African Vision and Eye Health
ISSN: (Online) 2410-1516, (Print) 2413-3183

Colour vision defects among South African male students and its impact on quality of life

Authors:
Rekha Hansraj[1]
Nonkululeko M. Gcabashe[1]
Nicale Chetty[1]
Xoliswa Hlabisa[1]
Anele Hlongwane[1]
Thobile Ngubane[1]
Mayuri Ramchurran[1]
Zandisile Nxumalo[1]

Affiliations:
[1]Department of Optometry, Faculty of Health Sciences, University of KwaZulu-Natal, Durban, South Africa

Corresponding author:
Rekha Hansraj,
hansrajr@ukzn.ac.za

Dates:
Received: 09 Jan. 2025
Accepted: 06 May 2025
Published: 18 July 2025

How to cite this article:
Hansraj R, Gcabashe NM, Chetty N, et al. Colour vision defects among South African male students and its impact on quality of life. Afr Vision Eye Health. 2025;84(1), a1031. https://doi.org/10.4102/aveh.v84i1.1031

Background: Colour vision defects are expected to have a negative impact on daily activities, education, misguided career choices, and mental and social well-being. Its prevalence among university students in South Africa remains unknown.

Aim: This study aimed to investigate the prevalence of colour vision deficiency (CVD) among male university students and its adverse effects on education, emotions, social life and everyday tasks.

Setting: The study was conducted in all colleges of the selected university.

Methods: Purposive sampling was used to select 272 male students aged 18–30 years, at all colleges of University of KwaZulu-Natal (UKZN). The Hardy-Rand-Rittler colour vision test (HRRT) and Ishihara colour vision test were used for the assessment of colour vision. The CVD-AES questionnaire was used to assess the adverse effects on participants with CVD in four subscale areas, viz. education, social life, emotion, and everyday tasks.

Results: A total of 272 male students, with a mean age of 20.61 years (s.d. = 2.08), participated. The occurrence of CVD was noted in 19 (7%) participants, with the majority (74%) being unaware of this defect. The most common type of defect was deutan (6.5%). Participants' responses indicated adverse effects on education, emotions, social life and everyday tasks, with CVD having a greater impact on the latter two.

Conclusion: The occurrence of CVD among male university students is significant, with many of them being unaware of it. Social life is most adversely affected, but adverse effects are noted in all subscales.

Contribution: This study provides further evidence to the prevalence of colour vision deficiency and its impact on quality of life.

Keywords: colour vision; colour vision deficiency; colour vision defect; quality of life; male; prevalence; CVD-AES questionnaire; adverse effect; impact.

Introduction

Colour vision (CV) is the ability to differentiate and thus perceive varying wavelengths of the light transmitted, emitted or reflected by objects.[1] The ability to differentiate these wavelengths, leading to CV, results from the combination of three classes of cone photoreceptors located within the retina, namely the long-wavelength sensitive cones (L), medium-wavelength sensitive cones (M), and short-wavelength sensitive cones (S). To see colour, light that reaches the retina is absorbed by the varying pigments in these three different photoreceptors.[2] A loss of the ability to perceive a certain wavelength or wavelengths of light and thus the inability to see certain colours or perceive their differences, resulting from an absence or malfunction of one or more photoreceptors, is termed colour vision deficiency (CVD), and it can be congenital or acquired. Congenital CVD is an X-linked chromosome condition affecting one or all three cone photoreceptors.[3,4] Acquired CVD may be related to ocular pathology, systemic conditions or ailments, and ocular side effects of certain medications such as ethambutol, toxic effects of chemicals (organic solvents, styrene, mercury, etc) and ocular trauma, while congenital defects are linked to inherited abnormalities of the photopigments rather than ocular pathology.[1] Clinically, congenital CVD may be present at birth, bilateral, stable and asymptomatic, while acquired defects may develop at any point in life, be unilateral or bilateral, progressive, and be symptomatic, including a reduction in visual acuity and visual fields.[5]

The basis of colour is differences in the peak sensitivities of the three classes of cones, with L-cones having a peak sensitivity of approximately 560 nm, M-cones approximately 530 nm and S-cones approximately 430 nm.[1,5] This difference in peak sensitivities results in L-cones having a greater

sensitivity to the colour red, M-cones to green and S-cones to blue.[1] Colour vision deficiency is therefore classified according to which cones are absent or malfunctioning. With respect to L-cones, an absence is termed protanopia and malfunction protanomaly, while in the absence of M-cones, the condition is termed deuteranopia and malfunction deuteranomaly, and in the absence of S-cones, the condition is termed tritanopia and tritanomaly in the case of a malfunction.[1] An absence of the cone will result in the inability to detect the colour that the cone is most sensitive to, while a malfunction will result in reduced perception of the colour that the cone is most sensitive to.[6] The aforementioned can be diagnosed during colour vision testing, which is not always included in South Africa, although it is recommended as part of a basic eye examination by the Professional Board for Optometry and Dispensing Opticians of the Health Professions Council of South Africa, leaving many individuals unaware of their colour vision status.[7,8,9]

Overall, a prevalence of CVD between 1.7% and 6.3% has been recorded across a range of studies, which included both male and female participants, over the past few years, including: 6.3% among Iranian industry workers,[10] 2.1% in Saudi university students,[8] 2.85% in Nigerian university students,[11] 4.1% in Ethiopian school children,[12] 3.9% in a Korean population,[13] 2.76% in South Indian school boys[14] 1.7% in Nigerian university students,[9] a 4.7% pooled prevalence in Iranian male students and 0.7% in female students following a meta-analysis on children aged 7 –18 years.[15]

As congenital CVD is X-linked recessive, it has been noted predominantly in male individuals, although it is transmitted by female individuals, with 8% of the female population being carriers.[16] The prevalence of CVD worldwide in the male population was reported as 5% to 8% compared to only 0.5% to 1% in women.[17] A similar distribution depicted in African populations was noted, with a prevalence of 2.34% and 1.23% in the Nigerian male and female population, respectively,[9] while Mitiku et al.[18] reported a prevalence of 3.75% and 0.68% in Ethiopian male and female individuals, respectively.

