

Colour vision deficiency among students in Lagos State, Nigeria

Olalekan A Oduntan,¹ Khathutshelo P Mashige,¹ Franklin E Kio²

1. Department of Optometry, School of Health Sciences, University of KwaZulu-Natal, Durban, 4000, South Africa.
2. Department of Optometry, Faculty of Life Sciences, University of Benin, Benin City, Nigeria.

Abstract

Background: Congenital colour vision defects are x-linked inherited, non-progressive and untreatable disorders that describe poor colour discrimination.

Objective: To determine the prevalence of congenital colour vision deficiency among students in Lagos, Nigeria.

Methods: A school-based cross-sectional, cluster sample study was conducted to test the colour vision of 2326 primary and high school students. Inclusion criteria were Snellen VA 20/20 or better and absence of known ocular pathologies. Colour vision deficiency (CVD) was evaluated with the Richmond-HRR colour vision test plates.

Results: There were 1014 (43.6%) males and 1312 (56.4%) females with a mean age of 13.40 ± 2.40 years (range = 7–22 years). The prevalence of CVD was 58 (2.5%), which was higher in males 49 (4.8%) than females 9 (0.7%). The prevalence of congenital CVD was significantly associated with males ($p = 0.00$), but not with females ($p = 0.22$). Of the 58 cases of CVD, 17 (0.7%) had protan deficiency, 38 (1.6%) had deutan deficiency and three (0.1%) were unclassified.

Conclusion: The prevalence of congenital CVD among students in Lagos is comparable to findings in other parts of Nigeria but differs from other parts of the country. These results strengthen the need to establish school vision screening.

Keywords: Colour vision deficiency, Richmond-HRR, prevalence, red-green defects, Nigeria.

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Introduction

Human vision relies on the ability to perceive a narrow window of electromagnetic radiation, and the sense of colour depends on the ability to discriminate among different wavelengths stimuli.¹ Colour vision is a function of three types of retinal cones, each with its specific-wavelength sensitivity; blue (tritan) at 414-424 nm, green (deutan) at 522-539 nm and red (protan) at 549-570 nm.² The various types of photoreception mediating vision and their functions have been discussed by many authors.^{1,2} Colour vision deficiencies (CVD) can be congenital or

acquired and congenital defects are inherited (genetic in origin), while acquired CVD are usually associated with other ocular and systemic conditions such as media opacities, macular diseases, optic neuropathies, and diabetes mellitus.³ Congenital colour vision defects are non-progressive and untreatable disorders, for which screening is done to enable children to understand the implications of their condition for a variety of life circumstances, including occupation.³ The historic aspects of colour vision defects have been reported⁴ and the genetic aspects published,² and will therefore not be presented in this article.

Abnormalities in or the absence of colour vision is often used to classify colour vision deficiency. When the colour deficiency is a result of abnormality of red-sensitive cones, the condition is known as protanomaly, and when the defect is caused by absence of the red sensitive cells in the macula, the condition is called protanopia.² Individuals with an abnormality of red-sensitive cones, and with an absence of these cones, are referred to as protanom-

Corresponding author:

Khathutshelo P Mashige,
Department of Optometry,
School of Health Sciences,
University of KwaZulu-Natal, Durban,
4000, South Africa
Email: mashige@ukzn.ac.za

alous trichromats and protanopes, respectively.² Those with an abnormality of green-sensitive cones have deuteranomaly, and with absent green cones have deuteranopia. The green colour deficient individuals are referred to as deuteranomalous trichromats. Those with blue-green deficiency caused by abnormality of blue-sensitive cones have a colour efficiency called tritanomaly, and when the blue-sensitive cones are absent it is called tritanopia. The individuals with abnormality of blue-green sensitive cones are referred to as tritanomalous trichromats and those with absence of the cones are called tritanopes.² According to Pease,⁴ occupations in the armed forces, aviation, electrical, railroad and maritime have colour standard required for employment, while other professions, such as geology, graphic designs and healthcare professions,⁵ require normal colour vision for effective, efficient and safe performance. Bacon⁶ found that the colour differentiation was needed for teaching and learning chemistry, physics and biology in secondary school. Gordon⁷ suggested that CVD affects the activities of children in school, leading to some psychological effect. It is therefore important that children know of their colour vision status, be advised on how to deal with the condition and what profession they might choose in order not to face occupational difficulties.

