



Research Article

Prevalence of Colour Vision Deficiency Among Individuals Seeking Pre-Employment Screening in A Tertiary Healthcare Facility in South India: A Cross-Sectional Study

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Received: 23-09-2025

Accepted: 06-10-2025

Available online: 20-10-2025

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Medical and Pharmaceutical Research

ABSTRACT

Background: Colour vision deficiency (CVD) impairs colour discrimination, posing safety risks in occupations requiring accurate colour perception. Limited data exist on CVD prevalence among adults undergoing pre-employment screening in South India.

Objectives: To determine the prevalence of CVD among individuals seeking pre-employment screening at a tertiary-care facility in South India and to examine associations with demographic characteristics.

Methods: We conducted a retrospective cross-sectional study of 332 adults who underwent pre-employment ophthalmological evaluation, including Ishihara pseudo isochromatic chart testing, between December 2022 and December 2023. Demographic variables (age, gender, education, residence) and clinical findings (visual acuity, fundus examination) were extracted from medical records. Descriptive statistics and chi-square tests ($\alpha=0.05$) assessed prevalence estimates and associations.

Results: Overall CVD prevalence was 9.9% (33/332), exclusively red-green defects. All CVD cases occurred in males (12.7% of 259 males; 0% of 73 females; $p<0.001$). Prevalence did not differ significantly by age group (<30 years: 8.8%; ≥ 30 years: 10.7%; $p=0.57$) or education level. A significant rural-urban disparity was observed (rural: 13.1%; urban: 4.3%; remote: 50.0%; $p=0.02$). Visual acuity was normal (6/6) in 89.5% of participants, and fundus abnormalities were rare (2.1%).

Conclusions: A substantial proportion of pre-employment candidates in South India exhibit undiagnosed red-green CVD, with male and rural predominance. Integration of routine colour vision screening into occupational health protocols and targeted awareness in rural areas are recommended. Future population-based and genetic studies should explore factors influencing CVD distribution in India.

Keywords: Colour vision Deficiency, Pre-employment Screening, Ergonomics, Ophthalmological evaluation.

INTRODUCTION

Colour vision deficiency (CVD), also known as colour blindness, is a congenital or acquired condition characterized by the inability to perceive colour differences under normal lighting conditions. This X-linked recessive genetic disorder predominantly affects males, with prevalence rates ranging from 5-8% in males and 0.4-1% in females globally. The most common forms are red-green colour vision deficiencies, which include protanopia, protanomaly, deuteranopia, and deuteranomaly, collectively accounting for approximately 95% of all CVD cases.^{1,2}

The epidemiology of CVD varies significantly across different populations and geographical regions. In India, studies have reported prevalence rates ranging from 0.9% to 11.36% among different populations, with substantial regional and ethnic variations. Among the Indian population, the prevalence in males has been documented between 2.76% to 7.52%, while female prevalence remains considerably lower at 0.37% to 0.83%. These variations highlight the importance of population-specific studies to understand the true burden of CVD in different regions.^{3,4}

The clinical significance of CVD extends beyond mere colour perception difficulties, particularly in occupational settings. Many professions require accurate colour discrimination for safety-critical tasks, including aviation, railway operations, electrical work, chemical industries, and healthcare. Individuals with CVD may face occupational limitations or safety risks when employed in colour-dependent tasks without appropriate screening. The Ishihara pseudoisochromatic plate test, developed in 1917, remains the most widely used screening tool for detecting red-green colour vision deficiencies due to its simplicity, accuracy, and cost-effectiveness.^{5,6}

Pre-employment medical examinations serve as crucial screening opportunities for identifying previously undiagnosed CVD. In India, government guidelines mandate pre-employment medical examinations for various positions, including vision assessment and colour vision testing using Ishihara plates. These examinations not only protect workplace safety but also provide individuals with knowledge about their condition, enabling informed career choices. However, comprehensive data on CVD prevalence in pre-employment screening populations from South India remains limited. Despite the clinical and occupational importance of CVD, many individuals remain undiagnosed until adulthood, often discovered incidentally during pre-employment screening. This late diagnosis can result in career limitations and psychological distress when individuals discover their condition after committing to specific educational or career paths. Early identification through systematic screening programs could facilitate appropriate career counseling and adaptive strategies.^{5,6}

The present study aims to address this knowledge gap by determining the prevalence of colour vision deficiency among individuals seeking pre-employment screening in a tertiary healthcare facility in South India and examining its association with demographic characteristics. Understanding the local prevalence of CVD in this population will inform occupational health policies, screening protocols, and career counseling programs in the region.

METHODOLOGY

Study Design and Setting

This retrospective cross-sectional study was conducted at a tertiary healthcare facility in South India. The study utilized data from medical records of individuals who underwent pre-employment screening in the ophthalmology department between December 2022 and December 2023.

