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# Comparative Study on Colour Vision Impairments in Diabetic and Hypertensive Patients in Imo State, Nigeria

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**ABSTRACT**
*The study was designed to evaluate colour vision impairments in diabetic and hypertensive subjects with a view to ascertaining the extent to which each of the two disease conditions affects colour vision. A total of twenty five diabetic (non-hypertensive) subjects and twenty five hypertensive (non-diabetic) subjects and control population (non-diabetic and non hypertensive, also made up of twenty five subjects) were used for the study. Colour vision tests were then carried out on each of the subjects, and the peculiarity of each test was formulated to provide a unique definition to each visual anomally (colour vision impairment) possibly present. The Ishihara test was employed to provide a quick and accurate assessment of colour vision deficiency of congenital origin while the "colour vision testing made easy" detected red-green colour deficiencies. The Farnsworth D-15 test was adopted to identify those with pronounced colour perception deficiencies. Results showed that diabetes and hypertension as disease conditions significantly affected colour vision. Hypertension, however, was found to produce more effect (colour vision impairment) their diabetes.*
**KEYWORDS**: *Hypertension, Diabetes, Defects, Colour vision*

## INTRODUCTION

Colour is an illusion that is created as a result of co-ordination between millions of nerves present in the brain which are co-ordinated via the eyes; and colour vision is an aspect of perception characterized by the attributes of hue, brightness and saturation (Millod, 2009)[1], and resulting from stimulation of the retina by visible photonic light levels.

Generally speaking, colour vision is the capacity of an organism or machine to distinguish objects based on the wavelengths or frequencies of the lights they reflect, emit or transmit. The perception of colour is therefore, a subjective

process where the brain and nervous system respond to the visual stimuli that emerge when incident light reacts with the several types of cone photoreceptors in the eye. The normal eye has an innermost layer of tissue called the retina, which consists of light photo-sensitive cells knows as cones and rods that absorb light rays and change them into electrical impulses or signals. The rods are said to be active in low light and the cones are active in normal day light and in colour vision[2]. In colour vision perception, the cone receptors are sensitive to light of a particular wavelength composition. It has been shown that humans possess three types of cone receptors, and that each type of cones possess a particular region of the visible spectrum[3]. Colour vision impairment or colour blindness then, is the inability to perceive difference between some of the colours that others can distinguish under the same environmental conditions[4]. Defective colour vision (colour vision impairment or colour blindness) may be classified according to the type of cone that is malfunctioning. The affected person may have a reduced, or loss of m-cone sensitivity (deuteranopia or deuteranomaly), a condition suffered by approximately six percent (6%) of the male population, or a defect or loss in L-cone sensitivity (protanomaly, or protanopia) which is found in about two percent (2%) of the males. Congenital defects in S-cone sensitivity affects both sexes equally although its frequency is very low. It has been, however, reported that simultaneous dysfunction in more than one cone type is entirely rare[5]. It is worth knowing that congenital colour vision defect tend to remain stable throughout life and are usually not associated with other retinal or optic nerve pathology, it is an inherited condition caused by a common X-linked recessive gene. Acquired defects, however, may have a more variable cause and are usually associated with observable pathology[6]. They usually result from diseases or injury damaging the optic newe or retina. Some of such diseases include glaucoma, diabetes, hypertension, chronic alcoholism, multiple sclerosis, macular degeneration, and Alzheimer's disease. Aging, medication and chemical exposure can also cause colour vision defect[7].

Again, acquired colour vision defect which can result from lesions of the macula can also be induced by changes in the optical media and chemical exposure. The age of onset of acquired colour vision defect is said to be after birth, with its type of severity fluctuating overtime[8].

Visual acuity is also often reduced in most cases of acquired coloru vision defect, leading to visual field defect. Persons affected have been shown to be more likely to display colour-naming errors because unlike those with congenital deficiencies they lack the life-long experience with defective colour perception.

Diabetes, which describes a group of metabolic diseases in which the person has high blood glucose either because insulin production is inadequate, or because the body's cells do not respond properly to insulin, or both, is very common in this part of the world (Nigeria). Even at global level, it was estimated in 2013 that over 382 million people throughout the world had diabetes[7].

In type 1 diabetes, where the body does not produce insulin (also referred to as insulin – dependent diabetes, juvenile diabetes, or early onset diabetes), patients will need to take insulin injections for the rest of their life. In type 2 diabetes, however, the body does not produce enough insulin for proper function, or the cells in the body do not react to insulin (insulin resistance) loosing weight, keeping to a healthy diet, doing plenty of exercise, and monitoring the blood glucose levels can be of great help in controlling the type 2 diabetes. The gestational diabetes affects only females during pregnancy. The majority of gestational diabetes cases could be controlled with exercise and proper diet.

