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New Cases of Myopia in Children

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Abstract

Objective—To report the percentage of new cases of myopia in 4,927 children, age 5 - 16 years, who participated in the Collaborative Longitudinal Evaluation of Ethnicity and Refractive Error (CLEERE) Study between 1989 and 2009.

Design—A multicenter, longitudinal, observational, volunteer study of refractive error and ocular development in children from five ethnic/racial groups.

Methods—Subjects were children who were not myopic (right eye's cycloplegic autorefraction of less myopia/more hyperopoia than −0.75 D in both principal meridians) at study entry. A new case was a diagnosis of myopia (right eye's cycloplegic autorefraction of −0.75 D or more myopia in both principal meridians) after study entry.

Results—Among the 4,556 children entering the study as not myopic, 749 (16.4%) were diagnosed as myopic after study entry. Among the 749, the age of diagnosis varied from 7 to 16 years, with the largest number, 136 (18.2%), diagnosed at age 11 years. New cases of myopia occurred in 27.3% of Asians, 21.4% of Hispanics, 14.5% of Native Americans, 13.9% of African Americans, and 11% of Whites. Females had more new cases, 18.5%, than males, 14.5%. Normal birth weight children had more new cases (16.9%), than low birth weight, (15.5%).

Conclusions—Sixteen percent of children enrolled in the CLEERE Study developed myopia during their school-age years. The percentage increased yearly until age 11 years, after which it decreased. New cases of myopia varied by ethnic/racial group.

Introduction

Myopia is a common and serious problem because of its high prevalence, ocular morbidity, and cost of treatment. Myopia commonly occurs in children during their early school years and increases in magnitude as they increase in age. Only a small number of studies[1-5] have reported the number of new cases of myopia that develop in children during their primary school years.

The studies reporting new cases of myopia have been limited to children of one[1-4] or three[5] ethnic/racial groups, have emphasized Asian children,[2-5] have been performed outside of the United States,[1-5] have had no[1] or short follow-up periods of one to three years,[3-5] have had small sample sizes,[1,2,5] and/or have not used cycloplegia for refractive error measurement.[2] The Collaborative Longitudinal Evaluation of Ethnicity and Refractive Error (CLEERE) Study is a longitudinal study with a design addressed many of these limitations. The CLEERE Study was conducted in the United States and included 4,927 children from five ethnic/racial groups: Asians, African Americans, Hispanics, Native Americans, and Whites. The study included children from grades 1 through grade 8 (ages 5 through 16 years) and tested them each year. Each ethnic/racial group included 500 or more children.

The purpose of this research is to report the percentage of new cases of myopia in the CLEERE Study from children who were not myopic when they entered the study.

Methods

Subjects were 4,927 children 5 to 16 years of age participating between 1989 and 2009 in the Collaborative Longitudinal Evaluation of Ethnicity and Refractive Error (CLEERE) Study, an observational study of ocular component development and risk factors for the onset of myopia in children of various ethnicities. The CLEERE Study is an extension of the Orinda Longitudinal Study of Myopia (OLSM), begun in 1989 in the predominantly white community of Orinda, California. From the total sample, there were 4,556 children who were not myopic when they entered the study. In order to improve generalizability, four additional clinic sites were added to recruit African-American children (Eutaw, Alabama), Asian children (Irvine, California), and Hispanic children (Houston, Texas). Testing of Native-American children began in Tucson, Arizona in 2000. Each affiliated university's institutional review board (University of California, Berkeley; The Ohio State University; University of Alabama at Birmingham; Southern California College of Optometry; University of Houston; University of Arizona) approved informed consent documents according to the tenets of the Declaration of Helsinki. Parents provided consent and children assent before the children were examined.

Ethnic/racial group designation was determined from a medical history form that had been completed by a parent. Parents selected one of the following six ethnic/racial designations (corresponding to the categories used by the National Institutes of Health as of 1997 when these data were first gathered): American Indian or Alaskan Native; Asian or Pacific Islander; Black or African American not of Hispanic origin; Hispanic; White not of Hispanic origin; Other, or unknown. Ethnicity was assigned to the target ethnic group for the given site when parents provided more than one ethnic/racial designation that included the site's targeted group (1.7% of subjects). If parents provided more than one ethnic/racial designation and neither included the site's targeted designation, the child was assigned to the non-White ethnic/racial designation**.** Any missing parent-reported data were filled in from investigator observation (5.7% of subjects). Investigator observation showed excellent agreement with parent-reported ethnic/racial designation. As children completed grade 8, they left the study and were replaced with newly enrolled first graders for a period of three years at Alabama and Houston, for five years at SCCO, and for eight years at Berkeley. At Tucson, children were enrolled in 2002 - 2004 and followed until grade 8. Because of student transfers to other schools, study withdrawal for other reasons, and termination of the study at a site before all of its subjects reached eighth grade, not all children had complete follow-up through eighth grade. A total of 61.1% of the sample was at least 13 years old at the last study visit.

