



Review Article on Colour Vision Defect

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ABSTRACT

Background: Colour Vision Defect (CVD) is a common disorder that is caused by damage done to retinal photoreceptors; cones. The disorder simply causes a person to have impaired vision of colour. This means that certain wavelengths and variation in hues may pose difficulty being received by one with CVD.

Aim: To analyze and appraise previous literature and their findings to formulate a review on Colour Vision Defect.

Method: A mapping review was done to analyze and understand previous qualitative and quantitative studies based on the topic of colour vision defect. Fifteen articles were reviewed in total, all of which included population-based studies, cohort studies and cross-sectional studies.

Results: Colour Vision Defect was found to have significant global prevalence with the most popular form of the defect being Deutan defect. The prevalence of CVD was found to be higher in males as compared to females, but it showed no predilection towards age and a sufficient amount of studies were not reviewed to make proper conclusions of the distribution of CVD with respect to ethnicity. The most common form of testing this disorder were Pseudoisochromatic plates, specifically the Ishihara Pseudo Isochromatic plates. There are no current treatments of CVD but bringing awareness of the disorder and having CV screenings at a young age were methods of management that were suggested to have a firmer grip on this disability.

Conclusion: Colour Vision Defect is a common disorder of the visual system that has gone unnoticed for some time now. It is very necessary to embark on bringing awareness of this defect as well as to have individuals properly advised on how to cope and make.

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CHAPTER ONE

INTRODUCTION

1.0 Introduction

One's ability to identify various hues as well as differentiate between different shades is known as colour vision. Colour composes of different wavelengths and intensities which make them unique. In a world filled with a myriad of colours it certainly is useful to have colour vision.¹ The use of colours are commonly used in the organisation of several aspects of the world to make human function much easier, it gives an alternative way to perceive the world rather than that of shapes and sizes.² Several studies that have shown that colour vision defect is one of the most common disorders of the visual system that many people are not aware of. This review is based on different studies done globally to analyze and better understand, the prevalence and distribution of CVD according to, methods for testing and their limitations as well as management of CVD.

1.1 Background Information

1.1.1 Causes of CVD

CVD can either be a congenital or an acquired. Congenital CVD means it is an inherited disorder that is non pathological, nor does it worsen or get better and is present from the time of birth.³ This type of CVD is simply caused by the inheritance of defective/ damaged X - chromosomes.³ Protanopia and deuteranopia are both predominantly products of congenital CVD whereas tritanopia is predominantly a result of acquired CVD. Acquired CVD usually occurs in conjunction with a pathological disease, trauma, exposure to large amounts of chemicals or it may even be a side effect of a medication one takes.⁴ It usually develops at some point throughout one's life. There is currently no form of treatment for either form of CVD but there are ways to alleviate the severity of acquired CVD for example, discontinued use of certain medication may reduce the severity of the disorder.⁴

Congenital protanopia and deuteranopia are sex-linked inherited disorders whereas tritanopia is an autosomal dominant non-sex-linked inheritance disease which therefore means it does not show preference between males and females.⁴ It can easily affect females as much as it can males. Both protanopia and deuteranopia unlike tritanopia has the inheritance pattern of X-linked recessive, this explains why it is more prone to males than females.⁴

1.1.2 PATHOGENESIS OF CVD

Cones are the photoreceptors within our retina that are responsible for colour vision. There are three types of these cones; Small(blue), Medium(green) and Long(red) which allows us to identify various wavelengths.² These cones are usually inherited and are used in distinguish colours, if one lacks one of the photoreceptors or they become damaged, that person will be considered to have colour vision deficiency (CVD).¹ This does not mean that the person is incapable of seeing all colours but simply they will have problems with seeing some colours.

