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# Prevalence and population genetic data of colour vision deficiency among students from selected tertiary institutions in Lagos State, Nigeria

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## Abstract

**Background:** Colour vision deficiency (CVD), also referred to as colour blindness, is the failure or decreased ability to distinguish between certain colours under normal lighting conditions. It is an X-linked genetic disorder with varying degrees of prevalence in different populations. There is presently no report on the prevalence of CVD among students of the selected tertiary institution. Hence, the present study was aimed at determining the occurrence and genetics of CVD among students from designated tertiary institutions in Lagos state. A cross-sectional survey was employed in recruiting 1191 study subjects from three tertiary institutions in Lagos, Nigeria.

**Results:** The overall occurrence of CVD among the study participants was 2.85%. There were 24 (4.29%) males and 10 (1.58%) females affected. Among the colour vision deficient individuals, 18 (1.51%) and 16 (1.34%) were deuteranomalous and protanomalous, respectively. Also, the prevalence of CVD varies across ethnic groups of the studied subjects with the highest occurrences (3.57%) observed in the Yoruba ethnic subpopulation and the least (1.45%) among the Hausas.

**Conclusions:** More males than females were found to be colour vision deficient, and there were more deutans than protans. Early screening for CVD should be encouraged among school children to guide the choice of future profession and help mitigate work hazards resulting from being colour deficient.

**Keywords:** Colour blindness, Wavelength, Allele frequency, Tertiary institutions, Lagos state

## Background

Colour vision deficiency (CVD) describes the failure of an individual to see traditionally, resulting from the failure of the retinal cones to discriminate the different wavelength stimuli [1, 2]. CVD has been used interchangeably with the term "colour blindness" to describe poor visual functions of the cone opsin genes responsible for colour perception [3, 4]. The physiological substrate of colour vision is the cone receptors of which there are three classes, each with different sensitivities to light wavelength including the blue cone—short wavelength, 420 nm; the green cone—medium wavelength, 530 nm; and the red cone—long wavelength, 560 nm [5, 6]. There are three main forms of CVD, namely red–green, blue–yellow and total colour blindness with red–green CVD being the most common of all [7]. Deuteranopia and protanopia, collectively referred to as red–green colour blindness, are a form of inherited colour vision deficiency where the ability to discriminate colour in the red–green region is lacking. This arises from the absence of M (deutan) or L (protan) pigments in the cone cells [8, 9]. Red–green colour blindness affects 5–8% of males and 0.5–1%

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of females globally and is transmitted to offspring via the X chromosome (*Xq28*) [4, 10].

Colour vision deficiency may be congenital (inherited) or acquired. While congenital colour vision deficiency (CCVD) arises from genetic disorder that affects the expression of the full complements of the cone genes, acquired colour deficiency results from environmental factors such as trauma, exposure to chemicals or reaction to certain medications [6, 11, 12]. The incidence of CCVD differs as per population, ethnicity and gender with a higher occurrence in males. Although statistics vary across different groups and geographical locations, the incidence CVD is less than 2% in native Americans and Australians, whereas it is 4% in Africans, 5% in Asian populations and about 8% in Caucasians [7]. However, the incidence is fast increasing among African descents. Red–green colour deficiency cannot be treated since this type of colour defect is non-pathologic. It is incurable and persists throughout life [13].

Because colour blindness is an asymptomatic and non-fatal disorder, most sufferers are usually unaware of the defect since their vision is otherwise normal. However, early diagnosis of CVD is important for preparing colour-blind individuals for future careers and to avoid mistakes in situations that might involve lives. In some jobs such as medical practices, traffic warden and driving, colour discerning has profound implications. Hence, it is essential that CVD is detected at an early age so as to guide against certain occupational hazards. The present study is aimed at providing a detailed description of colour vision deficiency among students from various tertiary institutions in Lagos, Nigeria, with a view to providing basic epidemiological and genetic data of colour blindness in this region where there is presently no report on the prevalence of CVD among tertiary institution students.