Generally, diabetes can affect the eye in a number of ways whose manifestations disturb normal vision. In diabetic retinopathy for example, blood vessels may swell and leak fluid, while in some bad cases, abnormal new blood vessels may grow on the surface of the retina. At first, patients of diabetic retinopathy may not notice changes in vision. But over time, diabetic retinopathy can get worse and cause loss of vision or impaired colour vision. An uncontrolled diabetes can also affect the lens, thereby leading to blurring of vision which comes and goes over the day.

A longer term effect of diabetes is that the lens can go cloudy, a condition known as cataract which so much affects vision. A person with diabetes is nearly twice as likely to get glaucoma (increase in fluid pressure inside the eye) which leads to optic nerve damage and impaired vision or loss of vision. On the other hand, hypertension or high blood pressure (a condition in which the arteries have persistently elevated blood pressure) can lead to damaged organs, as well as several illnesses affecting the visual system. Essential hypertension refers to the situation where the cause of the high blood pressure is unknown, while secondary hypertension refers to the high blood pressure with a known direct cause such as kidney disease, tumours, or birth control pills.[8] People suffering from high blood pressure are also prone to suffer hypertensive retinopathy (a disease in the eye that affects the retina) which may lead to changes in ratinal microvasculature; thereby affecting normal vision.

## MATERIALS AND METHOD

Both private and government owned clinics and hospitals constituted the investigation centres for the six month period study meant to screen the diabetic and hypertensive patients for colour vision defects. Patients suffering from other debilitating systemic diseases or anomalies were screened out; while those with refractive errors were corrected before the colour vision tests were carried out. A total of twenty five diabetic (non-hypertensive) and twenty five hypertensive (non-diabetic) patients (aged between forty five and fifty five years) were examined for colour vision loss or impairment in four randomly chosen clinics/hospitals in Imo State, Nigeria.

The colour vision tests, the Ishihara test, the colour vision testing made easy and the Farnsworth D-15 test; ophthalmoscopy, tonometry, external examination, subjective refraction, etc, were among the tests conducted on the patients already diagnosed either diabetic or

hypertensive. Prior to the tests, the case history of each patient was taken to unveil the complaints he/she had about his or her eyes. Their past ocular/visual or medical history was also taken to be sure there were no pathological issues capable of altering the test results. Their medication history was also required to rule out those on drugs that could affect the results. The subjects' colour vision testing done with daylight illumination involved the Ishihara colour vision test, the colour vision testing made easy (CVTME) and Farnsworth D-15 tests.

The peculiarity of each test was designed to provide a unique definition to each visual anomally (colour vision) present. The Ishihara test was therefore designed to provide a quick and accurate assessment of colour vision deficiency of congenital origin, while the "colour vision testing made easy detected red-green colour deficiency. On the other hand, the Farnworth D-15 test was used to identify those with colour perception deficiencies large enough to pose security problems. It was able to detect both red-green and blue-yellow anomalies, and was very useful in the detection of acquired colour vision anomalies.

**RESULTS**

Below are tabular presentations of the results of the study done on colour vision impairments in diabetic and hypertensive subjects.

**TABLE 1** Classification of clour discrimination abilities of hypertensive patients using farnsworth d-15 colour arrangement

For the right eye

| Classification | Total | Percentage (%) | Male | Percentage (%) | Female | Percentage (%) |
|---|---|---|---|---|---|---|
| SAE | 5 | 20.0 | 3 | 12.0 | 2 | 8.0 |
| SAE/NPA | 9 | 36.0 | 5 | 20.0 | 4 | 16.0 |
| SAE/PROTAN | 1 | 4.0 | 1 | 4.0 | 0 | 0.0 |
| SAE/SCOTOPIC | 1 | 4.0 | 1 | 4.0 | 0 | 0.0 |
| SAE/TRITAN | 9 | 36.0 | 5 | 20.0 | 4 | 16.0 |
| **TOTAL** | **25** | **100** | **15** | **60** | **10** | **40** |

**TABLE 2** Classification of clour discrimination abilities of hypertensive patients using farnsworth D-15 colour arrangement