More recently, studies have also focused on congenital CVD among university students, considering its influence on learning and career choices.[9,11,15] As mentioned, a pooled CVD prevalence of 4.7% in Iranian male students aged 7–18 years was found, while values of 2.85%, 2.34% and 2.1% were found among male university students in two separate Nigerian studies and in Saudi medical students, respectively.[9,11,15] Only one study on CVD was conducted in South Africa, which focused on the prevalence of congenital CVD among black school children aged 7–17 years in Durban by Mashige and van Staden[4] which reported an overall prevalence of 2.2%, with a 4.2% prevalence in male students and 0.6% in female students.

An earlier study by Barry et al.[19] reported that significant problems arise in health, lifestyle, emotions and careers as a result of colour vision deficiencies. Furthermore, colour-deficient individuals could experience difficulties with learning, food preparation, reading and/or identifying safety signs, using map navigation, tracking health problems, maintaining personal care, and may have limited career choices.[20] Colour vision deficiency impacts individuals' social interactions and thereby their emotional, mental and social well-being. Suciu et al.[21] identified the degraded quality of everyday life for colour-deficient patients, and yet, unfortunately, sufficient help and support for these colour-deficient individuals were not readily available. This would be expected to occur more often with acquired CVD and/or complete monochromatism, where visual acuity can also be affected. The aforementioned studies included people who were already diagnosed with CVD. In most cases, however, colour vision defective individuals are unaware of the deficiency until it is tested for. This could be related to the observation that many people with CVD, particularly when congenital, adapt and live normal lives.

While most studies on colour blindness have reported on the epidemiology of the condition, and many have alluded to its impact on quality of life (QoL), particularly in younger populations, only a few have documented this expected impact.[4,8,9,10,11,13,14,15,19,20] Stoianov et al.,[20] following an integrative review of the impacts of colour vision deficiency on the lives of people, concluded that many of the studies related to this subject were carried out over a decade ago and hence there is a need for further research in this area. This conclusion is particularly appropriate when considering the changes in the educational environment, both from a teaching and learning perspective, with a greater use of colour graphics over the last decade. Recognising this gap, the current study thus focused on CVD in a population of male university students and its impact on QoL, utilising a tool, the CVD-AES, developed specifically to assess the barriers to learning presented by CVD.[22]

Currently, the prevalence of CVD among university students in South Africa has not been reported, and the findings of this study can add this information to the current body of knowledge. Furthermore, because the impact of CVD on quality of life relating to academic performance and career pursuits remains largely unknown, this study will raise awareness among students and teachers of the possible impact of CVD on academic performance, also highlighting the importance of screening for CVD in routine eye tests to the optometric fraternity.

Methods

Study design

A cross-sectional, quantitative, descriptive research design was used for this study. The study setting was all colleges of the University of KwaZulu-Natal (UKZN), with the study population being male students. Non-probability, purposive sampling, because of time constraints for data collection, was

used to recruit 272 male students, aged 18–30 years and of all races, to participate in the study.

Data collection procedure

Data collection commenced once ethical clearance was obtained. Initial screening of the subjects involved distance visual acuity (VA) measurements using the Snellen chart, including only those with a distance VA of 6/24 or better in the study. Thereafter, each subject underwent a colour vision assessment using two colour vision tests, the Ishihara pseudoisochromatic 24-plate edition and the Hardy-Rand-Rittler colour vision test (HRRT), the order of which was randomised across subjects. These tests were chosen because of practical constraints and lack of access to a clinical setting for data collection. However, they are valid tests for the assessment of colour vision.[23,24] Both these tests were performed monocularly, with the test booklet held at 75 cm and under daylight illumination. The results were recorded on the appropriate recording sheet and interpreted as per guidelines in the respective manuals. If a colour vision defect was detected on either the Ishihara or HRR test, the subjects were required to fill out an electronic version of the validated Colour Vision Deficiency – Adverse Effects Scale (CVD-AES) questionnaire as an assessment of QoL.[22] This questionnaire was administered in English and quantifies the negative effects of defective colour vision and its impact in an educational context.[19] The different aspects evaluated by this questionnaire included education, social life, everyday experience and emotions. The questionnaire is closed-ended and contains statements pertaining to each of the four aspects, with the respondent required to indicate the applicability of that statement to themselves by choosing from a five-point Likert scale rating of alternatives, which include 'never, rarely, sometimes, often, and always'. The ratings are scored from 0 to 4, with the alternative 'never' assigned a '0' and 'always' assigned a '4'. Based on the scores, an impact score is calculated using the formula

$$Impact\ score = \frac{\sum \text{Given answers}}{Number\ of\ questions\ answered\ x\ 4}$$

The impact score ranges from 0 to 1, with a higher score on the CVD-AES indicating a higher negative impact of CVD.

The subjects were encouraged to be truthful when answering the questionnaire. The CVD-AES questionnaire was also conducted on a subset of colour normals (n = 19) for comparison. All procedures and instructions used during the data collection were standardised among the researchers by reading from a printed sheet for the various tests. A pilot study (n = 5) was conducted prior to the main study, with minimal modification required to the procedures prior to implementation.

Data analysis

Data were entered into Microsoft Excel and analysed using the Statistical Package for the Social Science (SPSS), version 28. Descriptive and inferential statistics, such as frequencies and means, were calculated. The Fisher's exact test, analysis of variance (ANOVA) and multivariate regression analysis were used to test the association between colour vision status and impact scores versus socio-demographic variables. Anova and the Mann-Whitney U tests were used to compare the means for the impact scores. All the tests were two-sided, and all p-values reported were tested at the $\alpha = 0.05$ level.