## Materials and methods

### Study subjects

The study was carried out among tertiary institution students in Lagos, Nigeria. Study subjects comprise students from the three major Nigerian ethnic groups—Hausa, Igbo and Yoruba. The Hausa form the largest ethnic group in Nigeria. They are a diverse but culturally homogenous people found primarily in the sparse savanna region of northern Nigeria. Over the years, the Hausas have traversed to other parts of Nigeria and other parts of Africa. The Yoruba are an ethnic population that inhabits Western Africa (Benin republic and Togo) and predominantly in south-west Nigeria. They account for up to 21% of Nigeria's population making them one of the largest ethnic groups in the country. The Igbos are native to the present-day south-east Nigeria with a significant number now found in other parts of the country including Lagos, Port Harcourt, Abuja. The Igbo ethnic group ranks third largest among the over 250 ethnic groups in the country.

### Ethical consideration

Approval for the study was granted by the Health Research Ethics Committee, College of Medicine of the University of Lagos (CMUL/HREC/06/21/857) before commencement. Before the actual investigation, informed consent was duly obtained from all participants after the aim and scope of the study were carefully explained to them. Only subjects who gave consent were recruited for the study. Protection of personal information of participants was maintained at all times.

### Sample size determination

Sample size was calculated according to Charan and Biswas [14].

$$\frac{Z^2_{1-\alpha/2}P(1-P)}{d^2} \tag{1}$$

$Z_{1-\alpha/2}$ = confidence level of 95% (1.96 $z$-score), $P$ = population proportion variance (0.5), $d$ = precision or confidence interval of 5% (0.05)

$$\text{Hence,} \quad \frac{(1.96)^2 \times 0.5 \times (1-0.5)}{0.05^2} = 384$$

### Sampling technique and inclusion/exclusion criteria

The study employed a cross-sectional sampling technique in recruiting 1191 participants aged 18–39 years from three higher institutions in Lagos state, Nigeria. These included the Federal College of Education—Technical, FCE(T); University of Lagos, UNILAG and Yaba College of Technology, YABATECH. There were 392 students recruited from FCE(T), 399 from UNILAG and 400 from YABATECH. All study participants are male and female Nigeria nationality. Individuals with obvious visual impairment, as well as albinisms, were excluded from the study.

### Colour vision deficiency test

CVD was determined using plates 1–17 of the 24-plate edition of the Pseudoisochromatic Ishihara colour vision test plates. Participants were screened 75 cm from the plate under natural daylight conditions. The subjects were asked to read and record what they observed from the numbers seen in the test plates 1–17. A data collection leaflet was specifically designed to capture each participant's observation as well as their demographic data. Colour vision assessment (normal or defective) was based on the readings of the first 15 of the Ishihara plates.

To be adjudged normal vision, an individual is expected to read at least 13 plates correctly. Individuals who can read only 9 or fewer plates correctly were classified to be colour (red–green) deficient, while plates 16 and 17 were used to categorize the form (protan or deutan) of colour vision deficiency.

### Data analysis

Relevant descriptive statistical analyses were performed using the IBM Statistical Package for Social Sciences (SPSS version 26). The Chi-square ($\chi^2$) test was used to determine the significant differences at 0.05 significance level. Allelic and genotypic frequencies of the normal ($p$) and affected ($q$) alleles were determined according to Hardy–Weinberg rules on the assumption that the populations are in equilibrium as previously done by Fareed et al. [15].

$$\text{Allele frequency: } p + q = 1 \tag{2}$$

$$\text{Genotype frequency: } p^2 + 2pq + q^2 = 1 \tag{3}$$

(a) For male gender:

$$q = \frac{\%\ \text{colour blindness}}{100}$$

Then, $p = 1 - q$.

(b) For female gender:

$$q = \frac{\sqrt{\%\ \text{colour blindness}}}{100}$$

Hence, $p = 1 - q$.

(c) For male and female gender:

$$q = \frac{1}{3} \times q\ (\text{male}) + \frac{2}{3} \times q\ (\text{female})$$

Therefore, $p = 1 - q$.

