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Evaluating the Role of Colored Filters (Red, Green) in Improving Color Vision Deficiency

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ABSTRACT

Background: Color Vision Deficiency (CVD) is defined as the inability to make discriminations based on the wavelength composition of the light, independent of its intensity. This is due to the abnormalities found in the cone cells of the retina. Some professional activities become so difficult that effective tools like colored filters are needed. These filters do not treat the condition overall, but they improve the perception of color and, therefore, the quality of life for all CVD patients. **Methods:** This study used an observational cross-sectional study design. 500 patients were screened for Color Vision Deficiency (CVD) for two months using the Ishihara test, visiting the Eye OPD of PIMS hospital. Patients who have CVD were then subjected to red and green filters to assess any improvement in the discrimination of colors. The data were then analyzed to find out whether these filters made any improvement in colour discrimination in CVD patients. **Results:** From these 500 people who were examined, 30 of them (6%) had Color Vision Deficiency (CVD). From these diagnosed patients, 73.3% were males,90% were red-deficient (Protanopia/Protanomaly), and the remaining 10% were green-deficient (Deuteranopia/Deuteranomaly). Red filters were effective for all patients when subjected to the Ishihara plate tests. Whereas green filters did not show any effect on CVD. These findings show the practical use of red filters for the enhancement of color vision for those with CVD. **Conclusion:** Red filters enhanced the color perceptions in patients with Color Vision Deficiency (CVD), especially in red-green deficient patients. This study confirms red filters can be used as an effective management device for CVD.

Keywords: Color Vision Deficiency, Red Filters, Green Filters, Daltonism, Ishihara Test

INTRODUCTION

Colour vision deficiency (CVD) is a genetically inherited disorder with a global prevalence of 300 million affected individuals, and red-green deficiency comprises 95 percent of all cases [1]. This is due to a defect in cone photoreceptors, namely, missing or

spectrally displaced L-cones (Protan defects) or M-cones (Deutan defects), which interfere with wavelength discrimination between 520 and 580 nm [1, 2]. Although historically referred to as colour blindness, CVD has a continuum of severity and important implications in everyday activities (e.g., reading traffic lights) and job eligibility (e.g., aviation, electrical work) [1, 3]. The diagnosis is based mainly on pseudoisochromatic plates (e.g., Ishihara tests), which are used to screen red-green deficiencies but are not sensitive enough to distinguish between subtypes or quantify severity [4, 5]. More importantly, such tests have limited potential to distinguish between protanopia and deuteranopia, and do not measure functional impairment in the real world [6]. The diagnostic tests, i.e., the Farnsworth-Munsell 100 Hue test or anomaloscopes, are required to accurately phenotype but are less commonly used in clinical practice [1, 3, 7].

Spectral filtering devices are part of the current management strategies. Coloured filters help to improve colour discrimination through selective absorption of overlapping wavelengths (545-575 nm) between defective cones and thus enhancing chromatic contrast [8, 9]. An example is the dyed contact lenses that contain rhodamine derivatives or Atto dyes that absorb the problematic mid-spectral light and have shown a 20 to 25% increase in Ishihara scores [2, 10]. Nonetheless, efficacy is dependent on the subtype of CVD, the lighting environment, cost, size, and incompatibility with corrective eyewear restricts the use of current solutions. Recent developments in nanoparticle-loaded lenses (e.g., gold/silver) have the potential to be used in dual-purpose ways (e.g., antibacterial and colour correction), but clinical testing is still in progress [11].

Colour vision deficiency (CVD) occurs due to the absence of pigment in cones or altered spectral sensitivity of the cones [12]. CVD can be of three types. Monochromacy, also known as Achromatopsia. It is a condition in which all three pigments present in cones are absent. People with monochromacy are totally colour blind and see all objects in grey. Dichromacy is a condition in which only one cone pigment is absent, and the other two are working properly. Red pigment is absent in protanopia, green pigment is absent in deuteranopia, and blue pigment is absent in tritanopia. Trichromacy is a condition in which all the receptors are present, but for any reason spectral sensitivity of one cone is altered. Such conditions include Protanomaly, Deuteranomaly, and Tritanomaly [13]. Colour vision deficiency can affect daily life as well as some professions where colour vision is needed to perform the job. In daily life, it can be difficult to choose clothes and buy fruit. Some professions that are affected by CVD are: pilots, electrical specialists, designers, and drivers. In this respect, the electricians require normal colour vision to recognise the color-coded wires, and the pilots should differentiate various transmissions when flying. Moreover, pathologists and ophthalmologists also need accurate colour vision [14, 15].

