorrected, presenting and best corrected VA of 6/12 or worse in the better eye, with corresponding values of 2.7%, 2.6%, and 0.78%. RE (61%) was also the major causes of reduced vision in eyes with VI[22]. The difference between these two studies, despite the age ranges differing by only two years, may be related to a higher prevalence of RE, especially myopia, in urban compared to rural areas, due possibly to differing education systems and the children's exposure to near-work activities.

Americas and European region Salomao *et al*[23] examined 2825 school children aged 11-14y sampled by cluster random technique from 374 schools in three districts of Sao Paulo, Brazil. VA was measured at 4 m using a standardized protocol, with the prevalence of uncorrected, presenting, and best-corrected VA of 6/12 or worse in the better eye being 4.82%, 2.67%, and 0.41%, respectively. RE contributed to 76.8% of children with VI in one or both eyes. O'Donoghue *et al*[24] reported on the Northern Ireland Childhood Errors of Refraction study, where VA was measured using a logarithm of the minimum angle of resolution (logMAR) protocol on 392 (6-7y) and 661 children (12-13y). Approximately, 3.6% of presenting VI in the better eye was found in the older (12-13y) children, which was higher than the 1.5% in the younger (6-7y) group. Approximately 25% of the children with RE presented for examination without spectacle correction.

A cross-sectional survey of children aged 5-18y living in a resource-poor community in Peru reported a high prevalence of VI, which may be attributed to its definition criteria. Participants completed a socio-demographic and health risk factor questionnaire and were screened for reduced distance VA, stereopsis, external eye examination and colour vision deficiency, with VI being defined as VA less than 0.2 logMAR (≤6/9). Of the 380 children who were examined, the mean uncorrected VA was found to be 0.07±0.13 logMAR, the findings indicating that 8.9% of the children were visually impaired in both eyes and 26.3% in one eye. Severe VI (<6/60) in both eyes was 0.3% and 0.7% in one eye, with the study recommending the performance of regular vision screening of children in Peru[25].

Oceania region Taylor *et al*[26] assessed low vision and blindness in 1694 Australian indigenous school-age children aged 5-15y, with a VA measurement of scholars randomly selected from 30 geographic areas. The rate of low vision, defined as best VA of less than 6/12 and equal to 6/60 was 1.5%, and the rate of blindness of best VA of less than 6/60 was 0.2%, with RE accounting for the most of their low vision. Relative risk of vision loss and blindness in the indigenous compared with the wider population children in Australia were found to be 0.2 and 0.6, respectively. In another school-based survey in Sydney, Australia, the prevalence of non-correctable

VI (VA<6/12) was only between 0.03% and 0.08%, which was 45 times lower than that reported in adults[27]. RE was responsible for 69.0% of the VI in the children.

Limitations of Previous Studies While all studies (Table 1), except for Sauer *et al*[25], included large sample sizes and traditional VA chart measuring technique, some flaws inherent in the study designs may have affected the generalizability of their findings. Some of the studies failed to state the eligibility criteria for participant recruitment[12]. In others, amblyopia was identified as a major cause of VI with no stated definition criterion[13,17,19-20], while others[14,25,27] failed to provide detailed information on the causes of VI in their study samples. In addition, the study by Ajaiyeoba *et al*[12] did not indicate the definition criteria used to identifying participants with VI. In relation to RE, the emphasis in some studies was on VI with RE[14,18,26], thereby undermining the quantification of children at risk of developing VI due to RE and preventing the development of screening and intervention strategies to prevent VI in this cohort.

DISCUSSION

Definition of Visual Impairment The definition criterion for identifying children with VI is very important. Until recently, the definition of VI was predicated on the second revision of the 10th ICD edition[28], which followed from a 1972 World Health Organization (WHO) study of blindness and demonstrated that the best corrected VA should be used as the basis for estimating VI[29]. At that stage, RE was not considered a priority and a major cause of VI, and was excluded from reports of the total number of persons with VI. However, data from recent population-based studies indicates that uncorrected RE contributes significantly to the total number of persons with VI[30]. Accordingly, the WHO adopted a new definition of VI in the revised ICD-10 version: 2016, and uses presenting VA and visual loss from uncorrected RE[31]. Under this classification, low vision (moderate and severe impairment) is defined as a presenting VA of less than 6/18, but equal to or better than 6/120, or a visual field loss to less than 20 degrees diameter in the better eye with best possible refractive correction.