## Results

### Demographic and prevalence data

This study was carried out among students of UNILAG, FCE(T) and YABATECH. A total of 1191 (559 males and 632 females) subjects participated in the study. These included 392 (167 males, 225 females) students from FCE(T), 399 (196 males, 203 females) from UNILAG and 400 (196 males, 204 females) from YABATECH, as highlighted in Table 1.

Table 2 highlights the prevalence of colour vision deficiency among male and female students from the studied higher institutions. Of the total study subjects, 34 individuals including 24 males and 10 females had colour vision deficient. This represents 2.85% of the sample population. The prevalence of colour blindness in male and female students was 4.29% and 1.58%, respectively. On an institutional basis, colour vision deficiency was most prevalent (17, 4.25%) among YABATECH students, while the least occurrence was observed among UNILAG students with a frequency of 2.01%. Among males, YABATECH students show the highest frequency of 11 (5.61%) while FCE(T) males have the least frequency of 5 (2.99%). This is also the same pattern among the female students with YABATECH having the highest prevalence rate of 2.94% among its female students while no female FCE(T) students had CVD with a 0% prevalence rate.

**Table 1** Information on study subjects

| Variables | *n* (%) |
|---|---|
| Institutions | |
| Federal College of Technology Technical, FCE(T) | 392 (32.9) |
| University of Lagos, UNILAG | 399 (33.5) |
| Yaba College of Technology, YABATECH | 400 (33.6) |
| Gender | |
| Male | 559 (46.9) |
| Female | 632 (53.1) |
| Ethnicity | |
| Hausa | 69 (5.8) |
| Igbo | 229 (19.2) |
| Yoruba | 700 (58.8) |
| Others | 193 (16.2) |

From the results obtained for the prevalence of different types of CVD by gender presented in Table 3, the frequencies of deuteranope and protanope individuals in the combined population of study subjects were 1.5% and 1.34%, respectively, with YABATECH students having the highest occurrence of protanomaly of 9 (2.25%). Deutan was 2.33% prevalent among the male students while protan prevalence was 1.97%. For the female students, however, there was a joint 0.79% prevalence of both anomalies, i.e. deuteranomaly and protanomaly.

Table 4 highlights the prevalence of CVD among the ethnic population of the three institutions. The prevalence of CVD was high among students of Yoruba ethnic group with a frequency of 25 (3.57%) when compared to the others ethnic groups, followed by the Igbo ethnic group with 6 (2.62%) and Hausa's 1 (1.45%) while the combined ethnic groups had the lowest prevalence of 1.04%. Evaluation of frequency of CVD among the institutions as per ethnicity showed that for the Hausa population, CVD was most prevalent among the FCE(T) students with 3.70% while none was recorded for

**Table 2** Prevalence of colour vision deficiency among male and female students of FCE(T), UNILAG and YABATECH

| Institution | Combined | | | Male | | | Female | | |
|---|---|---|---|---|---|---|---|---|---|
| | Normal *n* (%) | CVD *n* (%) | Total | Normal *n* (%) | CVD *n* (%) | Total | Normal *n* (%) | CVD *n* (%) | Total |
| FCE(T) | 383 (97.70) | 9 (2.30) | 392 | 162 (97.01) | 5 (2.99) | 167 | 221 (98.22) | 4 (1.78) | 225 |
| UNILAG | 391 (97.99) | 8 (2.01) | 399 | 188 (95.92) | 8 (4.08) | 196 | 203 (100.00) | 0 (0.00) | 203 |
| YABATECH | 383 (95.75) | 17 (4.25) | 400 | 185 (94.39) | 11 (5.61) | 196 | 198 (97.06) | 6 (2.94) | 204 |
| Total | 1157 (97.15) | 34 (2.85) | 1191 | 535 (95.71) | 24 (4.29) | 559 | 622 (98.42) | 10 (1.58) | 632 |

