

Prevalence of color vision deficiency among school-going boys in South India

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Purpose: Impact of color vision deficiency (CVD) on activities at school and productivity at work and consequential psychosocial difficulties has been reported. Although early detection and awareness help in overcoming these difficulties, screening for CVD is not a part of the school eye-screening initiatives in many countries. This study aimed at reporting the prevalence of CVD among school-going boys in Kanchipuram district, South India. **Methods:** The study was carried out as part of a school eye-screening program (SES) conducted in Kanchipuram district, Tamil Nadu, India for children between 6 and 17 years. The SES followed a three-phased protocol, which also included screening for CVD for all the boys between 11 and 17 years. The boys underwent CVD screening with Dalton's pseudo isochromatic plates (PIPs) followed by confirmation with Ishihara's PIP. The data were analyzed and the proportion of CVD in boys among different class grades, type of schools, location of schools, blocks of the district, and other clinical characteristics are presented. **Results:** Totally 250,052 children were screened in 1047 schools of which 74986 (60.61%) were boys between 11 and 17 years (mean age: 13.75 ± 1.91). The overall prevalence of CVD was found to be 2.76% ($n = 2073$; 95% confidence interval [CI]: 2.65–2.88). CVD was associated with urban locations (3.17% odds ratio [OR]: 1.90 95%CI: 1.69–2.13 $P < 0.05$) and public schooling (2.87%) (OR: 1.29 95%CI: 1.17–1.43 $P < 0.05$). Boys with CVD were less likely to have vision impairment ($P = 0.002$) and myopia ($P < 0.001$) as compared with boys with normal color vision. There was no significant difference in the proportion of other ocular conditions between children with and without CVD ($P > 0.05$). **Conclusion:** The study shows a significant proportion of CVD among boys in Kanchipuram district, India and its association with various demographic and clinical characteristics. Identification of CVD and counseling the stakeholders earlier through school children screening is crucial.

Key words: Color vision deficiency, color vision, Dalton's pseudo-isochromatic plates, school children

The worldwide prevalence of congenital color vision deficiency (CVD) is reported to be around 8% in men and 0.5% in women.^[1,2] Due to the X-linked inheritance pattern, men are predominantly affected and women become the carriers of the abnormal gene.^[3] Prevalence of CVD varies between 2% and 14% in different studies.^[3–11] Studies have also reported about the prevalence and mechanism of CVD among patients with myopia, amblyopia, media opacities, macular or retinal abnormalities, and optic nerve disorders.^[12–14] Apart from ocular clinical characteristics, CVD is also reported to be associated with low literacy rate, poor socioeconomic status, specific geographical locations, consanguinity, and Muslim communities.^[3,5,7,9]

Although there are no significant associations reported between levels of CVD, educational attainment, and choice of a career, people with CVD face difficulties in different stages of life.^[15,16] Especially during schooling, children struggle in subjects like science, mathematics, or social sciences where colors are predominantly used for identification of chemical solutions, colored wires, use of charts, or maps.^[16,17] Even in employment opportunities, people with CVD find it difficult to deliver work to expectations that would in turn hamper their career growth.^[17,18] Adding to the difficulties, spending years of education and monetary resources on the career force

people with CVD to remain in the career and few switch to other professions but with psychological stress.

Options of screening for CVD earlier and support to decide on a career are important at the right time. Testing for CVD among children as part of a school eye-screening program is not mandatory in countries like United Kingdom, India, whereas the Australian Government mandates to record the color vision status to provide counseling on career choices.^[16,19] Apart, the standards across many parts of the world include color vision screening as the last step in the pre-employment medical examination.^[16,19] With such an existing scenario, the study team decided to understand the prevalence of CVD among boys in the schools of Kanchipuram district, South India.

Methods

The study was conducted as part of a school children vision screening initiative covering refractive error needs of children between 6 and 17 years of age. The school eye-screening program was conducted in Kanchipuram district, Tamil Nadu, India

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served by the institution. Kanchipuram is the second highly populated district, with the highest literacy rate in the state. It was reported to be one of the economically rich districts with growth in overall education, health sector, and gender equity in the last decade.^[20] Kanchipuram district is divided into blocks and further sub-divided into clusters covering nearly 1448 km² and totally has 1694 schools. The study aimed to screen 300,000 school children in three years between 2016 and 2019. The study was approved by the Institutional Review Board and the Ethics Committee of the Vision Research Foundation, Chennai and the study followed the tenets of the Declaration of Helsinki.