Colour vision deficiency is usually diagnosed by using different tests such as Pseudo isochromatic test plates (Ishihara test), Hue discrimination test (The Farnsworth D15 test), Anomaloscope, Colour naming, and colour sorting [16]. Currently, there is no authentic and proven treatment for colour vision deficiency, but it can be managed through Gene Therapy and using filters in the form of contact lenses and glasses [17, 18]. Coloured filters are optical devices designed to modify the light spectrum reaching the retina, enhancing colour perception for individuals with Colour Vision Deficiency (CVD). These filters selectively allow certain wavelengths to pass while blocking others, significantly improving contrast between problematic colours such as red and green. For example, red filters permit red wavelengths to pass while blocking green and blue light, helping individuals with Protanopia or Protanomaly differentiate red from other colours.

Similarly, green filters enhance green tones by reducing red and blue wavelengths, assisting those with Deuteranopia or Deuteranomaly. This selective spectral adjustment addresses deficiencies in retinal cones (L-cones for red, M-cones for green) by minimizing overlapping signals and improving the clarity of distinct colours [19]. While coloured filters can enhance colour perception for individuals with colour vision deficiency (CVD), they come with notable limitations. Their effectiveness is often confined to specific lighting conditions and controlled environments, making them less dependable in real-world settings where lighting and colour complexity frequently change. Practical issues such as high costs, bulkiness, and incompatibility with other vision correction devices further hinder their widespread use. Emerging alternatives, such as dyed contact lenses and advanced filtering technologies, show promise in overcoming these challenges, though they still require extensive development and testing to become viable solutions [8, 19].

However, there are still considerable limitations to spectral filtering: a landmark 2022 study published in Nature showed that commercial filters (e.g., EnChroma) did not enhance performance on clinical colour tests, indicating a lack of translating laboratory results to real-world efficacy, and filters do not provide normal trichromacy and can decrease acuity or contrast

sensitivity [20]. To mitigate these limitations, this study investigates red and green filters in a clinical cohort following standardized Ishihara procedures to measure the extent of filter-mediated gains in colour discrimination, compare the efficacy of filters across CVD subtypes, and suggest cost-effective uses of filters in low-resource settings.

MATERIALS AND METHODS

This observational cross-sectional study was conducted at the Eye Outpatient Department (OPD) of Pakistan Institute of Medical Sciences (PIMS), Islamabad, from September to December 2024. The study utilized a standardized protocol to evaluate the efficacy of red (630 nm) and green (530 nm) optical filters (Heine Trial Lens Box, Germany) in improving colour discrimination among patients with congenital red-green colour vision deficiency (CVD). Participants aged 10–70 years were recruited consecutively from the OPD, with inclusion requiring a CVD diagnosis via Ishihara 38-plate edition and best-corrected visual acuity ≥6/12. Exclusion criteria encompassed acquired CVD (e.g., diabetic retinopathy), ocular surgery history, or neurological disorders. Of 500 screened patients, 30 (6%) met eligibility criteria and were enrolled. Therefore, 30 CVD patients were subjected to red and green filter evaluation.

DATA COLLECTION PROCEDURE

Data collection followed a three-phase protocol: First, screening involved Ishihara testing under standardized 1000 lux illuminate C lighting at 75 cm distance, with CVD diagnosis confirmed by ≥4 errors in the 24-plate diagnostic series. Second, baseline Ishihara scores were re-established without filters. Third, randomized red/green filter testing was conducted: filters were mounted in trial frames with peripheral light occlusion, followed by a 5-minute adaptation period before Ishihara re-administration, with a 30-minute washout between filter conditions. All tests were administered by two optometrists with daily lighting verification using a calibrated Lutron LX-112 illuminometer. Demographic data, CVD subtype classification, and Ishihara scores (pre/post-filter) were double entered into structured proformas, with 20% random audits for quality control. Ethical compliance was maintained through BIHS IRB approval (Ref: BIHS/IRB-2024-51) and PIMS (Ref: IRB-2024-OPD-78) and written informed consent.

STATISTICAL ANALYSIS

Data was analysed using a frequency distribution analysis using the Statistical Package for Social Sciences (SPSS) version 25, and the results were displayed in tabulated form in terms of frequencies and percentages.

RESULTS

The sample included 30 study participants with congenital red-green colour vision deficiency (CVD) and consisted of males (n=22, 73.3%) more than females (n=8, 26.7%). This 2.75:1 male-to-female ratio is consistent with the known epidemiologic trends of X-linked recessive inheritance of red-green CVD. The age of the participants was widely distributed between 10 and 70 years with a mean age of 27.17 years (SD=13.24), which was bimodally distributed with peak representation in the 10–30-year age groups. The large standard deviation (13.24 years) shows there is a high level of heterogeneity in age within the cohort, with adolescents and older adults.