The prevalence of CVD have been shown in many published studies to vary with respect to race, ethnicity and gender.^{8,9} In addition, the few studies that have been conducted on colour vision in other parts of Nigeria^{10,11,12} have yielded varying results, suggesting that data from different areas and ethnicities should be studied. Furthermore, the patterns across Africa are not uniform, with 1.8% in the Congo¹³ and 1.9% in Uganda,¹⁴ and 3.5% in Sudan.¹⁵ Such studies will provide useful information for the health professionals and policy makers, as well as parents of children with colour vision impairment.

Methods

This was an explorative, cross-sectional and quantitative study to determine the prevalence and types of CVD among primary and high school students in Lagos State, Nigeria. Lagos, located in the South-Western part of Nigeria, is the largest state in the country (population of approximately 21 million) and one of the largest in Africa.¹⁶ It is culturally and ethnically diverse, attracting residents

from across the country.¹⁶ It is the commercial capital of Nigeria and most of the inhabitants are Black. There are two public Universities in Lagos, as well as primary and high schools, many of which are public institutions. Lagos is divided into 20 Local Government areas (LGA) for administrative purposes due to the population size and physical extent of the state.¹⁶

Sampling procedure and sample size

A multistage sampling technique was used to identify the four local government community areas of Agege, Alimosho, Ifako/Ijaiye and Ikeja. Thereafter, simple random sampling was used to select eight schools from a total of 42 schools in these areas. Finally, a stratified multistage cluster random sampling was used to select participants. The minimum sample size for the study was determined using the formula for a prevalence study.¹⁷

$$N = \frac{Z^2 \times (P) \times (1 - P)}{C^2}$$

Where N = minimum required sample size, Z = value of z statistic at 95% confidence level = 1.96, P = assumed prevalence of congenital colour vision defects = 8% for maximum sample size, C = maximum acceptable sampling error = 1.6%.

Data collection

A pilot study was conducted among 100 participants outside the study area to establish any need for modification of the test procedures. The assessment consisted of data regarding socio-demographic details, visual acuity, retinoscopy, subjective refraction, pen torch examination, direct ophthalmoscope observation and colour vision testing. Visual acuity assessment was performed with a Tumbling E Snellen's chart in a well-illuminated outdoor environment, and all those with spectacles had their visual acuities assessed while wearing them. Thereafter, an ocular examination was done for the students with a retinoscope followed by subjective refraction, pen torch and direct ophthalmoscope through undilated pupils. Retinoscopy and subjective refraction were for refractive error determination and other tests were for ocular health examination. Colour vision was assessed using the Richmond-HRR (Richmond Products Inc), which was administered by a qualified optometrist under conventional fluorescent light and performed monocularly, with

all findings being recorded on the record sheet. The tests consists of 24 plates, with the first four being used for demonstration, and the remaining 20 being divided into three to test for problems CVD.

The procedures were explained to the students, with the demonstration plates(plates 1-4) being used to show them how the test and scoring worked. The students were asked to report how many symbols could be seen, what they were and where they were in the four corner areas. Except for the students who were colour vision deficient or malingering, they should see “OX” and “XΔ” in colour on the first two plates respectively, one coloured “O” in the third and no coloured symbol on the fourth.

The students were then told that the following 20 plates constituted the test, and that plate 5 contained one, two or no symbols. The screening plates (5-10) were then administered and the students were asked how many coloured symbols were seen, what and where they were. The responses were recorded as X O in the box provided for plate 5 on the scoring sheet, with the locations of the symbols being also recorded, as indicated by the students. If they correctly answered all three questions, a tick was placed beside the box by the examiner to indicate correct responses. However, if they made an error in answering any of the three questions, no tick mark was made.