Study procedures

Permission to conduct screening at the school premises was issued by the Education and Health departments of the State Government through a Government order. The Government Order copy was provided to the school authorities and a written informed consent was obtained from the administrative head of the school to conduct the screening. The block-wise and cluster-wise school list was available from the District Information System for Education. Schools that gave consent and did not have screening in the last year were enrolled.

Eye examination

School vision screening was conducted as per the three-phased protocol of the institution that was conducted in a pre-identified location at the school premises.^[21] The first phase is a basic screening that included visual acuity testing using a pocket vision screener that has log of minimum angle of resolution optotypes of 6/9,^[22] +1.50 diopter (D) test,^[23] external eye examination with torchlight and screening for non-strabismic binocular vision anomalies^[24] apart from the screening for CVD. All the boys from class grade 6–12 (age 11–17 years) underwent the color vision screening with Dalton's Pseudoisochromatic plate (PIP).^[25] Children who failed the first phase, those wearing spectacles, and/or found to have other ocular conditions underwent the second and third phase of the examination. The second phase included objective refraction using retinoscopy and subjective acceptance at the school itself by optometrists. Children identified with refractive errors were provided spectacles free of cost. In the third phase, for those children whose vision did not improve with refractive correction, examination using direct ophthalmoscopy was performed by trained optometrists and a reason for vision impairment was ascertained. All these children were referred to the base hospital for evaluation and management.

Screening for color vision deficiency^[25]

Dalton's pseudoisochromatic plates were used to screen for CVD in boys. Dalton's PIP was constructed as a screening tool to identify children with CVD in a large-scale screening setup. The construction of the plates was based on the pseudoisochromatic principle, closely resembling the principle of Ishihara's PIP. The screener consists of six sets with four plates in each that includes one demo plate and three screening plates. The screening plates were presented at 40–50 cm, at right angles to the line of vision for approximately 3 s. Color vision screening was conducted in the corridors where bright sunlight was available. Teachers and parents of the boys who failed both the color vision tests were informed about the nature of the condition and choice of subject stream and career choice. An IEC material on color vision and career choice was given to all the schools to be put up in their notice boards. Screening team underwent training for performing the test uniformly.

Definitions

Boys who failed to read three or more plates in two or more random sets of the Dalton's PIP underwent Ishihara PIP test. Boys who read less than 14 plates in the Ishihara PIP (38 plate edition) were confirmed to have CVD. Only the typical errors in reading the different types of Ishihara PIP were counted as errors and adequate time was given for every child to read the Ishihara PIP. Boys who were in class grades 1 to 5 were deferred for the color vision test. All other boys between class grades 6 and 12 underwent color vision screening with Dalton's PIP and were confirmed with Ishihara PIP. Boys who had refractive errors and/or other ocular pathologies also underwent color vision screening.

Vision impairment was defined as presenting visual acuity less than 20/30 (6/9). Mild vision impairment, moderate vision impairment, severe vision impairment, and blindness were defined as presenting visual acuity less than 6/12, 6/18, 6/60 and 3/60 in the better eye, respectively. Myopia was defined as spherical equivalent refractive errors less than -0.50 D and hyperopia, more than + 1.00D. Any spherical equivalent refractive error between + 1.00D and -0.50D, inclusive was defined in the study as "Other refractive errors." Spherical equivalent refractive error between -0.50D and -3.00D, inclusive was defined as mild myopia, between -3.00D and -6.00D was defined as moderate myopia, and less than -6.00D, inclusive was defined as high myopia. Children with other ocular conditions were classified under corneal abnormalities, conjunctival abnormalities, retinal pathologies, and neuro-ophthalmology-related disorders. Amblyopia was defined as best-corrected visual acuity of less than 6/12 and/or two or more lines difference in visual acuity between eyes.^[26]

The data were classified into different type of location of the schools (rural and urban), type of schools (public and private), class grades of middle (class grades 6–10; age 11–15 years), and higher secondary (class grades 11–12; age 16–17 years) and different blocks in the district.

