



## Original Article

# Assessing The Impact of Color Vision Deficiency on Quality of Life in High School Students

<sup>1</sup>Susan Tarawifa, <sup>2</sup>Jessica Jeane, <sup>1</sup>Rina Nofri Enis, <sup>3</sup>Tia Wida Ekaputri, <sup>4</sup>Mandy Putriyudi

<sup>1</sup>Anatomy department, Faculty Of Medicine And Health Science, Universitas Jambi, Jambi, Indonesia

<sup>2</sup>Bachelor of Medicine Program, Faculty Of Medicine And Health Science, Universitas Jambi, Jambi, Indonesia

<sup>3</sup>Biochemistry and Medical Biology Department, Faculty Of Medicine And Health Science, Universitas Jambi, Jambi, Indonesia

<sup>4</sup>Ophthalmology Department of Sriwijaya University, Palembang, Indonesia

E-mail Corresponding: [susantarawifa@unja.ac.id](mailto:susantarawifa@unja.ac.id)

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### ABSTRACT

**Background:** Color vision deficiency (CVD) is a hereditary visual disorder that limits color discrimination and may affect daily functioning, learning performance, and psychosocial well-being. Despite its prevalence, awareness and screening among students in Indonesia remain low.

**Methods:** A cross-sectional analytical study was conducted among 672 high school students selected through a cluster random sampling method. Color vision was evaluated using the Ishihara 38 Plates test, and quality of life was assessed using the Color Blindness Quality of Life (CBQoL) questionnaire, covering health, emotional, and daily activity domains. Data were analyzed using independent t-tests.

**Results:** Of 672 participants, 24 (3.6%) had CVD, predominantly males (91.7%). The deutan type was the most frequent (75%). Students with CVD showed significantly lower CBQoL scores than those with normal color vision in health ( $3.50 \pm 1.11$  vs.  $5.49 \pm 0.54$ ), emotional ( $3.64 \pm 1.13$  vs.  $5.78 \pm 0.35$ ), and daily activity domains ( $3.71 \pm 1.27$  vs.  $5.72 \pm 0.45$ ;  $p < 0.001$ ).

**Conclusion:** CVD significantly reduces students' quality of life. Early detection, educational adaptation, and awareness programs are essential in supporting students affected by these issues and promoting inclusive learning environments.

## INTRODUCTION

Color vision deficiency (CVD) is a visual impairment characterized by a decreased ability to distinguish specific colors. The condition results from functional abnormalities or defects in the cone photoreceptor cells of the retina, which are

responsible for detecting and processing the color spectrum.<sup>1</sup> This disorder has broad implications, potentially affecting daily functioning, health-related tasks, educational performance, occupational choices, and psychological well-being.<sup>1,2</sup>

Individuals with CVD often experience significant challenges in daily life, including difficulties in distinguishing traffic light colors, selecting appropriate clothing, and identifying color-coded symbols. From a clinical perspective, these limitations may have significant implications, such as difficulties in distinguishing the color of blood in urine or sputum, which can serve as important diagnostic indicators.<sup>1,3</sup> In the educational context, particularly among high school students, impaired color discrimination may hinder comprehension of learning materials, especially in disciplines such as chemistry, biology, and geography, where colored diagrams, graphs, and maps are frequently utilized.<sup>4</sup> This condition may also influence students' creativity, learning engagement, and self-confidence. Moreover, CVD can constrain career opportunities in professions that require accurate color perception. Psychologically, affected individuals may experience social stigma and discrimination, which can contribute to diminished self-esteem and, in some cases, psychological distress or depression.<sup>1,2,4</sup>

CVD is predominantly an inherited disorder, with most cases arising from X-linked recessive genetic mutations that affect the photopigments in retinal cone cells.<sup>1</sup> Consequently, the prevalence of CVD is substantially higher in males. Epidemiological data indicate that the prevalence of CVD is below 2% among Native American and Australian populations, approximately 4% in individuals of African descent, 5% in Asian populations, and around 8% among Caucasians.<sup>5</sup>

Despite its prevalence, CVD remains underdiagnosed and insufficiently recognized, both within the general community and among healthcare professionals. Although not life-threatening, CVD is a form of permanent disability that can affect the quality of life of those who suffer from it.<sup>2,3</sup> Therefore, screening and early detection are not only necessary but also crucial for identifying cases early on, providing appropriate education, and helping

sufferers adapt to their daily activities, education, and career choices.