1.1.3 TYPES OF CVD

There are 4 main types of CVD. The four types of deficiency are protan (red or long wave), duetan (green or middle wave), tritan (blue or short wave), and achromatopsia (total absence of colour vision, very rare disorder). A person who has normal colour vision is considered a trichromat, whereas someone who lacks one of these cones are knowns as dichromats.² There are different types of dichromats, this depends on which photoreceptor is absent or faulty. Protanopia indicates that the red photoreceptor is missing or faulty and deuteranopia indicates that the green receptor is the problem.² It is very rare that the blue photoreceptor is faulty/absent, but this type is known as tritanopia.² Monochromatic persons are said to be totally colour blind; they are only able to perceive light and this condition is also known as achromatopsia.³

1.0.4 TESTS TO DETECT CVD

There are several tests available that are used to detect if a person had CVD; such test are the Ishihara Pseudo Isochromatic plates, Farnsworth Dichotomous Test, Anomaloscope, Color Vision Testing Made easy and many others.⁴ Of these tests, the Ishihara Pseudoisochromatic plates seems to be the most popular. This test although, quite simply to understand and easy to administer only detects 2 of the 3 types of CVD, therefore should ideally be used in conjunction with another method of testing.⁵ The Ishihara test was designed to be done in natural daylight, extreme variations in lighting can affect the results of the test.⁶ The booklet is to be held at approximately 75cm from the patient at a 90-degree angle to their line of sight and the patient should not be given more than 3-4 seconds per plate.⁶ If these instructions are followed while administering the test it is guaranteed to give a reliable result.

The anomaloscope is a diagnostic instrument used to test CVD, it is also one of the most difficult methods.⁷ Apart from being difficult to administer, it is also a very expensive. This test entails the patient attempting to ‘match’ two stimulus: colour and brightness.⁷

The Farnsworth D 15 test is a less commonly used form of testing, it is an arrangement test. It evaluates 3 types of CVD and is considered a diagnostic test.⁸ Though this test covers the 3 types of CVD it is a bit more time consuming and difficult to understand. It consists of differently colours ‘caps’ which the person being tested is expected to arrange the ‘caps’ according to sequential hues.⁹ The results are then evaluated to properly diagnose CVD.

Colour Vision Made Easy testing is another pseudo isochromatic plate test. It is considered the pediatric gold standard test for CV.¹⁰ This test consists of shapes as compared to the Ishihara where numbers and patterns are used.¹⁰ This test procedure is very much similar to the Ishihara test.

1.1.5 TREATMENT OF CVD

Although there are a variety of clinical tests available, once diagnosed with CVD there is not much that can be done about it. There are currently no available treatments for CVD (Hasrod et al, 2016).⁴ CVD is a lifelong disability that the person has to live with. In some cases, persons with acquired CVD due to intake of some type of medication recovers their color vision when they discontinue intake of such medication .⁴

1.2 Problem Statement

With CVD being one of the most common disorders of the eye, it is astounding that there is a significant lack of knowledge and understanding surrounding this topic. Colours are so widely used in the world that it is crucial for persons to know and be aware of their colour vision status to have a clear understanding of the visual world. Therefore, this review aims to appraise and synthesize various literatures, reviews and research to compare and contrast several factors of CVD.

1.3 Aim of study

The aim of this review is to analyse previous knowledge on Colour Vision Deficiency to have a better understanding of the disorder.

1.4 Objectives of study

- To determine the prevalence and distribution of CVD

- To ascertain the methods of testing CVD
- The understand methods of management

1.5 Significance of study

- This study will serve as a guide and reference for further studies.
- It will also help create awareness to the public on the area where much need to be done regarding CVD.

1.6 Delimitation of study:

This study is delimited to CVD studies published online in English encompassed the prevalence and distribution of CVD, the methods of testing as well as the methods of management.

CHAPTER TWO

METHODOLOGY

2.0 Introduction

For this review, no new data was collected or analyzed. Studies conducted in different parts of the world relating to color vision deficiency were collected and compared to formulate this review. This chapter encompasses the methodology and outlined the details as to how studies were selected.

2.1 Research design

The design of this research was a mapping review. It entails gathering previous literature to assess and analyze their findings to formulate a review on a specific topic.²³ No new data was formulated but previous data were evaluated, and conclusions were made based on the objectives

2.2 Study Population

Studies that were based on Colour Vision Defect across the world were included in this review.