Ethical considerations

Ethical clearance was obtained from the Biomedical Research and Ethics Committee of the University of KwaZulu-Natal (BREC/00005581/2023) prior to data collection, and the tenets of the Declaration of Helsinki were adhered to where necessary. Informed consent was obtained in writing from all respondents. The identity of all respondents remained confidential, and the research data were only accessible to the researchers through a password-protected computer.

Results

Demographics and colour vision status

A total of 272 male students were enrolled in the study and included in the data analysis. The mean age of the sample was 20.61 years (s.d. = 2.08 years), with an age range between 18 years and 30 years. The sample included 86.8% (n = 236) black, 0.7% (n = 2) coloured, 11.4% (n = 31) Indian, and 1.1% (n = 3) Caucasians. The distribution of the participants according to their colour vision status, the college they were currently enrolled in, and their year of study is detailed in Table 1.

Of the total participants enrolled, 19 were found to have a colour vision defect; hence, a prevalence of 7% of CVD was found in the population under study (Table 1). Of the 19 participants, only one displayed a possible protan defect, while the remainder (n = 18; 94.7%) were found to be deutans. The Fisher's exact test revealed no associations between CVD and the college of enrolment (p = 0.409), nor with the year of study (p = 0.566). Furthermore, only 11.8% (n = 32) of all the participants screened reported having their CV assessed

TABLE 1: Sample distribution according to colour vision status, college, and year of study.

Student enrolment categories	*N*	%	CV status					
			Normal		Deutan		Protan	
			n	%	*n*	%	*n*	%
College								
Agriculture, engineering and science	98	36.0	88	32.4	9	3.3	1	0.5
Humanities	29	10.7	29	10.7	0	0	0	-
Health Sciences	92	33.8	85	31.3	7	2.5	0	-
Law and management	53	19.5	51	18.8	2	0.7	0	-
	272	100	253	93.0	18	6.5	1	0.5
Year of study								
1st	75	27.6	71	26.1	4	1.5	0	-
2nd	78	28.7	73	26.8	5	1.7	0	-
3rd	78	28.7	73	26.8	4	1.5	1	0.5
4th	39	14.3	34	12.5	5	1.7	0	-
5th	2	0.7	2	0.7	0	-	0	-
	272	100	253	93.0	18	6.5	1	0.5

CV, colour vision.

previously, with only five (26.32%) of those affected being aware of their CVD. The results from the Ishihara and the HRR test were significantly correlated (p = 0.000), with no differences in the diagnoses of the colour vision statuses of all participants noted between the two tests.

Adverse effects of colour vision deficiency

The participants (n = 19) diagnosed with CVD were required to complete the CVD-AES questionnaire to investigate the adverse effects, if any, of their CVD on four subscales of QoL, namely, education, social life, emotions and everyday tasks. The frequencies reported in this section are calculated based on only the total number of colour-deficient participants, that is, 19 and not the total sample for the study.

Subscale 1: Education

Subscale 1 focused on the adverse effects of CVD on the participants' education. Figure 1 depicts the participants' responses regarding difficulties experienced in various subjects, specifically because of their perception of colour. Based on the responses in Figure 1, the subjects most affected by colour vision defect were Arts (10.5% affected always), Science (10.5% affected always, and 5.3% often), and Geography (21% affected often or always), while Music and IT were not affected, as reported by those participants who had taken those subjects. Even though only 10.5% reported that their CVD sometimes made it difficult to answer questions in tests, it was noted that participants also reported an effect on reading information, rarely (26.3%), sometimes (26.3%), and always (5.3%). Two participants (10.5%) indicated that they sometimes had difficulty in setting learning targets and objectives because of their colour vision, while a relatively higher number (21.2%) found that it could interfere with communication with their teachers.

Subscale 2: Social life

Figure 2 shows the responses of the participants with CVD to statements related to their social life as Subscale 2. The aspect of social life assessed by the CVD-AES that appeared to be most affected was being laughed at for making mistakes because of their CV defect, as experienced by 21.1% always, 10.5% often and 15.8% sometimes. Of note is that 52.6%