Table 1: Demographic Profile of Patients

Variables	F	%
Male	22	73.3%
Female	8	26.7%
Patient Age (Years)±	27.17 ±13.241	

±: Mean ± Standard Deviation, N = 30

Out of thirty, red CVD patients were 27 (90%) while their green counterpart was only recorded in 3 (10%) patients. As such, it is evident that Red CVD was the most common type of color vision deficiency in the population under study.

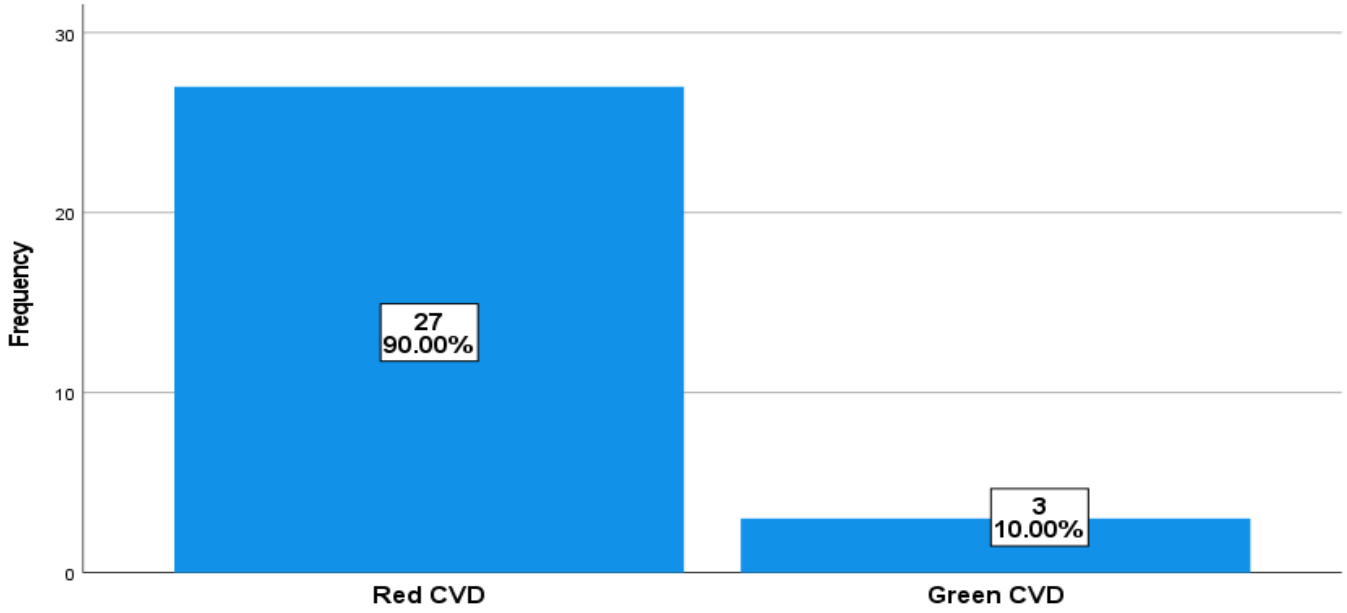

Figure 1: Type of CVD among Patients.

In both eyes, the patients were able to identify only 2 out of 38 (5.3 %) Ishihara plates, but after applying the red filter, they all managed to identify all the plates, which indicated 100% improvement in color discrimination for CVD patients.

Table 3: Recognition of Ishihara Plates in both Eyes before and After Applying Filters

	Total Plates shown	Total Plates Recognised without Filter	Total Plates Recognised with Red Filter	Total Plates Recognised with Green Filter
Right eye	38	2	38	2
Left eye	38	2	38	2

DISCUSSION

Colour vision deficiency (CVD) makes it difficult to see colours correctly, which affects daily life activities as well as some professional activities. Screening the local population for CVD, recognizing CVD patients, and utilizing green and red filters for improvement of colour discrimination can be beneficial in the management of CVD. The study provides a broader contribution to the management of CVD by synthesizing findings with existing literature. In this study, the prevalence of CVD is 6%, as 30 patients were diagnosed with CVD out of 500 patients in the eye OPD. This result is consistent with the general literature, which shows a prevalence of 4%–6% [21]. Data also showed that 73.3% of men had CVD, which depicts male predominance due to X-linked inheritance of congenital CVD. Since males have only one X chromosome, they are more prone to CVD. Routine screening in different settings is required because this condition is not well-known and can cause serious problems for some professions. The younger population usually remains undiagnosed [22]. If CVD is diagnosed in early life, then tools and strategies can be implemented to manage the condition, which in turn enhances the quality of life and professional activities of the individual.