Trained and certified examiners measured central refractive error using the Canon R-1 autorefractor (Canon USA, Lake Success, NY; no longer manufactured) between 1989 and 2000 and using the Grand Seiko WR 5100-K autorefractor from 2001 to 2007 (Grand Seiko Co., Hiroshima, Japan). Subjects were tested after mydriasis and cycloplegia. When subjects had an iris color of grade 1 or 2 testing was done 30 minutes after one drop of proparacaine

0.5% and two drops of tropicamide 1%.[6] When subjects had an iris color darker than grade 2, testing was done 30 minutes after one drop of proparacaine 0.5% and one drop each of tropicamide 1% and cyclopentolate 1%.[6]

Myopia was defined as −0.75 D or more myopia in both principal meridians. The results also include myopia defined as −0.50 D or more myopic spherical equivalent refraction to facilitate the comparison of these results with other studies. Low birth weight was defined as < 2,500 gm. Four other definitions of myopia are used in Tables 1 and 2 (−0.75 D and −1.00 D spherical equivalent, −0.50 D or more myopia and −1.00 D or more myopia in both principal meridians) to describe the effect of myopia definition on the number of entering non-myopes and the number of new cases of myopia.

Results

The CLEERE Study dataset includes 4,927 children. The range of myopia prevalence upon study entry was from 12.9% to 8.5% for a spherical equivalent of −0.50 D and −1.00 D or more myopia in both principal meridians, respectively (Table 1).

During the course of the CLEERE Study the percentage of children becoming myopic using the definition of −0.75 D or more myopia in both principal meridians was 16.4%; using the definition of −0.50 D spherical equivalent or more myopia, the percentage of children becoming myopic was 23.4%. Not surprisingly, the number of new cases of myopia was sensitive to myopia definition with spherical equivalent-based definitions yielding more cases of myopia than definitions based on the refractive error in both principal meridians. Using the most restrictive definition of myopia, −1.00 D or more myopia in both meridians, categorized 14% of the children as having become myopic (Table 2).

The age of onset of myopia ranged from 7 to 16 years. The highest percentage of new cases of myopia, 18.2%, occurred at age 11 years using the CLEERE Study definition of −0.75 D or more myopia in both meridians, and at age 10 years using the spherical equivalent of −0.50 D or more myopia definition. The largest percentage increase in new cases occurred between ages 7 and 9 years. After ages 10 - 11 years there was a steady decline in the percentage of new cases of myopia (Table 3).

The percentage of new cases of myopia varied among the five different ethnic/racial groups. Asians had the largest percentage of new cases, and Whites had the smallest percentage. The percentage of new cases using the CLEERE Study definition of −0.75 D or more myopia in both principal meridians were: 27.3% in Asians, 21.4% in Hispanics, 14.5% in Native Americans, 13.9% in African Americans, and 11% in Whites. The ranking of the ethnic/racial groups from highest to lowest in the percentage of new cases was essentially the same for both the CLEERE Study definition of −0.75 D and the −0.50 D spherical equivalent cutpoints, except for a reversal between African-American and Native-American rankings using the −0.50 spherical equivalent definition (Table 4).

Table 4 also describes the children's age at study entry and exit and their years of follow-up in the CLEERE Study. For the more conservative definition of myopia, ie, −0.75 D or more myopia in both meridians on cycloplegic autorefraction, the range in average age at study

entry for those who entered the CLEERE Study as non-myopes was about one year, lowest for Whites (8.11 years) and highest for Native Americans (9.45 years). The range in average age at study exit was two years, lowest for Asians (11.60 years) and highest for Native Americans (13.46 years). The average number of years of follow-up ranged from 3.44 for Asians to 4.30 for Whites.