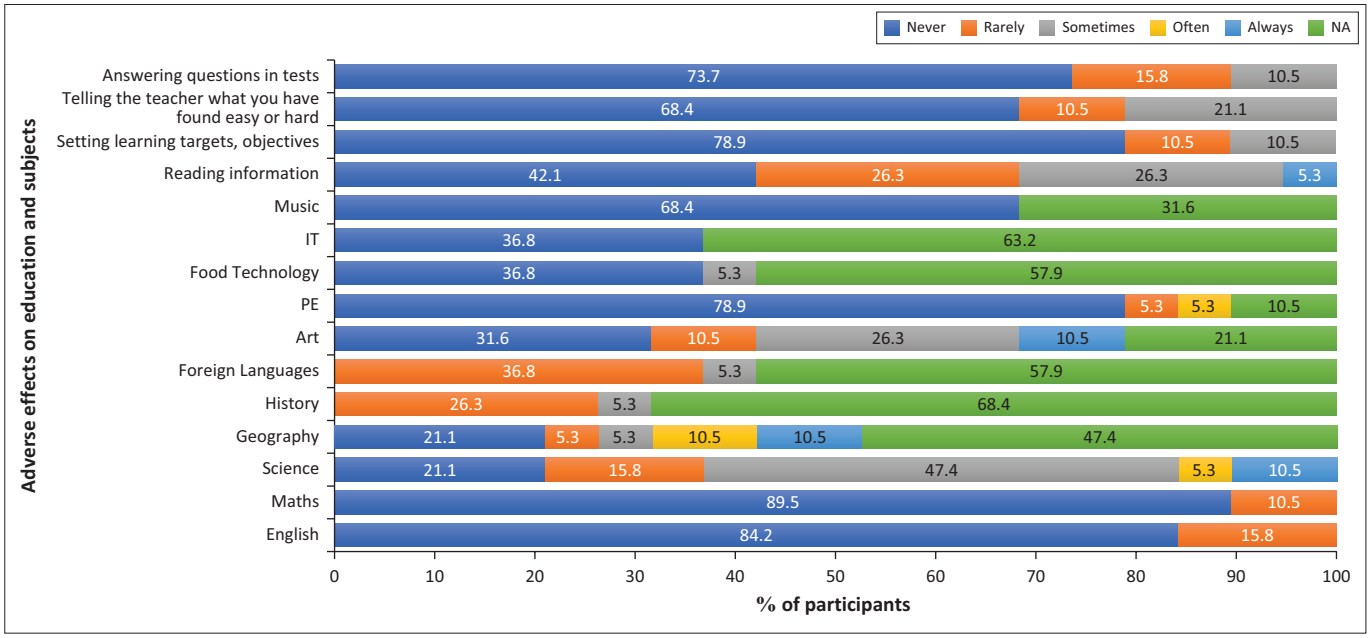

FIGURE 1: Participants' responses to Subscale 1 (education) of the colour vision deficiency – adverse effects scale.

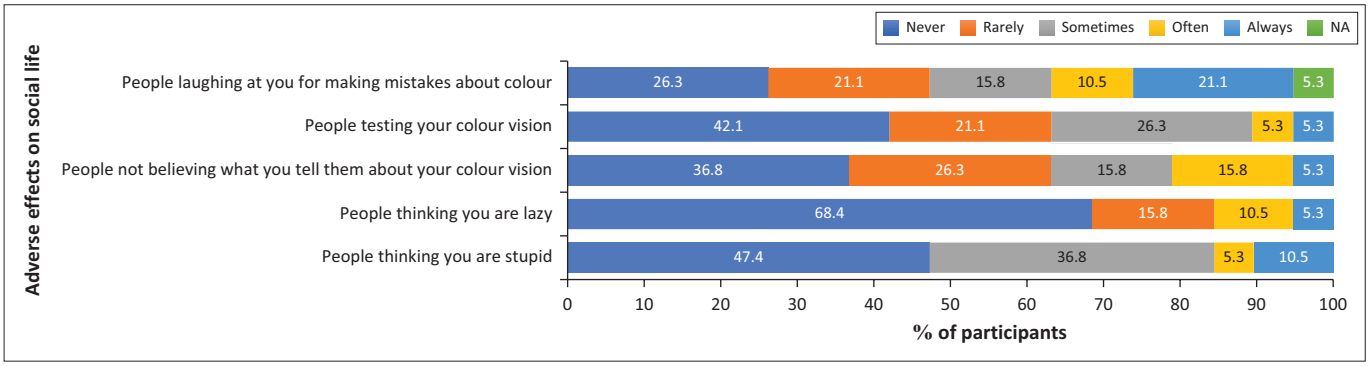

FIGURE 2: Participants' responses to Subscale 2 (social life) of the colour vision deficiency – adverse effects scale.

reported being perceived as stupid sometimes (36.8%), often (5.3%) or always (10.5%). The least affected aspect of social life was people thinking that those affected individuals are lazy, as reported by 15.8%.

Subscale 3: Emotions

The adverse effects on emotions because of poor colour perception were the focus of Subscale 3 and are detailed in Figure 3. The results suggest that the emotions the participants were most likely to experience as a result of their CVD were: feeling self-conscious, feeling like the odd one out, and feeling embarrassed. The negative emotions that the participants were likely to experience to a lesser extent because they had CVD were feeling special and/or unique, frustrated and sad. Similarly, the happy emotions were also experienced to a lesser degree.

Subscale 4: Everyday tasks

Figure 4 details the responses to the adverse effects of CVD on everyday tasks. Adverse effects while understanding information and doing arts and crafts were sometimes experienced, as reported by 47.4% and 42.1% of colour vision defective participants, respectively. The use of computers and devices was being affected adversely sometimes, as reported by 21.1%. Almost a fifth of colour-deficient participants experienced some difficulty with food choices and eating. The ability to use technology was the everyday task that was reportedly least affected.

Impact scores

For each of the subscales, an impact score, which could range from 0 to 1, was calculated. Table 2 details the descriptive statistics for the impact scores calculated.