A similar procedure was used with plates 6-10, turning the pages at about 3-second intervals, asking the students to answer the same questions as each page is turned. If all the six boxes were ticked to show correct responses, the student had normal colour vision and no more testing needed to be done. However, if plates 5 or 6 were not ticked, the student had defective blue-yellow vision and the examiner proceeded to show plates²¹⁻²⁴. If any of plates 7-10 were not ticked, the student has defective red-green vision and the examiner proceeded to show plates 11-20. If any plates of both screening groups (5-6 and 7-10) were not checked, the student was tested on all remaining plates (11-24). These 14 plates (21-24) provide diagnostic information as to the extent (mild, medium or strong) and type of defect (protan, deutan, tritan). Further information as applied to this procedure was adhered to as contained in the manual (HRR Instruction manual).¹⁸

Analysis

The data were coded and analysed anonymously using the Statistical Package for Social Sciences (SPSS) programme (SPSS for Windows, version 19; SPSS Inc., Chicago, Illinois, USA). Analysis was done with the assistance of a qualified statistician with descriptive and inferential statistics performed to compute prevalence and distribution of CVD with age and gender. A p value of less than 0.05 was considered statistically significant.

Ethical approval

Ethical approval to conduct the study was obtained from the Research Committee, Faculty of Life Sciences, University of Benin. Permission to conduct the study was also obtained from the Department of Education, Lagos State and the principals of the selected primary and high schools. Parents and/or legal guardians of the students who participated in this study signed consent forms, while the students provided informed assent. Confidentiality of data was maintained, and those found to have CVD were advised about their condition, and how it may affect their future choice of occupation or profession, as well as any other conditions that were identified during the various tests. Similarly, the parents/legal guardians of students who were found to have CVD were given feedback about their children's colour vision status.

Results

A total of 2326 primary and high school students participated in the study, their ages ranging from 7 to 22 years with a mean of 13.40 ± 2.40 years. There were 1014 (43.6%) male and 1312 (56.4%) female students, of whom 2268 (97.5%) had normal colour vision and 58 (2.5%) [95% CI: 1.1-3.6] had CVD. The prevalence of CVD was 49 (4.8%) [95% CI: 3.6-6.1] in males and 9 (0.7%) [95% CI: 0.4-0.9] in females. There was a statistically significant difference in the prevalence of CVD and male students ($p = 0.00$), but not statistically significant ($p = 0.22$) in the females. Of the 58 cases of CVD, 17 (0.7%) were protan, 38(1.6%) were deutan and three (0.1%) were unclassified. The prevalence of CVD was compared among younger and older students, with the differences among age groups not reaching statistical significance overall ($p = 0.08$). Table 1 shows the number and percentage of students with CVD stratified by age group and gender.

Table 1: Prevalence of CVD according to age and gender

Category	Total	Protans n (%)	Deutan n (%)	Unclassified n (%)	CVD n (%) [95%CI]	P-value
Age (years)						0.08
7 – 11	966	8(0.8)	11(1.1)	3(0.3)	12(2.2) [0.6-3.2]	
12 – 16	643	3(0.4)	12(1.9)	0	15(2.3) [0.8-3.3]	
17 – 21	717	6(0.9)	15(2.0)	0	21(2.9) [0.9-3.8]	
Gender						0.00
Male	1014	15(1.4)	31(3.2)	3(0.2)	49(4.8) [3.6-6.1]	
Female	1312	2(0.2)	7(0.5)	0	9(0.7) [0.4-0.9]	
Total	2326	17(0.7)	38(1.6)	3(0.2)	58(2.5) [1.1-3.6]	

Out of 58 affected students, 26 were mild deutans (1.12%), 10 were mild protans (0.43%) and three (0.1%)

could not be classified in any of sub-groups of red-green colour vision defects. The type and severity of CVD among the 58 (2.5%) students is shown in Table 2.