**Table 3** Prevalence of different types of CVD among male and female students of FCE(T), UNILAG and YABATECH

| Institution | Combined | | | Male | | | Female | | |
|---|---|---|---|---|---|---|---|---|---|
| | Deutan *n* (%) | Protan *n* (%) | Total | Deutan *n* (%) | Protan *n* (%) | Total | Deutan *n* (%) | Protan *n* (%) | Total |
| FCE(T) | 5 (1.28) | 4 (1.02) | 392 | 3 (1.80) | 2 (1.20) | 167 | 2 (0.89) | 2 (0.89) | 225 |
| UNILAG | 5 (1.25) | 3 (0.75) | 399 | 5 (2.55) | 3 (1.53) | 196 | 0 (0.00) | 0 (0.00) | 203 |
| YABATECH | 8 (2.00) | 9 (2.25) | 400 | 5 (2.55) | 6 (3.06) | 196 | 3 (1.47) | 3 (1.47) | 204 |
| Total | 18 (1.51) | 16 (1.34) | 1191 | 13 (2.33) | 11 (1.97) | 559 | 5 (0.79) | 5 (0.79) | 632 |

**Table 4** Prevalence of colour vision deficiency among different ethnic groups of the students of FCE(T), UNILAG and YABATECH

| Institution | Hausa | | | Igbo | | | Yoruba | | | Others | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Normal *n* (%) | CVD *n* (%) | Total | Normal *n* (%) | CVD *n* (%) | Total | Normal *n* (%) | CVD *n* (%) | Total | Normal *n* (%) | CVD *n* (%) | Total |
| FCE(T) | 26 (96.30) | 1 (3.70) | 27 | 69 (98.57) | 1 (1.43) | 70 | 231 (97.06) | 7 (2.94) | 238 | 57 (100.00) | 0 (0.00) | 57 |
| UNILAG | 17 (100.00) | 0 (0.00) | 17 | 86 (100.00) | 0 (0.00) | 86 | 237 (97.13) | 7 (2.87) | 244 | 51 (98.08) | 1 (1.92) | 52 |
| YABATECH | 25 (100.00) | 0 (0.00) | 25 | 68 (93.15) | 5 (6.85) | 73 | 207 (94.95) | 11 (5.05) | 218 | 83 (98.81) | 1 (1.19) | 84 |
| Total | 68 (98.55) | 1 (1.45) | 69 | 223 (97.38) | 6 (2.62) | 229 | 675 (96.43) | 25 (3.57) | 700 | 191 (98.96) | 2 (1.04) | 193 |

**Table 5** Prevalence of different types of colour vision deficiency among different ethnic groups of the students of FCE(T), UNILAG and YABATECH

| Institution | Hausa | | | Igbo | | | Yoruba | | | Others | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Deutan *n* (%) | Protan *n* (%) | Total | Deutan *n* (%) | Protan *n* (%) | Total | Deutan *n* (%) | Protan *n* (%) | Total | Deutan *n* (%) | Protan *n* (%) | Total |
| FCE(T) | 1 (3.70) | 0 (0.00) | 27 | 1 (1.43) | 0 (0.00) | 70 | 3 (1.26) | 4 (1.68) | 238 | 0 (0.00) | 0 (0.00) | 57 |
| UNILAG | 0 (0.00) | 0 (0.00) | 17 | 0 (0.00) | 0 (0.00) | 86 | 5 (2.05) | 2 (0.82) | 244 | 0 (0.00) | 1 (1.92) | 52 |
| YABATECH | 0 (0.00) | 0 (0.00) | 25 | 3 (4.11) | 2 (2.74) | 73 | 4 (1.83) | 7 (3.21) | 218 | 1 (1.19) | 0 (0.00) | 84 |
| Total | 1 (1.45) | 0 (0.00) | 69 | 4 (1.75) | 2 (0.87) | 229 | 12 (1.71) | 13 (1.86) | 700 | 1 (0.52) | 1 (0.52) | 193 |

UNILAG and YABATECH students from the same ethnic group. For Igbo population, the incidence of CVD was highest among YABATECH student and lowest (none) from UNILAG students. All students from the Yoruba ethnic population had colour vision deficiency with students from YABATECH leading with 5.05% followed by FCE(T), 2.94% and UNILAG, 2.87%.