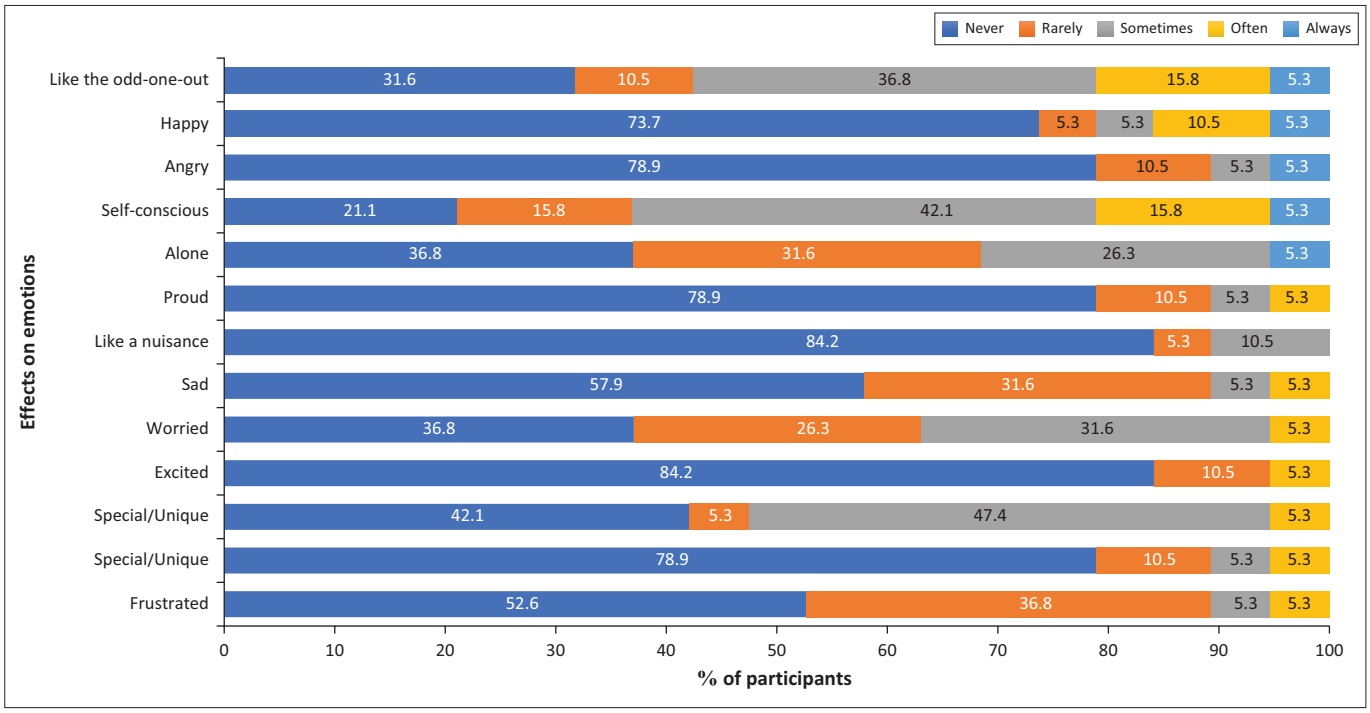

FIGURE 3: Participants' responses to Subscale 3 (emotions) of the colour vision deficiency - adverse effects scale.

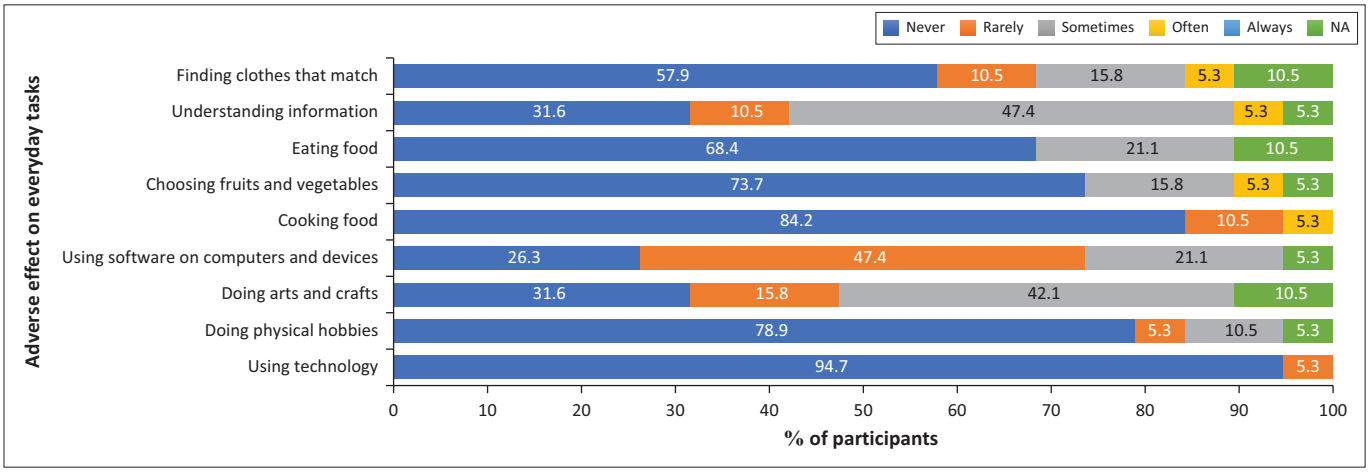

FIGURE 4: Participants' responses to Subscale 4 (everyday tasks) of the colour vision deficiency – adverse effects scale.

The higher the impact score, the more negative the impact. The highest impact score was noted for Subscale 2 (social life) and the lowest for Subscale 1 (education) (Table 2). Anova analysis revealed a significant difference (p = 0.014) in the means across the four subscales for the CVD participants. Multivariate regression analysis revealed no associations between demographics (age, year of study and college) and the impact scores for each of the subscales explored for the colour-deficient participants.

The CVD-AES was also administered to a small subset of the participants (n = 19) with normal colour vision for comparison. According to the Shapiro–Wilk test, all scores were not normally distributed. Thus, the nonparametric test (i.e. Mann-Whitney U test) was used to compare the mean and/or median value of scores between the two groups (Table 3).

Statistically significantly lower impact scores were noted for colour vision normal participants compared to colour vision deficient participants, for the total impact score and all subscales, with the exception of emotions.

Discussion

This study evaluated the occurrence of CVD among male students at a chosen South African university, as well as explored the possible adverse effects that could have an impact on the QoL of the affected individuals. Colour vision deficiency was detected in 7% of the sample in this study. When compared to previous reports on the prevalence of CVD among male university students, this finding of the current study was similar to those reported by Osman et al.[25] of 7.7% on a random sample of Egyptian students. A similar prevalence was also noted by Ahadi et al.[10] of 6.3%, but on a slightly older sample (mean age of 29 years). This finding is also similar to the worldwide prevalence of male individuals.

TABLE 2: Impact scores (means, standard deviation and range) for the four subscales assessed by the colour vision deficient adverse effects scale.

Subscale	Mean	s.d.	Range	
			Minimum	Maximum
Education	0.11	0.08	0.00	0.32
Social life	0.30	0.24	0.00	0.85
Emotions	0.19	0.15	0.00	0.62
Everyday tasks	0.20	0.19	0.00	0.67

s.d., standard deviation.

TABLE 3: Comparison of median impact scores for the colour vision deficient adverse effects scale between a subset of colour vision normals and the colour vision deficient participants.