2.3 Inclusion criteria

- Studies on CVD done between 2000 to 2020 and were published in English were included in this review.
- Studies of various research design such as cross-sectional studies, population-based studies, and cohort studies

2.4 Exclusion criteria

- Studies which were not based on humans were excluded

2.5 Sample size

For the purpose of this review a total of 15 articles have been read and reviewed. Articles were retrieved and searched from various database systems using PubMed, Google Scholar, Wiley Online Library, U.S National Library Medicine, BioMed Central, African Vision and Health Library and the Ophthalmology U.S National Library of Medicine. Initially 29 articles were retrieved but 14 were removed since they did not meet the inclusion criteria.

2.6 Data Collection

Data collection was done by firstly searching for articles online using phrases such as “Colour Vision Defect”, “Prevalence of Colour Vision Deficiency”, “Distribution of Colour Vision Defect”, “Methods of testing Colour Vision Defect” “The Most prevalent type of Colour Vision Defect” as well as “ Methods of Managing Colour Vision Defect” in several different search engines like BioMed Central and PubMed. After the articles were retrieved, they were categorized and analyzed based on the objectives of this review. The data obtained from the articles were grouped based on the prevalence of CVD, Methods of testing and methods of management. The articles were then analyzed and compared with each other to evaluate the findings and to form this review.

CHAPTER THREE

RESULTS

3.0 Prevalence and distribution of CVD

Table 3.1 presented the overall prevalence of CVD in different geographical locations as well as its distribution between genders. This tables shows that the highest prevalence of CVD was seen in North India followed by Ireland. The lowest prevalence was recorded in Nigeria.

Table 3.0: Prevalence and distribution of CVD

Authors	Year of Publication of Study	Geographical Location of Study	Sample Size	Overall Prevalence	Prevalence according to gender	
					Male	Female
Woldeamanuel et al. ¹¹	2018	Ethiopia	844	4.10%	3.60%	0.60%
Ativie et al. ¹²	2017	Nigeria	1500	1.87%	2.80%	0.70%
Oduntan et al. ¹³	2019	Nigeria	2326	2.50%	4.80%	0.70%
Mashige et al. ¹⁴	2019	South Africa	1305	2.20%	4.20%	0.60%
Oriowo et al. ¹⁶	2008	Saudi Arabia	1638	3.36%	5.85%	0.75%
Agarwal et al. ¹⁷	2014	Western India	595	2.02%	3.16%	0.40%
Fareed et al. ¹⁸	2015	North India	1028	8.75%	7.52%	0.83%
Mughal et al. ¹⁹	2013	Pakistan	2000	3.70%	2.40%	4.48%
Harrington et al. ²⁰	2020	Ireland	1626	5.29%	8.30%	1.80%

3.1 Prevalence and distribution of types of CVD

Table 3.2 presented the prevalence of the different types of CVD. The results showed that deuteranopia was the most prevalent type of CVD and there was no record of tritan defect in the eight studies reviewed. Although quite rare, Monochromatic persons were recorded in two studies with a very low prevalence rate.

Table 3.1: Prevalence and distribution of types of CVD

Author	Year	Sample Size of Study	Geographical Location	Dichromats			Monochromats
				P	D	T	
Woldeama nuel et al	2018	844	Ethiopia	42.90%	57.10 %		
Ativie et al	2017	1500	Nigeria	28.57%	57.14 %		10.71%
Oduntan et al	2019	2326	Nigeria	29.31%	65.51 %		
Mashige et al	2019	1305	South Africa	34.48%	65.52 %		
Xie et	2014	5960	America	34.00%	51.00 %		
Oriowo et al	2008	1638	Saudi Arabia	27.27%	72.72 %		
Agarwal et al	2014	595	Western India	8.33%	91.67 %		
Fareed et al	2015	1028	North India	22.22%	71.11 %		5.56%

3.2 Prevalence and distribution of CVD according to age.

Table 3.3 presented the prevalence of CVD according to age. The result showed that there was no preference in the distribution of colour vision deficiency with respect to age of the individuals. Various age groups showed similar prevalence rates.

Table 3.2: Prevalence and distribution of CVD according to age.