Table 5 shows the result of the two types of CVD observed in the study, i.e. protanomaly and deuteranomaly, among the different ethnic groups of students. For protanomaly, the ethnic group with the highest

colour blindness deficiency frequency is the Yoruba ethnic group with a frequency of (1.86%) with YABATECH students having a higher frequency of (3.21%) followed by FCE(T) (1.68%) then UNILAG having the lowest frequency of 0.82%. The least protanomaly frequency was observed in Hausa ethnic group 0% as no single student was colour blind. Whereas for deuteranomaly, the ethnic group with the highest colour frequency is the Igbo ethnic group with a frequency of (1.75%) with YABATECH students having a higher frequency of 4.11% followed by FCE(T) (1.43%) and UNILAG had the lowest frequency of 0%. The least deuteranomaly frequency was observed among students from Hausa ethnic group having a frequency of 1.45% with FCE(T) students having a higher frequency of 3.7%, while both UNILAG and FCE(T) students had 0%.

### Population genetic data

Figure 1a, b, c shows the allelic frequencies of colour vision deficiency among the male, female and combined population of students from the studied institutions. The frequency of the normal allele, *p*, was in the order FCE(T) > UNILAG > YABATECH from highest to lowest while the frequencies of allele *q* followed the opposite trend. Among the female students, the frequencies for alleles *p* and *q* were 0.99 and 0.01 for FCE(T), 1.00 and 0.00 for UNILAG, and 0.98 and 0.02 for YABATECH. The combined frequencies for allele *p* were 0.98, 0.99 and 0.97 for FCE(T), UNILAG and YABATECH, respectively, while allele *q* had 0.02, 0.01 and 0.03 accordingly.

In determining the genotypic frequencies, since a normal human male has a single X chromosome, the genotypic frequencies in males will be the same as the allelic frequencies for both *p* and *q*. However, the allele can recombine in females to form $p^2$ (homozygous dominant), *pq* (heterozygous dominant) and $q^2$ (homozygous recessive) as presented in Table 6. Consequently, the genotypic frequencies of $p^2$ were 0.9734 for FCE(T), 1.00 for UNILAG and 0.9660 for YABATECH. The heterozygote *pq* was highest in YABATECH with a genotypic frequency of 0.0169 followed by 0.0132 among FCE(T) students and 0.00 for UNILAG. The $q^2$ genotype had 0.02% in FCE(T), none in UNILAG and 0.03% in YABATECH (Table 6).