For the left eye

| Classification | Total | Percentage (%) | Male | Percentage (%) | Female | Percentage (%) |
|---|---|---|---|---|---|---|
| SAE | 2 | 8.0 | 2 | 8.0 | 0 | 0.0 |
| SAE/NPA | 12 | 48.0 | 5 | 20.0 | 7 | 28.0 |
| SAE/PROTAN | 3 | 12.0 | 3 | 12.0 | 0 | 0.0 |
| SAE/SCOTOPIC | 1 | 4.0 | 0 | 0.0 | 1 | 4.0 |
| SAE/TRITAN | 7 | 28.0 | 5 | 20.0 | 2 | 8.0 |
| **TOTAL** | **25** | **100** | **15** | **60.0** | **10** | **40.0** |

**TABLE 3** Distribution of colour discrimination abilities of hypertensive patients using s-index of vingrys and king-smith (1988)

| Eye | S-Index≤1.68 | Percentage (%) | S-Index≥1.68 | Percentage (%) |
|---|---|---|---|---|
| OD | 9 | 36.0 | 16 | 64.0 |
| OS | 13 | 50.0 | 12 | 48.0 |
| OU | 9 | 36.0 | 16 | 64.0 |

**TABLE 4** Classification of clour discrimination abilities of diabetic patients using farnsworth d-15 colour arrangement based on vingrys and king-smith (1988) vector analysis

For the right eye

| Classification | Total | Percentage (%) | Male | Percentage (%) | Female | Percentage (%) |
|---|---|---|---|---|---|---|
| SAE | 3 | 12.0 | 1 | 4.0 | 2 | 8.0 |
| SAE/NPA | 18 | 72.0 | 10 | 40.0 | 8 | 32.0 |
| SAE/DEUTAN | 1 | 4.0 | 1 | 4.0 | 0 | 0.0 |
| SAE/PROTAN | 1 | 4.0 | 1 | 4.0 | 0 | 0.0 |
| SAE/TRITAN | 2 | 8.0 | 2 | 8.0 | 0 | 0.0 |
| **TOTAL** | **25** | **100** | **15** | **60.0** | **10** | **40.0** |

**TABLE 5** Classification of clour discrimination abilities of diabetic patients using farnsworth d-15 colour arrangement

| Classification | Total | Percentage (%) | Male | Percentage (%) | Female | Percentage (%) |
|---|---|---|---|---|---|---|
| SAE | 1 | 4.0 | 0 | 0.0 | 1 | 4.0 |
| SAE/NPA | 15 | 60.0 | 9 | 36.0 | 6 | 24.0 |
| SAE/DEUTAN | 3 | 12.0 | 2 | 8.0 | 1 | 4.0 |
| SAE/PROTAN | 4 | 16.0 | 1 | 4.0 | 3 | 12.0 |
| SAE/TRITAN | 2 | 8.0 | 2 | 8.0 | 0 | 0.0 |
| **TOTAL** | **25** | **100** | **15** | **56.0** | **10** | **44.0** |

**TABLE 6** Distribution of colour discrimination abilities of diabetic patients using s-index of vingrys and king-smith (1988)

| Eye | S-Index≤1.68 | Percentage (%) | S-Index≥1.68 | Percentage (%) |
|---|---|---|---|---|
| OD | 18 | 72.0 | 7 | 28.0 |
| OS | 21 | 84.0 | 4 | 16.0 |
| OU | 18 | 72.0 | 7 | 28.0 |

**TABLE 7** Classification of colour discrimination abilities of control subjects for the right eye using farnsworth d-15 colour arrangement

| Classification | Total | Percentage (%) | Male | Percentage (%) | Female | Percentage (%) |
|---|---|---|---|---|---|---|
| NCV | 1 | 4.0 | 1 | 4.0 | 0 | 0.0 |
| NCV/NSV | 7 | 28.0 | 1 | 4.0 | 6 | 24.0 |
| NCV/TRITAN | 4 | 16.0 | 1 | 4.0 | 3 | 12.0 |
| SAE | 4 | 16.0 | 1 | 4.0 | 3 | 12.0 |
| SAE/NPA | 1 | 4.0 | 0 | 0.0 | 1 | 4.0 |
| SAE/PROTAN | 1 | 4.0 | 1 | 4.0 | 0 | 0.0 |
| SAE/TRITAN | 7 | 28.0 | 5 | 20.0 | 2 | 8.0 |
| **TOTAL** | **25** | **100** | **10** | **40.0** | **15** | **60.0** |