Table 2: Types and severity of CVD among the students

Type of colour blindness	Number of students (n)	Prevalence (%)
Mild protans	10	0.43
Mild deutans	26	1.12
Moderate protans	3	0.13
Moderate deutans	7	0.30
Strong protans	4	0.17
Strong deutans	5	0.14
Unclassified	3	0.10

Discussion

This study presents a detailed description of CVD for the first time among male and female primary and high school students in Lagos State, and thus provides the basic epidemiology of colour blindness in this region. Colour vision deficiency assessments enable patients to follow adaptive strategies that could minimise the risks associated with the disorder. Testing was done using the Richmond-HRR test, which is generally considered to be efficient for screening congenital CVD. In addition, the HRR test can reliably detect, categorise and grade the severity of the protan, deutan and tritan colour vision deficiencies.¹⁹ The Richmond-HRR is therefore not only a useful and simple diagnostic device, it also has sufficient sensitivity and specificity to allow investigators to use the results in a clinically meaningful way.¹⁹

The significance of normal vision involves absolute colour matching for many occupations.²⁰ For example, the traffic light signals are less obvious for deutans and protans, while deutan and protan individuals working with telecommunications and electric cables can recognise the blue and white wires but will be uncertain about the red, orange, brown and green.²⁰ Steward and Cole²¹ also reported that approximately 30% of people with abnormal colour vision had trouble judging the ripeness of fruit. The above suggests that colour perception is integral to an individual's understanding and engaging with the visual world, and those with these defects can experience hardships in everyday life. However, adaptive strategies and behaviours can help to deal with potential difficulties that CVD individuals face in both their professional and personal lives.³

The distribution of CVD was fairly consistent across the age categories (7-11: 2.2%, 12-16:2.3%, 17-22: 2.9%). Although this shows an increase in the prevalence of the defect with increasing age, the difference was not statistically significant ($p=0.08$). As CVD is a hereditary defect,

the prevalence in different age groups is statistically insignificant ($p > 0.05$). Table 3 provides an overview of CVD prevalence data in selected studies and an opportunity to compare our findings with those of other age, race and ethnic groups.

Table 3: Characteristics of colour vision defects reported compared with the findings of our study

Study	Ethnicity	Instrument used	Number	Age (years)	Overall prevalence	Prevalence (95% CI)	
						M	F
Africa			M/F			M	F
Present study	Nigerian	Richmond-HRR	1014/1312	7-22	2.5	4.8	0.7
Ugalahi et al ¹⁰	Nigerian	Ishihara, FM D-15	769/866	13.9±1.9	2.3	3.8	0.9
Abah et al ¹¹	Nigerian	Ishihara	149/178	5-17	1.5	N/R	N/R
Tabansi et al ¹²	Nigerian	Ishihara	N/R	N/R	2.6	N/R	N/R
Zein ²²	Ethiopian	Ishihara	954/1054	8-24	2.08	4.2(2.93-5.47)	0.2(0-0.45)
Rahman et al ²³	Libyan	Ishihara	163/179	17-24	N/R	1.841	0
Pickford and Pickford ²⁴	South African Zulu	Ishihara	N/R	N/R	N/R	3.337	0.233
Applemans ¹³	Congolese	Ishihara	N/R	N/R	1.8	N/R	N/R
Simon ¹⁴	Ugandan	N/R	N/R	N/R	1.9	N/R	N/R
Alrasheed et al ¹⁵	Sudanese	Ishihara	544/556	10-80	3.5	6.8(5.2-8.4)	0.6(1.0-2.2)
Asia/Middle East							
Qian et al ⁹	Chinese	Ishihara, FM 100	5819	N/R	N/R	4.46	0.65
Shah et al ²⁵	Indian	Ishihara	2674	N/R	N/R	8.73	1.69
Modaress et al ²⁶	Iranian	Ishihara	1136/922	12-14	N/R	8.18	0.43
Al-Aqtum and Al-Qawasmeh ²⁷	Jordanian	Ishihara	1200/218	18-27	N/R	8.7(4.97-12.47)	0.33(0.01-0.65)
Oriowo and Alotaibi ²⁸	Saudi Arabian	Ishihara	838/800	6-19	N/R	5.85(4.26-7.44)	0.75(0.15-1.35)
Mian et al ²⁹	Punjabi	Ishihara	214	N/R	N/R	4.89(0.0-0.0)	N/R
Chia et al ³⁰	Singaporean	Ishihara	1249	13-15	N/R	5.3	0.2
Europe							
Norn ³¹	Danish	Ishihara	173/186	N/R	N/R	8.67(4.48-12.86)	0.54(0-1.59)
	Inuit	Ishihara	290/250	N/R	N/R	1 (0-2.19)	0.4(0.3-1.18)
Malaspina et al ⁸	Caucasian	Ishihara	3285	13-20	N/R	6.10(5.28-6.92)	N/R
Rebato and Calderon ³²	Basque	Ishihara	174/218	15-25	N/R	4.02(1.1-6.94)	0.46(0-1.36)
Oceania							
Grosvenor ³³	Caucasian	Ishihara	817	N/R	N/R	6.50(4.81-8.19)	N/R
	Polynesian	Ishihara	571	N/R	N/R	2.60(1.29-3.91)	N/R