In the reviewed studies (Table 1), although VI was mostly defined as a VA of less than or equal to 6/12, a broad range of definition criteria was applied in its diagnosis: from a VA of 6/9 or less to less than 6/12, including Ajaiyeoba *et al*[12], who did not indicate the definition criterion for VI. The use of a VA of 6/9 by some studies will overestimate the prevalence of VI and weigh heavily on the cost of intervention services for affected individuals, and cause considerable psychological effect on the affected children and their families. When compared to other studies on African children, Megbelayin and Asana[13], who defined VI as a VA of 6/9 or less, reported a higher prevalence of VI than other studies[14,17-18] that utilized a VA of 6/12 or worse. The trend was also observed in the studies conducted in the Americas, where the study in Peru[25] that applied a VA threshold of 6/9 or less reported a higher prevalence of VI than another study in Brazil[23]. Studies have reported that the mean VA in young children was 6/7.5[32], and that an acuity of 6/12 or less would have a harmful effect on their vision[33] and potentially reduce their functional performance. When compared with the WHO definition of VI, the VA of 6/12 or less used by the RESC studies provides a better indicator to accurately estimate the magnitude of VI due to RE and a proper assessment of the demand for eye care services[34], including those with mild VI. Its use will also ensure timely detection and treatment of the underlying factors of mild VI before they progress to permanent.

Classification of Visual Impairment The categories of VI adopted by the majority of the studies reviewed suggest that a person with a presenting VA of worse than 6/60 should be regarded as blind. However, a substantial number of children who are classified as blind still have usable vision and can sustain activities of daily living independently[35]. Reports indicate that in developing countries, such as in Africa, approximately 20% of children categorized as blind were found to have significant residual vision[36-37]. The implications for rehabilitation and education is that children with low vision may be educated using techniques that are appropriate for those who are totally blind, despite their having some useful vision that can support other activities of daily living if they can be taught how to use it appropriately[38-39]. For instance, approximately 66% and 1.45% of children who were initially classified as blind but reading with the aid of Braille were found to have low and normal vison, respectively, after best refraction[40]. In view of the importance of functional vision, the WHO in 1992 added another perspective to the definition of VI that covers both distance and near vision[35]. The definition states that: a person with low vision is one who has impairment of visual functioning even after treatment and/or refractive correction, and has a vision in the better eye of less than 10 degrees from the point of fixation (or 20 degrees across), but who uses or is potentially able to use vision for planning or execution of a task. This functional definition ensures that people who have low vision, but with a VA of less than 6/120, are included in low vision programs and are eligible for appropriate services.

Regional Variations in the Prevalence and Causes of Visual Impairment The prevalence and causes of VI varied across the different regions[1] (Table 2). A lower prevalence of VI was reported for African children compared to other regions, especially Southeast Asian countries. This may be explained by the lack of robust epidemiological studies in developing countries such as Africa. The higher prevalence

of VI in Southeast Asian countries compared to other regions may be related to the reported high prevalence and severity of myopia in these populations. Myopigenic factors including: 1) genetic predisposition, such as ethnicity and a family history of high myopia; 2) intensive near work activities due to competitive education and schooling systems are common among Southeast Asian children[41], with myopic eyes being at risk of developing functional VI at a relatively young age[42]. In addition, the causes of VI varied widely among studies, which may be attributed to differences in socio-economic developments as well as the availability of efficient and broad screening strategies. These factors can all influence the prevalence and causes of VI in different regions.

Causes of Visual Impairment in School-Age Children

Uncorrected RE is a leading cause of VI and the second leading cause of treatable blindness among people of all age groups[43]. This is evident in the reviewed studies (Table 2), where 47%-92.7% of the reduced vision in school-age children was caused by uncorrected RE, and 0.3%-19.0% were caused by amblyopia. The risk factors for amblyopia include strabismus, anisometropia and congenital cataract or the less prevalent media opacification. Unlike VI associated with amblyopia, simple RE (RE not associated with amblyopia) is correctable with the use of appropriate spectacles and is thought to not affect normal visual development. According to the WHO, there would be over 19 million children less than 15y of age with VI worldwide, with 12.8 million being due to uncorrected RE. Consequently, Vision 2020 initiative: The Right to Sight, identified the correction of RE as one of its major objectives. The initiative advocates vision screening in schools with the provision of affordable spectacles[44]. Similarly, amblyopia can also be effectively treated with early detection and correction of the underlying amblyogenic risk factor[45].

However, the available evidence indicates that amblyopia is treatable, even in the teenage years[45-46]. Other studies show that improvements in binocularity and VA in the amblyopic eye can also be realized in adulthood[47-48]. Available treatments for amblyopia include patching or atropine therapy of the affected eye; surgery for strabismus and cataracts; and RE correction with spectacles or contact lenses. Overall, treatable causes were responsible for majority of the VI in the study populations (Table 2).

CONCLUSION

The present review has highlighted the prevalence and causes of VI in various countries as well as some methodological concerns regarding the reported studies. Diagnostic criteria for VI varied across the studies, and in some cases, the adopted definition criteria can overestimate the prevalence of VI. As the variation in diagnostic criteria can make comparing the results very difficult, it is important to develop a standard and uniform diagnostic criterion that is appropriate for detecting children at risk of developing a VI. Nonetheless, regional variations in the prevalence of VI were significant, and may be attributed to differences in socio-economic development, race, cultural factors, as well as, the availability of interventions, and implies that the prevalence data in one population cannot necessarily be extrapolated to another. The review also demonstrated that treatable causes were responsible for the most of the VI in the study populations, and highlights the need for adequate strategies that will promote vision screening in school children and the wider community, with the goal of timely detection and treatment of common visual problems.

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