The study included all eligible medical records from the specified time period, representing a comprehensive census of individuals seeking pre-employment screening at the facility during the study duration. The study utilized convenience sampling to recruit its population from medical records of individuals who presented to the ophthalmology outpatient department or were screened at industrial camps for pre-employment screening. Inclusion criteria were broad, encompassing all ages and genders, while records with incomplete data on color vision assessment were excluded. This approach aimed to capture a representative sample of individuals undergoing routine vision screening within the facility.

In this study, data were systematically extracted from patient medical records, including demographic and clinical history. A comprehensive ocular examination was performed, adhering to standardized protocols for assessing visual acuity and performing slit-lamp biomicroscopy and indirect ophthalmoscopy. Color vision deficiency (CVD) was assessed using the Ishihara pseudoisochromatic chart, which served as the gold standard for detecting red-green deficiencies. The primary objective was to determine the prevalence of CVD in pre-employment screening, while a secondary aim was to analyze its association with demographic characteristics.

Statistical Analysis

Data entry and analysis were performed using SPSS version 25 software. Descriptive statistics included frequency distributions and percentages for categorical variables, with prevalence calculations performed using standard epidemiological methods. Inferential statistics employed the chi-square test to assess associations between demographic characteristics and colour vision deficiency prevalence. Statistical significance was set at $p\text{-value} < 0.05$.

In this study, measures were implemented to ensure high data quality and minimize potential bias. To reduce information bias, a standardized form was used for systematic data extraction from medical records, and records with insufficient data were excluded. The use of Ishihara plates, a validated and standardized testing method, helped to minimize measurement bias. From an ethical standpoint, the study strictly adhered to institutional guidelines for medical record research. Patient confidentiality was maintained throughout, as all data were anonymized and handled retrospectively.

RESULTS

Study Population Characteristics

A total of 332 individuals seeking pre-employment screening were included in this retrospective cross-sectional study conducted between December 2022 and December 2023. The demographic distribution revealed a predominantly male population (259, 78.0%) compared to females (73, 22.0%). The majority of participants (196, 59.0%) were above 30 years of age, while 136 (41.0%) were younger than 30 years. Regarding educational background, primary education was

most common (172, 51.8%), followed by secondary education (111, 33.4%) and graduate level (49, 14.8%). Geographically, rural residents constituted the largest group (213, 64.2%), followed by urban residents (115, 34.6%), with minimal representation from remote areas (4, 1.2%).

Clinical Examination Findings

Comprehensive ophthalmological examination revealed that the majority of participants (297, 89.5%) had normal visual acuity of 6/6 on distance testing. Visual acuity of 6/9 was observed in 20 participants (6.0%), while other visual acuity levels were less frequent, including 6/12 in 9 participants (2.7%), 6/18 in 4 participants (1.2%), and 6/24 and 6/60 each in 1 participant (0.3%). All participants demonstrated normal near visual acuity (N6). Fundus examination revealed normal findings in 325 participants (97.9%), while abnormal findings were detected in 7 participants (2.1%), comprising 3 cases of diabetic retinopathy and 4 cases of hypertensive retinopathy.

Prevalence of Colour Vision Deficiency

The overall prevalence of colour vision deficiency in the study population was 9.9% (33 out of 332 participants). All identified cases were classified as red-green colour vision defects based on Ishihara pseudoisochromatic chart testing. No cases of blue-yellow colour vision deficiency were detected in this study population. Normal colour vision was present in 299 participants (90.1%).

Table 1: Ophthalmological characteristics of the study population

Variables	Sub-category	N	%
BCVA - distant	6/12	9	2.7%
	6/18	4	1.2%
	6/24	1	0.3%
	6/6	297	89.5%
	6/60	1	0.3%
	6/9	20	6.0%
BCVA - near	N6	332	100.0%
Colour vision	Normal	299	90.1%
	Red Green Defect	33	9.9%
Fundus examination	Normal	325	97.9%
	Abnormal	7	2.1%
If abnormal	Diabetic Retinopathy	3	
	Hypertensive Retinopathy	4	

Gender-Specific Analysis of Colour Vision Deficiency

A significant association was observed between gender and colour vision deficiency ($p < 0.05$). All cases of colour vision deficiency were exclusively found among male participants, with a prevalence of 12.7% (33 out of 259 males). No female participants demonstrated colour vision deficiency. The remaining 226 male participants (87.3%) and all 73 female participants (100.0%) had normal colour vision.

Age-Specific Distribution of Colour Vision Deficiency

The analysis of colour vision deficiency across age groups showed no statistically significant association ($p = 0.5712$). Among participants younger than 30 years, 12 out of 136 (8.8%) had colour vision deficiency, while 124 (91.2%) had normal colour vision. In the older age group (≥ 30 years), 21 out of 196 participants (10.7%) demonstrated colour vision deficiency, with 175 (89.3%) having normal colour vision.

Geographic Distribution of Colour Vision Deficiency

A statistically significant association was found between area of residence and colour vision deficiency prevalence ($p < 0.05$). Rural residents demonstrated the highest prevalence of colour vision deficiency at 13.1% (28 out of 213 participants), while urban residents showed a lower prevalence of 4.3% (5 out of 115 participants). Among the limited remote area residents, 2 out of 4 participants (50.0%) had colour vision deficiency, though this small sample size limits interpretation.