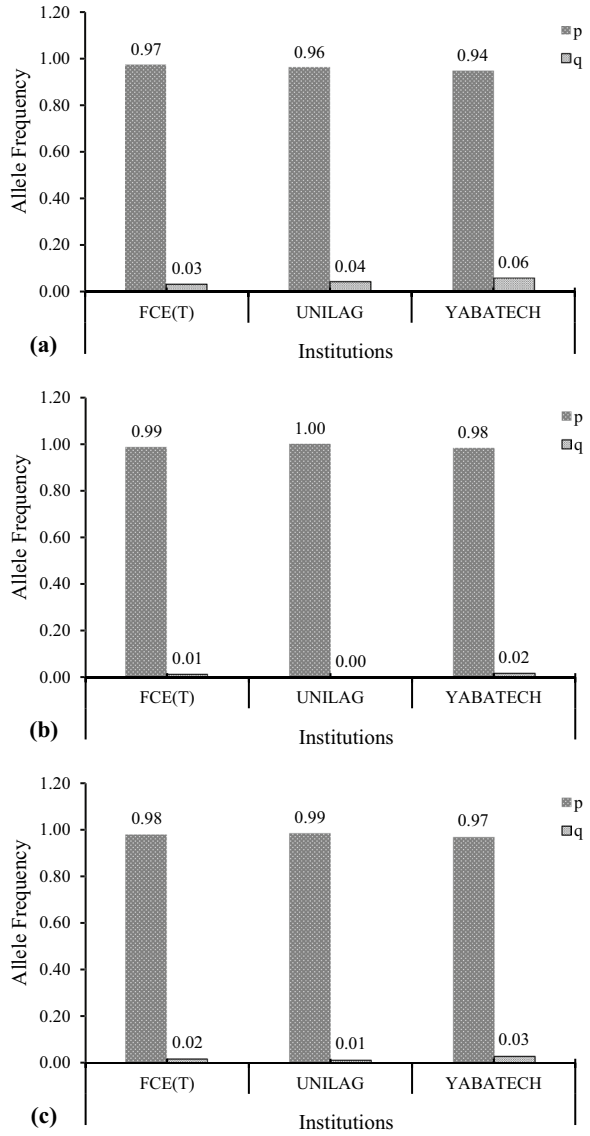


**Fig. 1** Allelic frequencies of colour vision deficiency among male (**a**), female (**b**) and combined population (**c**) of students of the studied institutions

**Table 6** Genotypic frequencies of colour vision deficient male and female subjects

| Institutions | Male | | Female | | |
|---|---|---|---|---|---|
| | *p* | *q* | $p^2$ | *pq* | $q^2$ |
| FCE(T) | 0.9701 | 0.0299 | 0.9734 | 0.0132 | 0.0002 |
| UNILAG | 0.9592 | 0.0408 | 1.0000 | 0.0000 | 0.0000 |
| YABATECH | 0.9439 | 0.0561 | 0.9660 | 0.0169 | 0.0003 |
| Average | 0.9577 | 0.0423 | 0.9798 | 0.0100 | 0.0002 |

## Discussion

Colour vision is prominent in understanding the visual world, and it is highly important in many occupations. For example, deuteranomals and protanomals are not able to distinguish the red and green traffic signals because their perception of these lights is poor. Also, red–green colour deficient persons working with electrical cables and telecommunication cannot clearly

distinguish the red, brown, orange and green cables. Also, a high number of people with CVD have problems telling the ripeness of fruits. As a result, people living with CVD are barred from certain occupations to prevent potential job hazard and/or for quality assurance purposes [16–19].

This study highlights the prevalence and genetics of CVD among Nigerian tertiary institution students in Lagos state. The overall prevalence of colour vision deficiency in the present study was 2.85%. This is in agreement with the findings of Mitiku et al. [20] who reported 2.85% CVD prevalence among students at Hawassa University, Ethiopia. Other studies from Nigeria and other countries that somewhat agree with this result include those of Aprioku and Awoyesuku [21] among secondary school students in River state, Southern Nigeria. Balasundaram and Reddy [22] also reported a prevalence of 2.6% among primary school children in Selangor, Malaysia. Similarly, Oduntan et al. [1] reported a prevalence of 2.5% in the research carried out among selected primary and secondary students in Lagos. The slight differences noted may have been as a result of the differences in sample size.

Differing from this study, Chia et al. [23] reported a higher prevalence (5.3%) among Singaporean children while Kim et al. [24] observed 5.9% among Korean males. The incidence of CVD in the present study is also lower to those reported among school children in Central [2] and Southern Ethiopia [25] with prevalence of 4.2% and 4.1%, respectively. Furthermore, Shah et al. [9] reported a higher prevalence (5.8%) in Manipur, India, compared to our result. On the contrary, a study by Ugalahi et al. [26] had a lower prevalence of 2.3% among secondary school students in Ibadan. Abah et al. [27] obtained a lower prevalence 1.5% among schoolchildren in Zaria, Northern Nigeria. Likewise, Ayanniyi et al. [28] reported a lower frequency of 1.2% in Ilorin. No case of total blindness was found in this study which conforms with the view this particular type of vision deficiency is a rare autosomal trait. The difference in the occurrence of colour vision deficiency in the present and previous studies may be attributed to several factors such sampling and analytical techniques as well as racial differences [20, 25]. Studies have shown that the prevalence of red/green colour blindness is different among different races, tribes and ethnicities as higher prevalence had been documented among Caucasians compared to African populations [7].