Subscale impact score	Colour vision deficiency						Mann-Whitney p
	No			Yes			
	Mean	s.d.	Median	Mean	s.d.	Median	
Education	0.06	0.04	0.07	0.11	0.08	0.12	0.007*
Social life	0.09	0.19	0.00	0.30	0.24	0.25	0.000*
Emotions	0.15	0.12	0.21	0.19	0.15	0.19	0.578
Everyday tasks	0.02	0.03	0.00	0.20	0.19	0.14	0.000*
Total impact score	0.08	0.05	0.09	0.18	0.12	0.18	0.001*

s.d., standard deviation.

*, statistically significant.

with inherited CVD (8%), although this is based on subjects of European Caucasian descent.[26] A lower prevalence of between 1.7% to 3.8% was noted in other studies also focused on university students but including all genders.[8,9,11,15] Only one study reported colour deficiency (2.2%) in South Africans, but the population consisted of school children (7 years – 17 years).[4] The difference in the prevalence finding of the current study when compared to some other studies may be attributed to varying sample sizes, sampling strategies, and demographics of the samples. It was also noted that a higher prevalence was reported by studies that included only male subjects or when the results for only the male gender were reported. This may be related to the prevalence of CVD, reportedly higher in male individuals than female individuals, attributed to it being an X-linked chromosome condition, and may be one of the reasons for the higher occurrence noted in the current study.[3] Furthermore, Birch,[26] in a systematic review of the prevalence of red-green colour deficiency, alluded to an expected rise in the prevalence of this condition in men of African ethnicity, and this was later also corroborated by Fakorede et al.[11] The sample under scrutiny in this study comprised the majority of black Africans.

Among the different types of colour vision deficiencies, only red-green deficiencies were found in the current study, with deutan deficiency being the most prevalent and protan deficiency noted in only one participant. This finding is similar to that reported in all studies that focused on colour deficiency among university students, as well as on all other age groups and ethnicities, including the one on South African school children, where the frequencies of deutans and protans in male subjects were 2.7% and 1.5%, respectively.[4,8,9,10,11,12,25,26] While the literature is unclear on an explanation for the predominance of deutan defects, it may be attributed to genetics, as was noted by Bowmaker,[27] who studied visual pigments and molecular genetics of colour blindness and reported a 4:1 ratio for deutan versus protan defects.

In the current study, although the mean impact scores for all subscales assessed by the CVD-AES tool remained in the lower half of the possible range, implying a lower negative impact, adverse effects from CVD were noted in all four subscales (education, social life, emotions, everyday tasks) which are expected to impact the QoL of an individual. Furthermore, when the impact scores of the participants with CVD were compared to those of a subset of colour vision normals, statistically significantly lower impact scores were noted in the latter for all subscales, with the exception of emotions.

Subscale 1 of the CVD-AES focused on the adverse effects of CVD on education. Subjects in which the colour vision-deficient participants reported a greater frequency of adverse effects were Arts, Science and Geography. Individuals with CVD may thus be at a disadvantage when undertaking subjects in which colour is often key in the didactic component – this finding is supported by the

reports by Barry et al.[19] that colour-blind children may fall behind in subjects where colours are an important part of learning.[28,29] Grassivaro Gallo et al.[29] also found that colour-blind school children experience more learning difficulties than their colour vision normal counterparts. In a tertiary institution, this may also occur with colour-related tasks, as noted by Chakrabarti[30] in a review paper of medical students and professionals reporting difficulties, for example, when viewing histology slides – hence the assertions by some authors that CVD can be disadvantageous to careers in medicine, engineering, fashion designing and the military.[8,10,28] Some participants in the current study reported difficulty in answering questions, communicating challenges with educators, as well as setting learning targets and objectives, while many participants reported difficulty with reading information, which are similar to the reports included in the systematic review by Stoianov et al.[20] It was noted in the study by Mashige[31] that a child with normal colour vision has an ability to identify a wide range of colours, whereas a child with deuteranomaly, which is the most common form of CVD noted from previous studies and the current one, can only accurately name about four colours within a standard box of 24 coloured pencils. Notably, learning difficulties when engaging with coloured chalk on a blackboard have also been experienced.[19] The education and teaching environment has evolved over the years from the use of traditional chalkboards to more digital platforms with the use of colour graphics to enhance presentations and aid students in the understanding of information. Therefore, it may be expected that individuals with CVD will experience difficulties with educational tasks as well as sharing these difficulties with educators. Educators can consider the use of symbols, shapes, sizes, textures and patterns, and not only colour, to make information more understandable for students with CVD. Additionally, high-contrast materials could be used to read and interpret information more easily.

Colour vision deficiency also has a significant impact on one's social life, which was also noted in the current study, with the highest mean impact score produced for Subscale 2 focused on social life.[19,20,32] As noted from findings on Subscale 2, the most affected aspect was being laughed at for making mistakes, as well as being perceived as stupid because of being colour-deficient. Similar findings were noted by Barry et al.[19] Furthermore, Chakrabarti[30] revealed that colour-deficient individuals are often described as being slow learners, which could have a negative impact on them psychologically and evoke negative reactions from parents and educators.[29] As an individual progresses through formal education, there is an increasing use of colours, which may cause them to fall behind in their studies, creating a negative stigma, thereby reducing their confidence during social engagement and in relationships with others, especially those who are part of their routine.[20] In the leisure arena, an individual with CVD may experience difficulties with playing sports, for example, they may pass the ball to the opposite team because of the confusion of the vest colours.[28,33] These challenges and perceptions may directly affect one's self-esteem and mental health. This, in turn, could negatively influence intrapersonal and interpersonal relationships, making it difficult for one to interact efficiently with mentors and peers, subsequently leading to a poor learning environment and impacting academic performance and achievements.