Data analysis

Data were entered into a screening software and downloaded information from the software was cleaned, coded, and analyzed using Microsoft Excel (version 2017) and Statistical Package for the Social Sciences version 17.0 (SPSS Inc., Chicago, Illinois). The overall prevalence of CVD and prevalence among class grades, location, type of schools, and the different blocks of the district were reported. Logistic regression was used to understand the association between CVD and other variables.

Results

There were 13 blocks and 220 clusters in Kanchipuram district. The blocks are represented in Fig. 1. There were 1047 schools that did not have an eye screening in the last year and gave consent for the screening. Out of the 303,618 children enrolled in these schools there were 250,052 (82.35%) children present on the days of screening, of whom 123,720 (49.48%) were boys. There were totally 74,986 (60.61%) boys in the class grades 6 to 12 (mean age: 13.75 ± 1.91; age range: 11–17 years) that underwent color vision screening as part of the school eye-screening protocol. There were 58907 (78.56%) boys in middle school and 16079 (21.44%) boys in higher secondary school, 21422 (28.57%) and 53564 (71.43%) in public and private schools, respectively, 21911 (29.22%) and 53075 (70.78%) in the rural and urban region, respectively.

Prevalence of CVD and associations: The overall CVD among boys was found to be 2.76% ($n = 2073$) (95% confidence interval (CI): 2.65–2.88). Regression analysis showed that children from urban region (3.17%) were more likely to be color vision deficient than children from rural region (1.79%) (odds ratio [OR]: 1.90 [95% CI: 1.69–2.13] $P < 0.05$), whereas public school going children (2.87%) were more likely to be color vision deficient (OR: 1.29 (95%CI: 1.17-1.43) $P < 0.05$) as compared to private school children (2.50%). No significant difference was found between different age groups ($P = 0.17$). The proportion of CVD among higher secondary school children who already had chosen a stream of education was separately analyzed. CVD was seen in 2.92% ($n = 347$) higher secondary school boys from government schools and 2.80% ($n = 118$) higher secondary school boys from private schools and the difference was not significant ($P = 0.66$). The age-standardized prevalence of CVD among boy between 6 and 17 years of age was found to be 2.77% (95% CI: 2.65–2.88).

There was a significant difference in the proportion of CVD between different blocks where schools were located (Chi-square test 136.46, $df = 12$, $P < 0.05$) with the highest proportion of CVD in Block V (3.40%), Block X (3.36%), Block VIII (3.19%) and Block VII (3.13%), whereas the lowest proportion was noted in Block IV (1.49%), Block XII (1.26%), Block VI (1.21%), and Block XIII (1.12%) blocks. Table 1 represents the association between CVD, class grades, type of schools, and location of schools. Fig. 1 presents the prevalence of CVD in the blocks of Kanchipuram district.

On average, the Muslim community covers 4% of the district's population.^[27] The areas from the sub-districts (Block VI, Block II, II, IV, Block X, Block XIII) covering more than 10% of Muslim community was analyzed separately to understand the association of CVD among different communities and presence of CVD. There was no significant association between the subdistricts and CVD ($P = 0.16$).

Of the 74986 boys screened, 7644 (10.19%) children underwent the second phase of refraction after the basic screening and among them 128 (0.17%) boys had CVD and 7516 (10.12%) had normal color vision. The prevalence of vision impairment among children with CVD was found to be 2.60% ($n = 54$) which was lesser when compared to children with normal color vision, 3.95% ($n = 2878$) ($P = 0.002$). There was no significant association between mild vision impairment ($P = 0.52$), moderate vision impairment ($P = 0.42$), blindness ($P = 0.08$) and the presence of CVD. The prevalence of refractive error among boys with CVD (5.26%) was significantly lesser than boys with normal color vision (9.24%) ($P < 0.001$). The details of refractive errors and other ocular conditions among normal and color vision deficient are provided in Table 2.

Other ocular conditions were found among 24 (1.16%) children with CVD and 1386 (1.88%) children with normal color vision. It was seen that the status of amblyopia was not significantly different among children with CVD (0.10%) and normal color vision (0.11%) ($P = 0.89$). Also, there was no significant difference between the proportion of retinal disorders ($P = 0.19$) and neuro-ophthalmology-related disorder ($P = 0.35$) among children with CVD and normal color vision.