In the present study, fewer females than males are colour vision deficient in all the studied institutions. The prevalence of CVD ranged from 2.99 to 5.61% among males and between 0 and 2.94% among females indicating a gender-specific pattern of inheritance. The reported prevalence of CVD 4.29% among the male students is in tandem with the results obtained in different Indian populations [11, 29]. Similarly, several authors have reported higher prevalence of CVD among males than females [30–32]. The higher incidence of this disorder among males is not unexpected since colour blindness is an X-linked recessive disorder. This type of trait usually affects more males than females because males have one X chromosome; hence, there is no second X chromosome to counter the effect of the recessive allele. Females will have to be homozygous recessive to exhibit the disorder. The single X chromosome in males, if affected, is predominant to colour blindness, while females with two X chromosomes can compensate for an affected X chromosome, thereby decreasing the risk of CVD.

This study further shows that deutan occurs in higher percentage than protan. The overall incidences of deuteranomaly and protanomaly are 18 (1.51%) and 16 (1.34%), respectively. Deutan was the most common type of CVD when compared among the different gender, with a rate of 2.33% among male and 0.79% among females. The prevalence of protan was 1.97% among males and 0.79% among females. This finding is in arrangement with several researches carried out in various countries such as Jordan [33], India [34] and River state, Nigeria [21], where the most prevalent pattern of CVD was the deutan type.

A 1998 study by Bowmaker [35] pointed out that the most common form of anomalous colour vision is deuteranomaly. Deuteranomaly has been reported as the most prevalent type of red–green colour anomaly by several authors [36–38]. Individuals suffering from deuteranomaly and protanomaly find it difficult to perceive red, orange, brown and green colours; they only recognize blue and white colours. Individual with this defect can experience hardship in everyday life as colour perception is important to an individual in understanding the visual world. Different factors contribute to the prevalence of CCVD between different populations and regions, and this factor includes population movement, the molecular genetics of the gene on the X chromosome, and natural selection.

In this study, colour blindness in the combined student's population is more prevalent among the Yoruba ethnic group (3.57%), followed by the Igbo ethnic group with 2.62% and Hausa's 1.45%. Diverse frequencies of colour vision deficiency have previously been reported for different ethnic groups, race and tribes [15, 20]. In a separate study, the frequencies of 1.81% in Northern Nigeria are predominantly occupied by the Hausas, 3.3% in the Yoruba's south-west Nigeria and 2.11% in the Niger delta region. Among the colour-blind subjects, the incidences of deuteranomaly and protanomaly vary per ethnic group. Overall, deutan incidences

range from 1.45% in the Hausa population to 1.75% in the Igbo subjects, while protans vary from zero per cent in Hausa to 1.86% in Igbo. Other population groups have a joint 0.52% prevalence for protanomaly and deuteranomaly. It can be stated that there is no significant difference in the prevalence of colour blindness among Nigerian populations notwithstanding the geographical differences. Odeigah and Okon [39] posited that the prevalence of colour blindness cannot be accounted for based on ethnic composition of samples.

## Conclusions

The prevalence of colour vision deficiency among the students in the study area was of 2.85%. The percentage of CVD was higher among males 4.29% as compared to females 1.58%. Students' awareness of CVD status was found to be very low. This indicates the need for establishing continuous visual screening programmes among school students. As a recommendation, screening for CVD should be carried out early in students before admission into tertiary institutions to help in career choices for colour blind individuals.

### Abbreviations

CVD: Colour vision deficiency; CCVD: Congenital colour vision deficiency.

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### Authors' contributions

STF, KOA and BO contributed to conceptualization; LGA contributed to data curation; STF and KOA contributed to formal analysis; LGA contributed to investigation; STF and KOA contributed to methodology; STF, KOA and BO contributed to project administration; STF contributed to supervision; validation; and visualization; STF contributed to roles/writing—original draft; KOA and BO contributed to writing—review and editing. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript. All authors read and approved the final manuscript.

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### Availability of data and materials

The data sets used analysed during the current are available from the corresponding author on reasonable request.

## Declarations

### Ethics approval and consent to participate

This study was approved by Health Research Ethics Committee of College of Medicine, University of Lagos (CMUL/HREC/06/21/857).

### Consent for publication

Not applicable.

### Competing interests

The author declares that he has no competing interests.

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