Authors	Year of Publication of Study	Age Grouping of Sample Size	Prevalence of CVD
Ativie et al. ¹²	2017	10-60	1.87%
Oduntan et al. ¹³	2019	7-22	2.50%
Mashige et al. ¹⁴	2019	7-17	2.20%
Oriowo et al. ¹⁶	2008	6-19	3.36%
Agarwal et al. ¹⁷	2014	9-19	2.02%
Fareed et al. ¹⁸	2015	6-15	8.75%
Mughal et al. ¹⁹	2013	18-21	3.70%
Harrington et al. ²⁰	2020	6-13	5.29%

3.3 Methods of testing used.

Ishihara a pseudoisochromatic plates was the most common form of testing used.

Table 3.3: Methods of testing used.

Authors	Age Group of Sample Size	Method of Testing used.
Ativie et al. ¹²	10-60	Ishihara Pseudoisochromatic Plates
Oduntan et al. ¹³	7-22	Richmond-HRR Test.
Mashige et al. ¹⁴	7-17	Colour Vision Made Easy Test Plates
Xie et al. ¹⁵	2-6	Ishihara Pseudoisochromatic Plates
Oriowo et al. ¹⁶	6-19	Ishihara Pseudoisochromatic Plates
Agarwal et al. ¹⁷	9-19	Ishihara Pseudoisochromatic Plates
Fareed et al. ¹⁸	6-15	Ishihara Pseudoisochromatic Plates
Mughal et al. ¹⁹	18-21	Ishihara Pseudoisochromatic Plates
Harrington et al. ²⁰	6-13	Richmond HRR Test.

3.4 Methods of Management.

The result showed that screening of children for CVD was the most suggested method of management.

Table 3.4: Methods of managements.

Authors	Year of Study	Methods of management
Chakrabarti et al.. ²¹	2015	• Early detection of CVD: Screenings at young age • Bringing awareness of the disorder.
Mulusew et al.. ²²	2013	• Early detection of CVD: Screenings at young age • Bringing awareness of the disorder.

CHAPTER FOUR

LITERATURE REVIEW AND DISCUSSION

4.0 Introduction

There is a myriad of studies done globally on CVD, this review is based on comparing these studies and reviews to have a better, clearer understanding of the disorder. Within this review the focus was based on the following: the prevalence and distribution of CVD, methods of testing as well as methods of management of CVD.

4.1 Prevalence of CVD

4.1.1 Prevalence of Colour Vision Defect in Africa

Studies done in Ethiopia (Wolkite),¹¹ Nigeria (Ugep, Cross River State and Lagos),^{12,13} and South Africa (Durban),¹⁴ reported the prevalence of CVD to be 4.1%, 1.87%, 2.5% and 2.2% respectively. The study done in Ethiopia recorded the highest prevalence as compared to the other studies. Of all studies reviewed from the African continent, the research, which was done in Ugep, Cross River State was the only one which was not solely done on school going children but a common denominator of the studies was that CVD was more prevalent in the male gender. Also, the most common form of CVD detected overall was deuteran defect.

4.1.2 Prevalence of Colour Vision Defect in America

A cross sectional study done in preschool children in Los Angeles,¹⁵ recorded 1.6% prevalence of CVD with only a mere 0.1% being females. Within this study it was also recorded that deuteranopia was the most common form of CVD that was recorded.

4.1.3 Prevalence of Colour Vision Defect in Asia

Across the globe in the continent of Asia, several studies were done on school going children of various age groups. Studies done in Saudi Arabia,¹⁶ Western India,¹⁷ and North India,¹⁸ and Pakistan,¹⁹ recorded prevalence of CVD to be 3.36%, 2.02%, 8.76% and 3.70% respectively. The study done in Pakistan was the only research thus far that recorded CVD to be more common in females than males at 4.4% and 2.4% for females and males. Differences in findings could be due to variations in location, ethnicity or race, this study also highlighted that the prevalence rates of CVD in different parts of the continent such as Nepal and Iran were higher in males therefore,¹⁹ further investigations would be required to fully understand the reason for such results.

4.1.4 Prevalence of Colour Vision Defect in Europe

Lastly, in a study done on school going children in Ireland, the prevalence of CVD was reported to be 5.29%.²⁰ Compared to studies done in Western India,¹⁷ South Africa,¹⁴ and Nigeria,^{12,13} CVD seemed to be more common among Europeans. Like the many studies reviewed, this study as well recorded CVD to be higher in males (8.3%) than females (1.8%).