The adverse effects of CVD on one's education and social interactions can be expected to have a negative impact on emotional well-being. Responses to Subscale 3 revealed that the negative emotions more frequently experienced by CVD individuals were feeling self-conscious, like the odd one out, and embarrassed. It was also noted that positive emotions like feeling happy, proud and excited were experienced less frequently when compared to the negative ones. The experience of similar negative emotions of anxiety, depression and lack of self-esteem related to colour blindness was also noted by Barry et al.[19] and Grassivaro Gallo et al.[29]

Subscale 4 of the CVD-AES explored everyday tasks that were adversely affected by colour deficiency. Tasks more frequently affected were understanding information, which includes reading labels, graphs and maps, doing arts and crafts, and using software on computers and devices. Tagarelli et al.[32] found that CVD individuals experience difficulties with all tasks associated with being able to drive a car. Stoianov et al.[20] found similar results, which suggested difficulty with reading or identifying safety signs and warnings, using map navigation, as well as confusing medications if not labelled clearly, which impacted self-care. In addition, Chakrabarti[30] found that CVD individuals experience trouble in everyday life tasks, such as recognising traffic signals as well as colour-coded information in electrical appliances, chemical tests and colours of food. Challenges with everyday tasks, including those related to self-care, independence and leisure, could contribute to reduced physical, mental and social well-being, thereby reducing QoL. Many participants in the current study reported difficulty using software on computers and devices, which constitute everyday tasks for learners and are pivotal for educational purposes among university students, thus potentially impacting the quality of learning negatively.

The majority of the affected individuals in the current study were unaware of their CVD, which has been the general reporting from many previous studies.[8,9,12,19,25,29,30] This finding is of significance based on the assertion by Barry et al.[19] that the challenges experienced as a result of colour blindness in early life may continue, especially in individuals who are not diagnosed. Moreover, the adverse effects of undiagnosed CVD may hinder an individual from performing optimally in their chosen careers, as well as negatively impact their self-confidence.[28,29] This highlights the importance of colour vision testing early on in life and the awareness of the adverse effects of CVD.

The current study provides further insight into the adverse effects of CVD on various aspects of life, particularly as it relates to young individuals at the height of their studies and career choices. The use of the CVD-AES, which is a validated tool to assess the adverse effects of CVD in an educational context, makes the findings of this study relevant to the younger population with CVD. It is also the first study to use this tool in studying the QoL in young colour-deficient individuals and on the African continent. Although the onset of CVD and its adverse effects happen early on in life, the administration of the CVD-AES tool on a relatively mature learner in exploring the adverse effects of colour deficiency on education may provide more reliable findings than those from a school-going population. Furthermore, the CVD-AES allows for quantification of the adverse effects, which Stoianov et al.[20] emphasised a need for. However, recall, particularly for the probe questions in the subscale on school education, could be affected by the time lapse. In view of time constraints, the current study focused data collection only on male individuals, considering that the second objective of the study was to report on the adverse effects of CVD on a sizeable number of participants. Thus, as the participants could not be randomly sampled with females excluded, caution is exercised in the use of the term 'prevalence' and any generalisability of the findings from this study. Generalisability of the findings is also limited because of the relatively small number of subjects found to have CVD who subsequently completed the CVD-AES.

Conclusion

This study has noted that 7% of a male university population, selected with non-probability sampling, have a CVD, with a higher number of deutan colour deficient. A quantitative determination of the adverse effects of colour deficiency in the population under study revealed adverse effects on education, social life, emotions and everyday life related to the condition, which are expected to impact on quality of life.

Acknowledgements

Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

R.H. and N.M.G. supervised this study and were involved in conceptualisation, data analysis and editing of all written drafts of the manuscript. R.H., N.M.G., N.C., X.H., A.H., T.N., M.R. and Z.N. were involved in data collection and writing of the manuscript. All authors read and approved the final article.

Funding information

The authors received no financial support for the research, authorship, and/or publication of this article.

Data availability

The datasets used and/or analysed during the current study are available from the corresponding author, R.H., upon reasonable request.

Disclaimer

The views and opinions expressed in this article are those of the authors and are the product of professional research. They do not necessarily reflect the official policy or position of any affiliated institution, funder, agency or that of the publisher. The authors are responsible for this article's results, findings and content.