## METHOD

This study employed a quantitative analytic approach with a cross-sectional design. The study population comprised all high school students in Jambi City. A cluster sampling technique was utilized to select participating schools, and within each selected school, students were chosen through simple random sampling. A total of 672 students who met the inclusion criteria participated in the study.

Color vision deficiency was assessed using the *Ishihara 38 Plates* test, while participants' quality of life was measured using the *Color Blindness Quality of Life (CBQoL)* questionnaire.<sup>2</sup> The *Ishihara 38 Plates* results were classified into four categories: normal, anomalous trichromat, dichromat, and monochromat. The CBQoL questionnaire consisted of 23 items, divided into three domains: health, emotional well-being, and daily activities.<sup>2</sup> Responses were scored on a 6-point Likert scale, where lower scores indicated poorer quality of life. Data were analyzed using univariate and bivariate analyses, with the *independent t-test* applied to evaluate statistical differences.

This research was conducted in accordance with the ethical principles outlined in the *Declaration of Helsinki*. Ethical approval was obtained from the Health Research Ethics Committee of the Faculty of Medicine and Health Sciences, Universitas Jambi, under approval number 988/UN21.8/PT.01.04/2024.

## RESULT

A total of 672 high school students participated in this study. As shown in Table 1, 24 students (3.6%) were identified as having color vision deficiency (CVD), while 648 students (96.4%) demonstrated normal color vision. Based on gender distribution, 299 participants (44.5%) were male and 373 participants (55.5%) were female. Of the participants with color vision deficiency, 22

were male and 2 were female. Regarding the type of color vision deficiency, the majority were classified as deutan type (18 students;

75%), while protan type was identified in 6 students (25%). No cases of monochromacy were found among the participants.

**Table 1.** Characteristics of Respondents

Variable	Frequency (n)	Percentage (%)
Color Vision Status		
Color Vision Deficiency	24	3.6
Normal Color Vision	648	96.4
Gender		
Male	299	44.5
Female	373	55.5
Color Vision Deficiency Based on Gender		
Male	22	91.7
Female	2	8.3
Type of Color Vision Deficiency		
Protan	6	25
Deutan	18	75
Monochromat	0	0

Table 2 showed a comparison of Color Blindness Quality of Life (CBQoL) scores between participants with color vision deficiency (CVD) and those with normal color vision, matched for age and gender (N = 24 pairs). In the health domain, participants with CVD had a mean CBQoL score of  $3.50 \pm 1.106$ , compared to  $5.49 \pm 0.539$  in the normal vision group ( $t = -7.904$ ,  $p < 0.001$ ). Similarly, in the emotional domain, the mean score for the CVD group was  $3.64 \pm 1.133$ ,

substantially lower than the  $5.78 \pm 0.349$  observed in the control group ( $t = -8.859$ ,  $p < 0.001$ ). In the work and daily activity domain, the mean score for participants with CVD was  $3.71 \pm 1.268$ , whereas those with normal color vision scored  $5.72 \pm 0.447$  ( $t = -7.340$ ,  $p < 0.001$ ). The consistent statistical significance ( $p < 0.001$ ) across all domains underscores the broad impact of CVD on various aspects of functional and psychosocial health.

**Table 2.** Quality of Life of Age- and Gender-Matched Participants (N = 24 pairs)

Variable	CVD, M (SD)	Normal, M (SD)	t	p
CBQoL – Health	3.50 (1.11)	5.49 (0.54)	- 7.90	< .001
CBQoL – Emotion	3.64 (1.13)	5.78 (0.35)	-8 .86	< .001
CBQoL – Work	3.71 (1.27)	5.72 (0.45)	- 7.34	< .001

## DISCUSSION

Color vision plays a prominent role in the learning process and in understanding the visual environment. Color vision deficiency (CVD) can significantly affect an individual's quality of life, particularly in academic, social, and emotional domains.<sup>1,2,6</sup> Students with CVD may struggle to identify colors in learning materials or during laboratory activities, which can impact their

self-confidence and influence their future educational and career choices.<sup>4, 19</sup>

This study highlights the relationship between color vision deficiency (CVD) and quality of life among senior high school students in Jambi City. Of the 672 students assessed, 24 were identified with CVD, the majority of whom were male. This finding aligns with previous research demonstrating that color vision deficiency is more prevalent in males due to its X-linked genetic

inheritance pattern.<sup>7</sup> Males possess only one X chromosome; a mutation affecting this chromosome directly manifests as CVD. In contrast, females have two X chromosomes, enabling the normal allele on one chromosome to compensate for the defective allele on the other. This compensatory mechanism explains the considerably lower prevalence of CVD observed in females.<sup>6,18</sup>