Discussion

The study reports the prevalence of CVD and the associated clinical characteristics among school-going boys aged between 11 and 17 years. The prevalence of CVD is similar to the other parts of the country and few other countries from Asia.^[3-11] From the results of the study, we find that 2.76% of boys were found to have CVD. This proportion is almost similar in a proportion of uncorrected refractive error in some parts of the country.^[28] Extrapolating this, there could be 17 million boys affected with CVD in the country. The current education system emphasizes on using colors as teaching and learning tool and this would pose a serious difficulty for children with CVD both in terms of getting used to and adapting to the system.^[29]

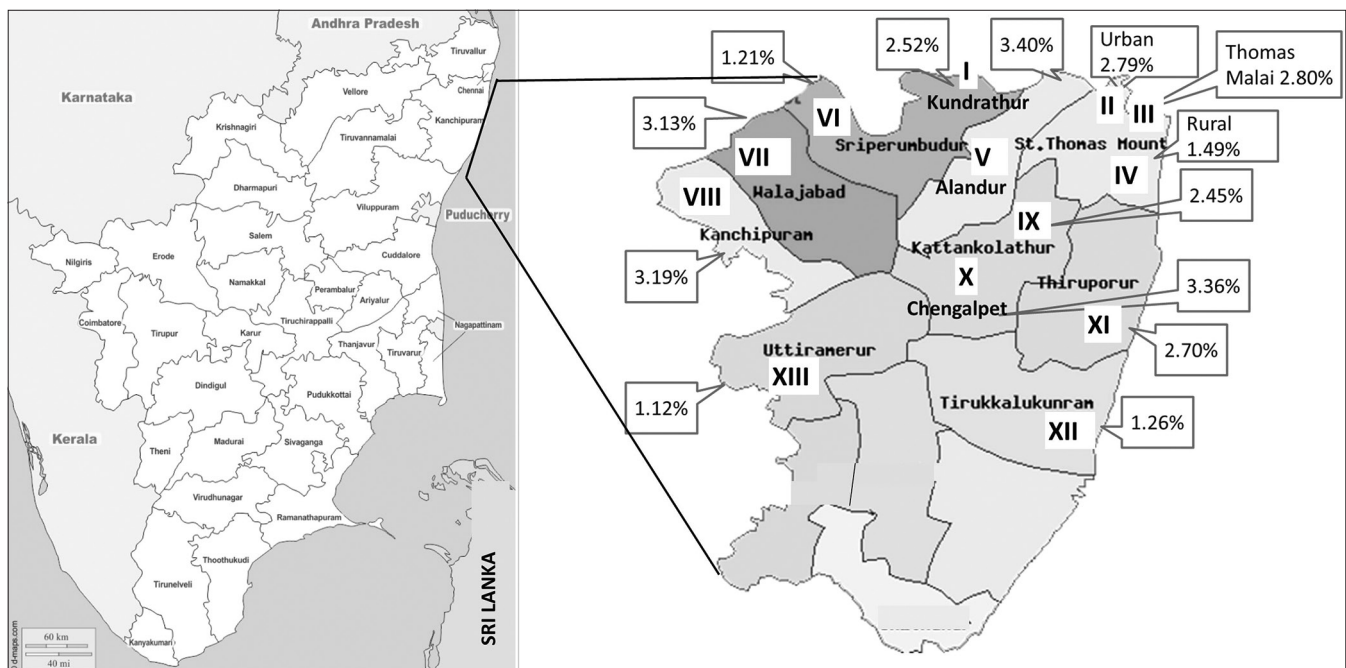


Figure 1: Prevalence of color vision deficiency across the blocks of Kanchipuram district, South India

Table 1: Association between color vision deficiency, age groups, location and type of schools

Demographics	Total (n)	Color vision deficiency (n)	Prevalence (%)	Odds ratio (95%Confidence Interval) (P)
Total	74986	2073	2.76	
Class groups				
Middle	58907	1608	2.73	Reference
Higher secondary	16079	465	2.89	1.06 (0.97-1.16) (P=0.17)
Type of school				
Private	21422	535	2.50	Reference
Public	53564	1538	2.87	1.29 (1.17-1.43) (0.001)
Location of school				
Rural	21911	392	1.79	Reference
Urban	53075	1681	3.17	1.90 (1.69-2.13) (0.001)