Overall, 18% of the sample who entered the CLEERE Study in the first grade as non-myopes and developed myopia by the eighth grade were followed all the way through to grade 8. Table 5 depicts the myopia onset results for the children whose last visit was conducted when they were at least 13 years old. In summary, there were 649/2536 or 25.6% new cases of myopia by the spherical equivalent of −0.50 D or more myopia definition among those last seen at age 13 years or older compared to the 1006/4290 or 23.4% new cases of myopia depicted in Table 2 for the same myopia definition. The corresponding comparison for the myopia definition of −0.75 D or more myopia in both meridians is 494/2734 or 18.1% for those 13 years of age an older versus 16.4% in Table 2. The inclusion of children of all ages, regardless of the years of follow-up or their age at last study visit, underestimates the proportion of new cases of myopia by about 2%.

There was a small difference in the onset of new cases of myopia by gender that was consistent across both the −0.75 D CLEERE Study and the −0.50 D spherical equivalent definitions of myopia. Using the CLEERE Study definition of −0.75 D or more myopia in both meridians, 18.5% of females and 14.5% of males were new cases of myopia. (Table 6).

Low birthweight has been associated with the onset of myopia.[7] Among the children in the CLEERE Study, there was a clinically inconsequential 1.4% difference between the normal and low birthweight groups. The percentage of new cases of myopia with normal birthweight was 16.9% and with low birth weight was 15.5%.

Discussion

Studying the development of myopia in children is difficult. As a result, few large studies have been conducted that assessed new cases of myopia in children.[1-5] Factors that make studying myopia development difficult include the gradual onset of the condition, the relatively few new cases that occur each year, the need to follow the same children for many years, and the difficulty in obtaining access to children. Because of these problems, a large initial group of children who can be followed for many years is required. This study design is expensive, requires a long-term commitment by a group of investigators, and the long-term support of parents and institutions that provide access to their children.

There are no other studies that have the combined characteristics of the CLEERE Study, that is, a large number of children, a long duration of follow-up, and a diverse ethnic/racial mix of children. The small number of existing myopia development studies were generally well done but were limited in different ways. Zhao et al., Fan et al., and Saw et al. only followed their initially non-myopic children for one to three years.[3-5] Edwards and co-workers followed their children for five years but did not use cycloplegic autorefraction to measure myopia and only had 110 non-myopic children.[2] Most of the studies were limited to Asian

children in the Far East,[2-5] usually Chinese children from different areas, except for one study by Mäntyjärvi that enrolled Finnish children from one community.[1] Two studies that had large sample sizes of 3,149 (Fan et al.[4]) and 4,621 (Zhao et al.[3]) only followed them for one and two years, respectively.

The percentage of new cases of myopia is dependent on the definition of myopia. The CLEERE Study definition, −0.75 D or more myopia measured by cycloplegic autorefraction in both principal meridians, was chosen because this amount of myopia is likely to affect school and other daily activities, such as seeing the board from the back of a classroom, viewing television across a room, and playing sports. It was also chosen because it exceeded the measurement error of autorefraction[8] and because it appeared to be the minimum amount that most clinicians would prescribe for a newly myopic child. The −0.50 D or more myopia spherical equivalent definition used in earlier studies is more liberal and could include some refractive errors that are not traditionally defined as myopia, e.g., mixed astigmatism. Because the spherical equivalent definition includes lower amounts of myopia and refractive errors that are not traditionally defined as myopia, the percentage of new cases with this definition was, of course, greater than the percentage of new cases using the definition in the CLEERE Study. This is an important factor to recognize when groups with high astigmatism are included and spherical equivalent is a less useful definition.

Myopia is a problem that affects children of all ages, both genders, and many ethnic/racial groups. In the CLEERE Study, at least 1 out of 6 children had myopia (−0.75 D or more myopia in both principal meridians on cycloplegic refraction) by the age of 16 years. Although there were differences in the percentage of new cases of myopia between different ethnic/racial groups, every group had at least 11% percent of children who became myopic.