The prevalence of CVD detected in the present study was 2.5% (58 of 2326 students), comparable to the 2.3% reported in Ibadan, South West Nigeria¹⁰ and the 2.6% reported in Port Harcourt, Southern Nigeria¹² but higher than the 1.5% found in Zaria, Northern Nigeria¹¹ (Table 3). Ethnically based studies that were conducted in Asia, Europe and Oceania reported higher prevalence of CVD than the current study, which could be due to racial differences. This suggests that CVD varies among races and geographical regions of the world.

In this study, the prevalence of CVD was higher among males (4.8%) than females (0.7%) with a significant asso-

ciation between gender and CVD ($p < 0.05$). This is an expected finding as CVD is a genetic disorder transmitted through the sex-linked recessive X chromosome.^{2,32} There were no congenital tritans observed in this study; this type of CVD is reported to occur very rarely, with a prevalence of 1:15 000 to 1:50 000 (0.002-0.007%) of the population.^{1,2} Although in some careers a CVD does not debar entry, it can be an impediment, specifically in those occupations that involve colour matching such as in industries (paint, textile, plastic, decorates, furniture), transport (rail, road, aviation, maritime), defense (police, armed force, fire and rescue services) and other occupations (electricians, technicians, telecommunications, me-

chanics).³⁴ Early detection of CVD is therefore important in making decisions about future career choices. It is also important for parents and teachers to make necessary adjustments during teaching to ensure effective learning of those with CVD.

All the colour vision deficient students in this study were not aware of their status, which could negatively affect their daily lives and future careers choices. It is suggested that students diagnosed with CVD be counselled concerning the effects of defective colour vision on activities of daily living, learning progress and occupations that require critical colour judgment. Eye care practitioners and occupational therapists should advise CVD patients at an early age to find adaptive strategies that will enable them to make appropriate choices about activities of daily living and future occupations. Finally, colour vision testing should form part of routine eye examination, as its assessment also helps to determine the functional and structural integrity of the visual system. The findings highlight the need to include vision screening as part of a comprehensive school health programme, specifically in poor communities that are unlikely to be able to afford to pay for such services. Colour vision deficiency is only one of many vision problems that could affect students and impact on their activities of daily living and school work. Every effort needs to be made to keep students in school to enable them to maximise their adult life opportunities, and to prevent avoidable dropouts due to vision problems that could have been addressed with a simple eye test.

Conclusion

An overall prevalence of congenital CVD of 2.5% was found to be similar to other Nigerian studies in Ibadan (South West) and Port Harcourt city (South) but differs from that in Zaria (North), and highlights the need to conduct local studies to establish regional vision baselines to inform policies and against which changes can be monitored over time. The inclusion of colour and other vision screening in school eye health may ensure early detection of students with CVD in order to offer them appropriate vocation and career guidance.

Conflict of interest

None declared.

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