Table 2: Clinical characteristics among children with and without color vision deficiency

Clinical characteristics of children	With Color Vision Deficiency		Without Color Vision Deficiency		Odds Ratio (95%Confidence Interval)	P
	n	%	n	%		
Vision Impairment	54	2.60	2901	3.98	1.55 (1.17-2.03)	0.001
Overall spherical equivalent refractive error	109	5.26	6734	9.24	1.83 (1.50-2.22)	<0.001
Refractive errors (based on spherical equivalent)						
Myopia	76	3.67	4862	6.67	1.87 (1.49-2.36)	<0.001
Mild	66	3.18	3819	5.24	1.68 (1.31-2.15)	<0.001
Moderate	9	0.43	865	1.19	2.75 (1.42-5.31)	0.002
Severe	1	0.05	178	0.24	5.07 (0.71-36.21)	0.10
Hyperopia	1	0.05	72	0.10	2.01 (0.28-14.54)	0.48
Other refractive errors	32	1.54	1800	2.47	1.61 (1.13-2.29)	0.006
Other ocular conditions						
Amblyopia	2	0.10	82	0.11	1.16 (0.28-4.74)	0.83
Neuro-ophthalmology related	3	0.14	61	0.08	0.57 (0.18-1.84)	0.35
Retina	2	0.10	27	0.04	0.38 (0.09-1.61)	0.19

It should also be understood that people with CVD either would not be employed or work with difficulty compared to their normal color vision peers in specific occupational set-ups.^[17,18] The huge population also raises the need for color vision inclusive work environments that would help people with CVD to be more productive. Though such attempts were made in the community-based rehabilitations, work environments still lack such options.^[18]

Our study showed that 2.89% of children at the level of higher secondary education who have already chosen a stream of education, were color vision deficient. Rejections in career at a later stage would force them to find an alternative career and also affect their psychological status.^[19] Children with CVD were also more in the Government-run schools and urban regions. These children because of their low socioeconomic status and illiterate parents, are likely to have minimal higher education opportunities and lesser exposure to the choice of careers.^[30] If children with such lesser opportunities undergo rejections during job placements, would lead to higher mental stress and in turn put them in a lower socioeconomic status. A recommendation for the schools to screen children for CVD and counsel before the choice of stream could be advocated by the Education departments.

Our study evaluated the relationship between myopia and CVD and found that the proportion of myopia was lesser

among children with CVD. Previous studies reveal that eyes sensitive to L-cones develop myopia during the process of emmetropization due to longitudinal chromatic aberrations. Children with CVD who have reduced sensitivity to short or long wavelengths are less likely to develop myopia than children with normal color vision.^[12] But the results related to amblyopia were not in alignment with the other studies.^[14] This could be because of more numbers of anisometropic amblyopes in our study compared to the predominant strabismic amblyopes in other studies.^[13]

Results from the study show that there were significant differences in the prevalence of CVD in different blocks of Kanchipuram district. Though the literature suggests that consanguinity, literacy rates, and socioeconomic status could be associated with increased prevalence of CVD in different geographical locations,^[3,5,7,9] information regarding such details of the children from different blocks were not collected during the screening process. Hence, definitive conclusion could not be made regarding the proportional difference between the blocks of the district.

Because of a lack of treatment, color vision screening is not included in the conventional vision screening protocols. The commandments of the screening also necessitate the need for an effective treatment to be present to carry out screening for a

condition.^[31] But keeping in mind the number of children with CVD, and limited career choices on jobs, incorporating early color vision testing as part of the school eye-screening programs could help the children. Screening should be performed along with counseling and awareness sessions to the stakeholders preferably before the decision on a stream of education.

Conclusion

Our study shows a significant proportion of CVD among boys in Kanchipuram district, India and its association with various demographic and clinical characteristics. Identification of CVD by school eye health screening and counseling of the stakeholders are essential.

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Conflicts of interest

There are no conflicts of interest.

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