The three largest existing studies of myopia development reported new cases of myopia, using a definition of −0.50 D or more myopia spherical equivalent that occurred after one to three years of follow-up in mostly Chinese children.[3-5] Fan et al. (2004) reported that 14.4% of their sample became myopic after one year of follow-up and that 10-year-old boys and 11-year-old girls had the highest amounts of myopia.[4] Zhao et al. (2002) reported that 18.5% (cumulative incidence) became myopic after a 28.5-month follow-up period, children 5 years old had the smallest amount of myopia and children 12 years old had the largest amount, and girls had more myopia than boys.[3] Saw et al. (2005) reported that 42.7% (cumulative incidence) became myopic over a three-year follow-up period, 49.5% among 737 Chinese children and 27.2% among 229 Malaysian and 53 Indian children.[5]

These results are difficult to compare with the CLEERE Study because the CLEERE Study included different ethnic/racial groups and the Asians in the CLEERE Study were not limited to Chinese children; however, the Asian children in the CLEERE Study and the Chinese children in the previous three studies had significant amounts of myopia, using the −0.50 D or more myopia spherical equivalent definition. The results of the CLEERE Study and these studies agree that the number of new cases of myopia appears to peak around age 10 - 12 years.

This study was intentionally designed so that each site preferentially recruited the ethnic/racial group that was best represented in its surrounding community. For example, all the Asian children were recruited in California; of course, expecting recruitment of Asian children in either Eutaw, Alabama or Houston, Texas would have been in vain. It is difficult, therefore, to separate out the effects of location and socioeconomic status from ethnicity/race, but it is difficult to envision a study design in which these three variables could be separated from another. Nonetheless, the necessity of site- and ethnicity-/race-specific recruitment is a limitation of the CLEERE Study.

The CLEERE Study shows that myopia was present in a small percentage of children age 7 years. More children became myopic every following year as the children continued in school through age 16 years. Over 75% of the new cases of myopia occurred between ages 9 - 13 years. This onset and development pattern was the same regardless of the definition of myopia.

There was a small difference in the percentage of new cases of myopia between genders, with girls having more new cases than boys. This result is similar to the results found in other studies.[1, 3-5] This result could possibly occur from girls maturing earlier than boys and would be consistent with the trend of an increasing number of new cases of myopia with age.

This study found a small difference in the percentage of new cases of myopia in children who had a normal birthweight compared to those with a low birthweight. The percentage was higher in children with normal birthweight, which would not support possible associations between low birthweight and myopia. Further studies may be needed to determine if there is a difference in myopia between infants with low birthweight only and those with low birthweight and other risk factors or diseases, such as Down syndrome or retinopathy of prematurity.

The CLEERE Study sample is not representative of the population of children in the United States. Studies in the United States that attempted to be representative of the entire population and collected vision data did not assess the development of myopia in school age children.[9,10] Although the CLEERE Study is not representative, it is to date the largest and most diverse longitudinal study of refractive error in children in the United States. With awareness of this limitation, the data can be cautiously used to make limited inferences about the development of myopia in children. Trends in the CLEERE sample include the observation of a slow rate of onset of myopia in young children, with the highest percentage of new cases of myopia around the presumed age of puberty; the effect of myopia definition on the number of new cases; the relative equality in the number of new cases of myopia between girls and boys; and, within ethnic/racial groups, the highest percentage of new cases of myopia among Asians compared to other groups.

With the continual onset of new cases of myopia during the primary school years, there needs to be a means of identifying the children who become myopic and that enables them to receive treatment. Unfortunately the Patient Protection and Affordable Care Act signed into law on March 23, 2010 may not include vision care for children, unless they are eligible

for Medicaid. Because of this general lack of vision care for children, additional work will be needed to ensure that all myopic children receive the treatment they need.

Conclusions

One in six children enrolled in the CLEERE Study became myopic. These included children from each major ethnic/racial group: Asians, African-Americans, Hispanics, Native Americans, and Whites. Among those becoming myopic, the age of onset peaked around age 10 to 11 years. There was no clinically significant difference in new cases of myopia between the normal and low birthweight groups. The high percentage of new cases in the CLEERE Study sample is consistent with the findings of others and supports the need for new programs and policies to address myopia in children.