**TABLE 8** Classification of colour discrimination abilities of control subjects for the left eye using farnsworth d-15 colour arrangement based on vingrys and king-smith (1988)

| Classification | Total | Percentage (%) | Male | Percentage (%) | Female | Percentage (%) |
|---|---|---|---|---|---|---|
| NCV | 1 | 4.0 | 1 | 4.0 | 0 | 0.0 |
| NCV/NPA | 4 | 16.0 | 2 | 8.0 | 2 | 8.0 |
| NCV/NSV | 7 | 28.0 | 3 | 12.0 | 4 | 16.0 |
| NCV/TRITAN | 4 | 16.0 | 1 | 4.0 | 3 | 12.0 |
| SAE/NPA | 3 | 12.0 | 1 | 4.0 | 2 | 8.0 |
| SAE/PROTAN | 3 | 12.0 | 3 | 12.0 | 0 | 0.0 |
| SAE/TRITAN | 3 | 12.0 | 2 | 8.0 | 1 | 4.0 |
| **TOTAL** | **25** | **100.00** | **13** | **52.0** | **12** | **48.0** |

**TABLE 9** Distribution of colour discrimination abilities of control subjects using s-index of vingrys and king-smith (1988)

| EYE | S-Index≤1.6 | Percentage (%) | S-Index≥1.6 | Percentage (%) |
|---|---|---|---|---|
| OD | 11 | 44.0 | 14 | 56.0 |
| OS | 12 | 48.0 | 13 | 52.0 |
| OU | 9 | 36.0 | 16 | 64.0 |

**TABLE 10 a.** Control/hypertensive subjects' overall colour discrimination abilities for the right eye (data from tables 1 and 7).

| | Control Subjects | Hypertensive Subjects | Total |
|---|---|---|---|
| Normal | 12 ($E_1$) | 0 ($E_2$) | 12 |
| Abnormal | 13 ($E_3$) | 25 ($E_4$) | 38 |
| **Total** | **25** | **25** | **50** |

**Calculating for expected values (E)**

$E_1 = \frac{12 \times 25}{50} = 6;$ $E_2 = \frac{12 \times 25}{50} = 6;$

$E_3 = \frac{38 \times 25}{50} = 19;$ $E_4 = \frac{38 \times 25}{50} = 19;$

$X^2 = \frac{(12-6)^2}{6} + \frac{(0-6)^2}{6} + \frac{(13-19)^2}{19} + \frac{(25-19)^2}{19}$

$X^2 = 6 + (0\ 1.89 + 1.89 = 9.78$

$X^2$ tab $= 0.95\ (r-1) = 3.84$

$X^2$ cal $= 9.78, > 3.84$

Based on this result, hypertension significantly affects colour vision of the patient on the right eye.

**TABLE 10 b.** Control/hypertensive subjects' overall colour discrimination abilities for the left eye (data from tables 2 and 8).

| | **Control Subjects** | **Hypertensive Subjects** | **Total** |
|---|---|---|---|
| Normal | 16 ($E_1$) | 0 ($E_2$) | 16 |
| Abnormal | 9 ($E_3$) | 25 ($E_4$) | 34 |
| **Total** | **25** | **25** | **50** |

**Calculating for expected values (E)**

$E_1 = \frac{16 \times 25}{50} = 8;$ $E_2 = \frac{16 \times 25}{50} = 8$

$E_3 = \frac{34 \times 25}{50} = 17;$ $E_4 = \frac{34 \times 25}{50} = 17;$

$$X^2 = \frac{(16-8)^2}{8} + \frac{(0-8)^2}{8} + \frac{(9-17)^2}{17} + \frac{(25-17)^2}{17}$$

$X^2 = 8 + 0 + 3.76 + 76 = 15.52$

$X^2$ tab $= 0.95\ (r-1) = 3.84$

$X^2$ cal $= 15.52, > 3.84$

Based on this result, hypertension significantly affects colour vision of the patient on the left eye.

**TABLE 11a.** Control/diabetic subjects' overall discrimination abilities for the right eye (data from tables 4 and 7).

| | **Control** | **Diabetic Subjects** | **Total** |
|---|---|---|---|
| Normal | 12 ($E_1$) | 0 ($E_2$) | 12 |
| Abnormal | 13 ($E_3$) | 25 ($E_4$) | 38 |
| **Total** | **25** | **25** | **50** |

**Calculating the expected values (E)**

$E_1 = \frac{12 \times 25}{50} = 6$; $E_2 = \frac{12 \times 25}{50} = 6$

$E_3 = \frac{38 \times 25}{50} = 19$; $E_4 = \frac{38 \times 25}{50} = 19$;

$$X^2 = \frac{(12-6)^2}{6} + \frac{(0-6)^2}{6} + \frac{(13-19)^2}{19} + \frac{(25-17)^2}{19}$$

$X^2 = 6 + 0 + 1.89 + 1.89 = 9.78$

$X^2$ tab $= 0.95\ (r-1) = 3.84$

$X^2$ cal $= 9.78, > 3.84$

Based on the above result, diabetes significantly affects colour vision of the right eye of its victims.