4.2 Distribution of Colour Vision Defect

4.2.1 Distribution according to age

In a study in Ugep Nigeria,¹² on patients aged 10 to 60 years, 28 had CVD 16 of whom were under the age of 20 whereas 9 subjects were between the age of 41-50.¹² The minority were within the age of 21-40.¹² Also in another study, CVD was reported to be more common in persons within the age group of 13-17.¹³ In other studies done around the world, CVD showed no preference to the age of individuals,^{14,15,16,17,18} as persons who had CVD were from varying age groups.

4.2.2 Ethnicity

A population-based study of 5960 study subjects of different ethnic backgrounds¹⁵ including Blacks, Asians, Hispanics and Non-Hispanic whites showed that there is in fact a significant difference in distribution of CVD with respect to ethnic background. 1.4% of persons who had CVD in this study were Blacks, 3.1% were Asians, 2.6% Hispanic and 5.6% were Non-Hispanic white males.¹⁵ A significant difference among the ethnic groups were also recorded.¹⁵ Another study in Ethiopia also highlighted that the prevalence of CVD varies according to geographical location as well as ethnicity but since this study was done among one certain group of people no statistical difference was reported.¹¹

4.2.3 Methods of Testing:

The Ishihara Pseudoisochromatic plates are the most popular methods used in detecting CVD.²¹ Within various studies done across the globe, this was the form of testing utilised throughout studies.^{11,12,15,16,17,18,19} This may have been the most popular test because of its ease of administration as well as that it is not a very time-consuming test.⁵ This test is also a very easy test to use with kids although in some studies variation of the pseudo isochromatic plates were used for very young children together with the colour vision made easy test.^{14,15} This test was used since the study subjects were very young and this is the gold standard for

testing for CVD in small kids. Other studies used the Richmond Hardy-Rand-Rittler (Richmond HRR) pseudoisochromatic plates for the detection of tritan defect.^{13,20}

4.3 Methods of Management:

According to studies in West Bengal, India,²¹ and South Africa,⁴ there are currently no known treatment options for CVD because CVD is taken as a lifelong disability. The study in India highlighted that if persons are made aware of their CVD at a young age, they will better adapt and adjust to their surroundings and life choices including future careers. Similar reports were made in a study in Central Ethiopia,²² this study also agreed with creating awareness of CVD to help with easy adaptation. Another study done in South Africa, reported that although there is no treatment for CVD, in cases such as acquired CVD where certain medication caused a decrease in the quality of CV, it was suggested that decrease intake/use of these medications can alleviate the severity of CVD.

CHAPTER FIVE

CONCLUSION

5.0 Conclusion

Color Vision Defect is a common disorder that has gone unnoticed for some time now. There is a significant prevalence of CVD globally with the higher prevalence in males than females and deutan defect was the most common form of CVD. Most studies did not report the distribution of CVD according to age and ethnicity. Ishihara Pseudoisochromatic plates were the most popular color vision test used in most studies. Screening in order to create awareness was the most suggested form of managing CVD in order to advise those with the defect accordingly.

5.1 Limitation

There were a few limitations associated with this review such as:

- The sample size of articles reviewed was too small to represent the prevalence of CVD properly and accurately in the world.
- There were few studies done on Colour Vision Defect in many parts of the world. For this review, most of the articles reviewed were from the Asian and African continent, there were very limited studies available in the United States of America as well as Europe. No studies from the Caribbean or Australia were found.
- Even though there were research from Africa and Asia, most were from Nigeria and Ethiopia, but these studies are not sufficient to represent the entire Continent.

5.2 Recommendations

- Colour Vision Screening should be mandatory within schools so there will be early detection of the disability.
- Counselling should be given to persons with CVD so they can properly cope with the disorder as well as make more informed choices.
- More studies should be done on CVD to bring awareness of the disorder, prevalence, methods of testing and methods of management
- More focus should be allocated to the distribution of CVD among different ethnicities.

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