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Table 1

Entering myopes and non-myopes as a function of myopia definition

	Entering Myopes n (%)	Entering Non-Myopes n (%)
Myopia Definition - Spherical equivalent		
−0.50 D or more myopia	637 (12.9%)	4290 (87.1%)
−0.75 D or more myopia	513 (10.4%)	4414 (89.6%)
−1.00 D or more myopia	417 (8.5%)	4510 (91.5%)
Myopia Definition - Myopia in both principal meridians		
−0.50 D or more myopia	458 (9.3%)	4469 (90.7%)
−0.75 D or more myopia	371 (7.5%)	4556 (92.5%)
−1.00 D or more myopia	314 (6.4%)	4613 (93.6%)

Table 2

Number of new cases among those who enter the study as non-myopes using different myopia definitions

	New cases n (%)	Remaining non-myopes n (%)
Myopia Definition - Spherical equivalent		
−0.50 D or more myopia	1006 (23.4%)	3284 (76.6%)
−0.75 D or more myopia	838 (19%)	3576 (81%)
−1.00 D or more myopia	740 (16.4%)	3770 (83.6%)
Myopia Definition - Myopia in both principal meridians		
−0.50 D or more myopia	867 (19.4%)	3602 (80.6%)
−0.75 D or more myopia	749 (16.4%)	3807 (83.6%)
−1.00 D or more myopia	648 (14%)	3965 (86%)

Table 3

First age at which the definition of myopia was observed

Age (Years)	Myopia Definition Spherical Equivalent −0.50 D or more myopia N= 1006	Myopia Definition Both Principal Meridians −0.75 D or more myopia N = 749
7	25 (2.5%)	11 (1.5%)
8	80 (8.0%)	59 (7.9%)
9	150(14.9%)	100(13.4%)
10	175(17.4%)	122(16.3%)
11	161(16.0%)	136(18.2%)
12	157(15.6%)	112(15.0%)
13	142(14.1%)	111(14.8%)
14	91 (9.0%)	80 (10.7%)
15	23 (2.3%)	12 (1.6%)
16	2 (0.2%)	6 (0.8%)

Table 4

Percent of children in each ethnic/racial group who developed new cases of myopia, as a function of two different myopia definitions and their study follow-up.

		Entering non-myopes				Age at study entry (years)		Age at study exit (years)		Years of Follow-up	
		Remained non-myopic		New case of myopia							
		N	%	N	%	Mean	SD	Mean	SD	Mean	SD
Definition of myopia	**Ethnicity**										
Spherical equivalent –0.50 D or more myopia	**Native American**	361	78.99	96	21.01	9.35	1.68	13.39	1.73	4.04	2.05
	Asian	369	64.62	202	35.38	8.06	1.98	11.59	2.22	3.53	2.15
	African American	548	77.95	155	22.05	9.17	2.66	13.34	1.67	4.17	2.39
	Hispanic	655	70.35	276	29.65	8.76	2.24	12.70	2.04	3.94	2.30
	White	1321	83.19	267	16.81	8.05	2.15	12.38	1.91	4.33	2.21
	Other	29	74.36	10	25.64	8.33	2.30	12.16	2.09	3.83	2.48
Both meridians –0.75 D or more myopia	**Native American**	449	85.52	76	14.48	9.45	1.77	13.46	1.68	4.01	2.08
	Asian	449	72.65	169	27.35	8.16	2.06	11.60	2.24	3.44	2.16
	African American	631	86.08	102	13.92	9.21	2.67	13.36	1.67	4.15	2.39
	Hispanic	788	78.56	215	21.44	8.83	2.28	12.74	2.03	3.91	2.30
	White	1453	88.98	180	11.02	8.11	2.18	12.41	1.89	4.30	2.21
	Other	36	83.72	7	16.28	8.50	2.38	12.20	2.05	3.70	2.44

Table 5

New cases of myopia as a function of two different myopia definitions in the subsample of children whose last study visit was at age 13 years or older.

Definition	Number entering as non-myopes	New cases n (%)	Remaining non-myopes n (%)
Spherical equivalent −0.50 D or more myopia	2536	649 (25.6%)	1887 (74.4%)
Both principal meridians −0.75 D or more myopia	2734	494 (18.1%)	2240 (81.9%)

Table 6

Percent of males and females who developed new cases of myopia – using two definitions

Gender	–0.50 D or more myopia (spherical equivalent)	>–0.50 D remaining non-myopes	–0.75 D or more myopia in both principal meridians	>–0.75 D remaining non-myopes
Male	464 (21.4%)	1704 (78.6%)	(332) 14.5%	1965 (85.5%)
Female	542 (25.5%)	1580 (74.5%)	(417) 18.5%	1842 (81.5%)
Overall	1006 (23.4%)	3284 (76.6%)	(749) 16.4%	3807 (83.6%)