The identification of 33 individuals with colour vision deficiency during pre-employment screening has important implications for occupational placement and workplace safety. All affected individuals were males, consistent with the X-linked inheritance pattern of red-green colour vision deficiencies. The higher prevalence observed in rural populations compared to urban populations warrants further investigation and may influence targeted screening strategies. These findings underscore the importance of systematic colour vision assessment in pre-employment medical examinations, particularly for positions requiring accurate colour discrimination for safety-critical tasks.

The study demonstrates that colour vision deficiency remains a significant condition among individuals seeking employment, with nearly 1 in 10 participants affected.

Table 2: Factors associated with Colour Vision Deficiency

Characteristics	Colour Vision				p-value
	Red Green defect		Normal		
Gender					
Male	33	12.7%	226	87.3%	<0.05
Female	0		73	100%	
Age					
Less than 30	12	8.8%	124	91.2%	0.5712
More than 30	21	10.7%	175	89.3%	
Area of residence					
Urban	5	4.3%	110	95.7%	<0.05
Rural	28	13.1%	185	86.9%	
Remote	2	50%	2	50%	

DISCUSSION

The present retrospective cross-sectional study found an overall colour vision deficiency (CVD) prevalence of 9.9% among individuals undergoing pre-employment screening at a tertiary healthcare facility in South India, with all cases being red–green defects and exclusively affecting males (12.7% of males; 0% of females). These findings are broadly consistent with both national and international epidemiology of CVD, while also highlighting unique regional patterns. Globally, the prevalence of red–green CVD in males ranges from 5% to 8%, and in females from 0.4% to 1%. The slightly higher male prevalence in this South Indian cohort (12.7%) may reflect population-specific genetic factors or consanguinity patterns that elevate gene frequency of opsin mutations. Studies from European and North American populations report male prevalence of 7–8% and female prevalence of 0.4–0.6%, whereas East Asian cohorts demonstrate somewhat lower male prevalence (~4–6%). Thus, our findings fall at the upper end of the global range, suggesting that South Indian populations may harbor a higher burden of red–green CVD.^{7,8}

Prior Indian investigations have reported widely varying CVD prevalence depending on region and study population. A North Indian study of school children reported a male prevalence of 7.8% and female prevalence of 0.5%. In Western India, an adult population study found a male prevalence of 6.2% and female prevalence of 0.3%. Conversely, a South Indian community-based survey documented male prevalence as high as 11.4% and female prevalence of 0.7%. Compared to these, the 12.7% male prevalence observed in our pre-employment screening cohort is slightly higher, potentially due to the adult working-age demographic and self-selection of individuals seeking occupational clearance. The absence of CVD among female participants aligns with the very low female prevalence reported across India (0.3–0.8%).^{9,10}

While some international studies have suggested a mild decline in detectable CVD with advancing age—attributed to acquired lens changes rather than congenital deficiency—our study found no significant age-based variation in prevalence (8.8% in <30 years vs. 10.7% in ≥30 years; $p=0.57$). This consistency with prior adult Indian studies implies stability of congenital red–green deficiencies across the adult lifespan. Educational level did not demonstrate a clear association with CVD, similar to other reports indicating that CVD prevalence is independent of socioeconomic or educational status.^{10,11}

The significant rural–urban disparity in CVD prevalence (13.1% vs. 4.3%; $p<0.05$) has not been widely reported in previous Indian literature. International occupational health guidelines emphasize the importance of colour vision screening for safety-critical roles such as transport, electrical work, and healthcare diagnostics. The higher rural prevalence underscores the need for targeted career counselling and adaptive workplace strategies in predominantly rural regions.^{5,6}

The study's strengths include a sizeable cohort ($N=332$), the use of standardized Ishihara testing, and a comprehensive ocular examination that provided a holistic assessment of participants' health. However, the retrospective design and reliance on medical records introduce potential information and selection bias, which limits the generalizability of the findings. The small sample size for remote-area residents ($n=4$) prevented robust subgroup analysis, and the absence of molecular genotyping precluded a detailed characterization of the underlying genetic basis of colour vision deficiencies.

CONCLUSION

This study demonstrates a 9.9% overall prevalence of red–green colour vision deficiency among pre-employment screening candidates in South India, exclusively affecting males (12.7%) and showing a significant rural predominance.

These findings align with national and international epidemiology, while highlighting region-specific variations. Routine colour vision screening in occupational health protocols is essential for safety-critical roles. Targeted awareness and career counselling programs in rural communities may mitigate the impact of undiagnosed CVD. Future prospective and genetic studies are warranted to further elucidate determinants of CVD in diverse Indian populations.

Conflicts of interests: The authors declare no conflicts of interest.

Author contribution: All authors have contributed in the manuscript.

Author funding: Nil

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