**TABLE 11b.** Control/diabetic subjects' overall discrimination abilities for the left eye (data from tables 4 and 8).

| | **Control** | **Diabetic Subjects** | **Total** |
|---|---|---|---|
| Normal | 16 ($E_1$) | 0 ($E_2$) | 16 |
| Abnormal | 9 ($E_3$) | 25 ($E_4$) | 34 |
| **Total** | **25** | **25** | **50** |

**Calculating for expected values (E)**

$E_1 = \frac{16 \times 25}{50} = 8;$ $E_2 = \frac{16 \times 25}{50} = 8$

$E_3 = \frac{34 \times 25}{50} = 17;$ $E_4 = \frac{34 \times 25}{50} = 17;$

$$X^2 = \frac{(16-8)^2}{8} + \frac{(0-8)^2}{8} + \frac{(9-17)^2}{17} + \frac{(25-17)^2}{17}$$

$X^2 = 8 + 0 + 3.76 + 3.76 = 15.52$

$X^2$ tab $= 0.95\ (r-1) = 3.84$

$X^2$ cal $= 15.52, > 3.84$

The result shows that diabetes significantly affects colour vision of the left eye of its victims.

**DISCUSSION**

Analysis of colour discrimination of the hypertensive subjects showed that all the subjects had abnormal colour discrimination on the right eye. It was shown that 44% had abnormal colour discrimination defect involving either protan, tritan, or scotopic vision, while 36% had substantial arrangement error/non polar arrangement (SAE/NPA). The remaining (20%) had SAE. The result also showed that all the hypertensive subjects had abnormal colour discrimination on the left eye. 44% had defects involving either protan, tritan or scotopic vision while 48% had substantial arrangement error (SAE) and non-polar arrangement (NPA). 8%, however, had only SAE.

Results on the distribution of colour discrimination abilities of the hypertensive subjects using the scatter index (s-index) of Vingrys and King-Smith (1988) indicated that 86% of the hypertensive subjects had normal s-index, showing that only 24% had abnormal s-index. Furthermore, it was observed that total colour difference score (TCDS) of Bowman (1982) increased with increasing number of transpositional crossovers in the right and left

eyes. Al the subjects, however, had abnormal colour confusions index (CCI).

When compared with the control, it was deduced that hypertension, leading to hypertensive retinopathy affects colour vision.

As for the diabetic subjects, all had abnormal colour discrimination on the left eye. 32% had abnormal colour discrimination involving defects of either protan, tritan, or scotopic vision. 62% of them had SAE/NPA, and 4% had SAE. The S-index had higher abnormal value (28%) than the control. Diabetic subjects, therefore had greater difficulties discriminating colours than the control. As in the case of hypertensive subjects, the total colour difference score (TCDS) of Bowmans (1982) also increased with increasing number of transpositional crossover in the right and left eyes in diabetic subjects.

Apart from the abnormal colour discrimination problem that was common among the subjects in this group, all also had colour confusion index, unlike the control group that were not diabetic. Diabetes, therefore, was said to have affected the colour vision of the subjects used for the research.

Comparing the findings made on the hypertensive and diabetic subjects, it could be inferred that both hypertension and diabetes cause abnormal total colour difference score (TCDS) and abnormal colour confusion index (CCI), and abnormal C-index, as the estimates of the error score in the two study groups were higher than the control. With the S-index, the hypertensive subjects could be said to be more affected as 64% of them had abnormal values, as against the 24% of the diabetic subjects. Since S-index shows the selectivity of degree of scatter in the cap arrangement, it has been deduced that hypertension caused more random arrangement than diabetes.

Furthermore, prevalence of colour vision defects was found to be higher in hypertension (44% each for OD and OS) than in diabetes (16% and 31% for OD and OS respectively).

Again, tritan defects were found to be higher in prevalence in hypertension (36% and 28% for OD and OS respectively) than in diabetes (8% each for OD and OS). These findings have therefore provided the needed results to adduce that hypertension affects colour vision more than diabetes.

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