The most interesting result of this study was that red filters showed improvement in colour discrimination ability for green colour vision deficient (Deuteranopia /Deuteranomaly). This result was not expected as red filters are meant to improve deficiency in L-cones, responsible for the perception of red colour. However, past studies have also explained this mechanism. Mohammed Elsherif observed that red filters reduce the spectral overlaps between L and M cones as red filters improve contrast sensitivity and spectral separation [23]. Similarly, Ro et al. reported that red filters showed improvement in colour discrimination in green colour vision deficient by increasing spectral contrast [19, 23]. This occurs due to the similar spectral sensitivities of the L and M cones in red-green deficiencies. Red filters create a much-reduced differentiation between the other two wavelengths. This improved wavelength differentiation assists patients with green CVD. These findings underscore the apparent utility of red filters and may inform future studies for CVDs, as the mechanism of action across the various subtypes of CVD appears to be complex and requires further investigation.

The red filters provided a highly significant improvement in Ishihara plate recognition tests for 100% of the CVD patients, confirming their overwhelming effectiveness. Green filters, in contrast, showed no measurable improvement for the patients. These results agree with observations by Pastilha, who proposed that task-oriented filters (for example, a filter of red) deliver significant improvement in colour discrimination for red-green deficiencies, at least in controlled environments [24]. According to Ro et al., green filters do not provide a good solution for spectral overlap, and therefore red filters are the only clear superior choice [24]. That doesn't just put superiority in terms of reaching out to vibrancy but also promotes contrast and distinction in the visible spectrum. There was a significant improvement in the recognition of Ishihara plates after the use of filters, which was recorded in the study. Patients could recognize only 2 out of the 38 plates before the filters were applied. After the red filters were applied, this number jumped to all 38 plates being recognized accurately, showing how a simple red filter can have such a dramatic effect. These findings were consistent with those of Pastilha, which showed that red filters minimize the presence of visual noise in tasks with difficulty in recognizing elements such as erythema that are of a similar colour to the background during clinical examinations. This substantial gain offered by red filters illustrates their potential use in managing CVD in clinical and practical settings [21].

Some significant practical implications can be derived from the outcomes of the study. The finding of enhanced colour discrimination can help improve the use of certain daily activities by people with CVD, such as the recognition of traffic lights, clothing, colour color-coded information, among others. These improvements are likely to improve the quality of life of many people with CVD greatly. For professionals working in colour-dependent occupations like pilots, electricians, and graphic designers, red coloured glasses may be a cheap and simple solution. Those glasses may reduce the number of colour-blind people and thus increase the safety and productivity of some of these workers. Elsherif pointed out the relevance of purpose-built devices for specific tasks, and this research helps to further strengthen existing data that utilizes the use of red filters for the treatment of CVDs as a practical instrument.

LIMITATIONS AND RECOMMENDATIONS

Screening of 500 patients revealed only 30 cases of CVD. This small number puts a limit on the applicability of these findings. There is a need for large sample sizes and broader demographic representation in future research to validate the results. Although a highly reliable and commonly used test for identifying CVD, the Ishihara test does not specify the type of colour vision deficiency. This puts a limit on providing appropriate findings and recommendations according to the subtypes of CVD. For future studies, the use of more appropriate devices, such as the Anomaloscope, is highly recommended. This study concentrated only on red and green filters, thereby narrowing their scope considerably in the light of potential advances such as nanoparticle filters and dyed contact lenses. The red filter was effective, but the green filter showed no improvement. In future research, exploring a greater variety of tools and techniques may provide a more holistic picture of how CVD can be managed.

CONCLUSION

Colour vision deficiency CVD creates difficulty in daily life, especially in those careers that demand precise discrimination of colours, for example, healthcare, certain areas of technology, and color-coded industries as well. This study concludes that the

management of CVD is greatly improved using red filters. Red filters were found to play a vital role in the enhancement of colour discrimination, thus accentuating their effect in improving the daily life of the CVD patients.

CONFLICT OF INTEREST

The authors declared no conflict of interest.

AUTHOR CONTRIBUTION

Ayesha Rahman and Shaheenullah Wazir conceptualized the study and drafted the manuscript. Maira Manzoor helped with study design and data analysis. Areeba Abbassi and Sifatullah Marwat assisted in data collection, review of literature, and refining the manuscript. Khadija Masood and Arooj Fatima provided support in data analysis and critical review of the manuscript.

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