References

1. Hasrod N, Rubin A. Deficiency of colour vision: A review of congenital and acquired colour vision deficiencies. Afr Vis Eye Health. 2016;75(1):1–6. https://doi.org/10.4102/aveh.v75i1.365
2. Taore A, Lobo G, Turnbull PR, et al. Diagnosis of colour vision deficits using eye movements. Sci Rep. 2022;12(7734):1–14. https://doi.org/10.1038/s41598-022-11152-5
3. Neitz J, Neitz M. The genetics of normal and defective colour vision. Vis Res. 2011;51(7):633–651. https://doi.org/10.1016/j.visres.2010.12.002
4. Mashige KP, Van Staden DB. Prevalence of congenital colour vision deficiency among Black school children in Durban, South Africa. BMC Res Notes. 2019;12(324):1–5. https://doi.org/10.1186/s13104-019-4374-1
5. Hart WM. Acquired dyschromatopsias. Surv Ophthalmol. 1987;32:10–31. https://doi.org/10.1016/0039-6257(87)90070-1
6. Zarazaga AF, Gutiérrez Vásquez J, Pueyo Royo V. Review of the main colour vision clinical assessment tests. Arch Soc Esp Oftalmol. 2019;94(1):25–32. https://doi.org/10.1016/j.oftale.2018.08.010
7. Professional board for optometry and dispensing opticians of the Health Professions Council of South Africa [homepage on the Internet]. 2020 [cited 2023 Feb 20]. Available from: https://www.hpcsa.co.za/Uploads/ODO_2019/Policy%20and%20Guidelines/THE_BASIC_EYE_EXAM_2020.pdf
8. Alamoudi NB, AlShammari RZ, AlOmar RS, et al. Prevalence of colour vision deficiency in medical students at a Saudi University. J Fam Community Med. 2021;28(3):196–201. https://doi.org/10.4103/jfcm.jfcm_235_21
9. Nwobodo E, Darawuzie N, Ikwuka DC. Colour perception studies on students of Nmandi Azikiwe University Nnewi Campus, Nigeria. Cyprus J Med Sci. 2022;7(2):191–195. https://doi.org/10.5152/cjms.2021.2216
10. Ahadi M, Ebrahimi A, Rahmani S, et al. Prevalence of refractive errors and colour vision deficiency in a population of industry-workers in Abhar, Iran. Medicine. 2021;100:46(e27758). https://doi.org/10.1097/MD.0000000000027758
11. Fakorede ST, Akpan LG, Adekoya KO, et al. Prevalence and population genetic data of colour vision deficiency among students from selected tertiary institutions in Lagos State, Nigeria. Egypt J Med Hum Genet. 2022;23(73):1–8. https://doi.org/10.1186/s43042-022-00287-9
12. Woldeamanuel GG, Geta TG. Prevalence of colour vision deficiency among school children in Wolkite, Southern Ethiopia. BMC Res Notes. 2018;11(838):1–5. https://doi.org/10.1186/s13104-018-3943-z
13. Kim H, Ng JS. Prevalence of colour vision deficiency in an adult population in South Korea. Optom Vis Sci. 2019;96(11):866–873. https://doi.org/10.1097/OPX.0000000000001441
14. Krishnamurthy SS, Rangavittal S, Chandrasekar A, et al. Prevalence of color vision deficiency among school- going boys in South India. Indian J Ophthalmol. 2021;69(8):2021–2025. https://doi.org/10.4103/ijo.IJO_3208_20
15. Rezaei L, Hawasi E, Salari N, et al. Prevalence of color blindness in Iranian students: A meta-analysis. J Ophthalmic Vis Res. 2022;17(3):413–423. https://doi.org/10.18502/jovr.v17i3.11580
16. Deeb SS, Kohl S. Genetics of colour vision deficiencies. Dev Ophthalmol. 2003;37:170–180. https://doi.org/10.1159/000072046
17. Mandal A. Colour blindness prevalence. [homepage on the Internet]. c2023[updated 2023 Jul 06; cited 2023 Feb 18]. Available from https://www.news-medical.net/health/Color-Blindness-Prevalence.aspx
18. Mitiku RG, Tolera BS, Tolesa ZG. Prevalence and allele frequency of congenital colour vision deficiency (CCVD) among students at Hawassa University, Ethiopia. J Egypt Public Health Assoc. 2020;95(10):1–6. https://doi.org/10.1186/s42506-020-00037-y
19. Barry JA, Mollan S, Burdon AM, et al. Development and validation of a questionnaire assessing the quality of life impact of colour blindness (CBQoL). BMC Ophthalmol. 2017;17:179–180. https://doi.org/10.1186/s12886-017-0579-z
20. Stoianov M, De Oliveire MS, Dos Santos Ribeiro Silva MCL, et al. The impacts of abnormal colour vision on people's life: An integrative review. Qual Life Res. 2019;28:855–862. https://doi.org/10.1007/s11136-018-2030-1

21. Suciu C, Suciu V, Perju-Dumbrova L, Nicoara SD. A review on today's burden affecting the quality of life for colour blind patients. Ro J Neurol. 2020;19(2):61–64. https://doi.org/10.37897/RJN.2020.2.1
22. Pattie C, Mullally S, Jordan G. CVD-AES: Construct and concurrent validity of a novel scale to measure the adverse effects of congenital colour vision deficiency. Journal of the International Colour Association. 2022;31:3–12.
23. Cole BL, Lian KY, Lakkis C. The new Richmond HRR pseudoisochromatic test for colour vision is better than the Ishihara test. Clin Exp Optom. 2006;89:73–80. https://doi.org/10.1111/j.1444-0938.2006.00015.x
24. Salvia J, Ysseldyke, J. An analysis of the reliability and validity of the Ishihara color plates with mentally retarded males. Percept Mot Skills. 1971;33:243–246. https://doi.org/10.2466/pms.1971.33.1.243
25. Osman S, Khalaf S, Mohhamed H, et al. Prevalence and predictors of colour vision defects among Egyptian university students. East Mediterr Health J. 2021;27(4):399–406. https://doi.org/10.26719/emhj.20.128
26. Birch J. Worldwide prevalence of red-green colour deficiency. J Opt Soc Am A. 2012;29(3):313–320. https://doi.org/10.1364/JOSAA.29.000313
27. Bowmaker JK. Visual pigments and molecular genetics of colour blindness. News Physiol Sci. 1998;13(2):63–69. https://doi.org/10.1152/physiologyonline.1998.13.2.63
28. Chan XBV, Goh SMS, Tan NC. Subjects with colour vision deficiency in the community: What do primary care physicians need to know?. Asia Pac Fam Med. 2014;13(10):1–10. https://doi.org/10.1186/s12930-014-0010-3
29. Grassivaro Gallo P, Panza M, Viviani M, et al. Congenital dyschromatopsia and school achievement. Percept Mot Skills. 1998;86(2):563–569. https://doi.org/10.2466/pms.1998.86.2.563
30. Chakrabarti S. Psychosocial aspects of colour vision deficiency: Implications for a career in medicine. Natl Med J India. 2018;31(2):86–96. https://doi.org/10.4103/0970-258X.253167
31. Mashige KP. Impact of congenital colour vision defect on color-related tasks among schoolchildren in Durban, South Africa. Clin Optom. 2019;11:97–102. https://doi.org/10.2147/OPTO.S204332
32. Tagarelli A, Piro A, Tagarelli G, et al. Colour blindness in everyday life and car driving. Acta Ophthalmol Scand. 2004;82(4):436–442. https://doi.org/10.1111/j.1395-3907.2004.00283.x
33. Ugalahi MO, Fasina O, Ogun OA. Impact of congenital color vision defect on color-related tasks among Secondary School Students in Ibadan, South West Nigeria. Niger J Ophthalmol. 2016;24(1):20–24. https://doi.org/10.4103/0189-9171.179914