The study further shows that the deutan type of CVD occurred at a higher frequency than the protan type. The overall incidences of deuteranomaly and protanomaly were 18 (75%) and 6 (25%), respectively. Deutan was identified as the predominant form of CVD in both genders.<sup>19</sup> This finding aligns with previous research conducted in other regions, including Jordan and India, which also reported the deutan type as the most prevalent form of color vision deficiency.<sup>6,7</sup> Students affected by deuteranomaly or protanomaly may encounter difficulties in distinguishing specific colors—particularly red and green—which can interfere with learning processes and practical activities that rely on accurate color discrimination.<sup>8,20</sup>

The reduction in quality of life observed among students with color vision deficiency, as demonstrated in this study, highlights the significant impact of impaired color perception on physical, emotional, and social well-being.<sup>1,2</sup> From a health perspective, the lower average scores indicate that these students experience difficulties in distinguishing specific colors essential for daily functioning, such as recognizing changes in food coloration or visible physiological symptoms.<sup>2,3</sup> This finding is consistent with Berry et al., who reported that individuals with color vision deficiency experience limitations in visual activities requiring accurate color discrimination, which may indirectly influence overall health and quality of life.<sup>2,21</sup>

Based on the emotional domain, students with CVD demonstrated lower quality-of-life assessments compared to those with normal color vision. This suggests

significant psychological implications, including increased stress, lowered self-esteem, and anxiety related to social stigma. In line with the findings of previous study individuals with CVD often feel isolated and may avoid activities that necessitate accurate color discrimination due to embarrassment or fear of failure.<sup>11,22</sup> Furthermore, the competitive nature of the academic environment may intensify these challenges, as students with CVD may perceive themselves as less capable in subjects that rely heavily on color differentiation, such as art, chemistry, or biology.<sup>4,16</sup>

In terms of daily activities, affected students exhibited significantly lower scores compared to those with normal color vision. This finding highlights the challenges they face in performing routine tasks such as recognizing traffic lights, selecting appropriate clothing, or operating devices that rely on color-coded indicators.<sup>23,24</sup> These results align with previous studies indicating that difficulties in color discrimination can adversely affect an individual's efficiency and productivity in various aspects of daily life.<sup>2,17</sup>

The present study revealed a significant negative correlation between the severity of color vision deficiency and quality of life. As the degree of visual impairment increases, the overall quality-of-life scores of respondents decrease. These findings underscore that color vision deficiency is not merely a visual limitation but also affects psychosocial and emotional well-being.<sup>2,10</sup> Therefore, appropriate interventions such as the use of color-corrective lenses or the development of adaptive digital technologies are essential to support individuals with color vision deficiency in performing their daily activities.<sup>12,13</sup>

In addition, the importance of implementing awareness and education programs in schools should be emphasized, particularly to increase understanding of the impact of color vision deficiency and to provide adequate support for affected students. For instance, career counseling programs can assist students with color

vision deficiency in selecting educational and career paths that align with their abilities and limitations, thereby reducing feelings of marginalization.<sup>14,18</sup> This approach is consistent with the recommendations of UNESCO (2020), which advocate for inclusive education by ensuring equal access and tailored support for students with special needs, including those with color vision deficiency.<sup>15,25</sup>

Overall, this study highlights the importance of addressing CVD among students. The impact of this condition extends beyond visual limitations, influencing psychological well-being, social interactions, and daily functioning. These findings provide a strong foundation for the development of targeted interventions, awareness programs, and inclusive educational policies that support students with color vision deficiency, thereby enhancing their overall quality of life.

## CONCLUSION

This study demonstrates that color vision deficiency (CVD) exerts a significant

negative impact on various aspects of quality of life among high school students, including health-related, emotional, and functional domains. Students with CVD exhibited notably lower quality-of-life scores compared to their peers with normal color vision, highlighting the broader psychosocial and practical implications of this visual impairment. These findings highlight the importance of early detection and the integration of targeted educational and counseling interventions to facilitate adaptation and optimize learning experiences for affected individuals.

Furthermore, the implementation of inclusive educational policies and awareness programs is essential to promote understanding, reduce stigma, and enhance the overall well-being of students with CVD. Future studies should focus on longitudinal assessments and the evaluation of interventional strategies aimed at mitigating the long-term impact of color vision deficiency on academic performance and psychosocial outcomes.

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