Comparison of two colour vision tests used in current ophthalmic practice

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Abstract

Objectives: To determine the validity of Richmond 4th edition HRR test, as a screening test to detect colour blindness, using Ishihara's test as a standard test and to do comparison between these two tests in the diagnosis of congenital colour blindness. Patients and methods: This is a prospective study done on 150 patients attending Ophthalmic Outpatient Clinic at Al-Jumhory Teaching Hospital / Mosul-Iraq from the 1st of January till 30th of June 2012. Results: 150 subjects was enrolled in the study, age range 15-25 years, mean 20.67 years ± 2.74, males:130 (86.67%), females:20 (13.33%). Seven subjects discovered to have congenital red-green deficiency using Ishihara’s colour vision test, while 12 subjects have same problem while using Richmond HRR 4th edition, three of whom have mild defect, seven have moderate defect, and two only had sever defect. No such grading is possible with Ishihara’s test. HRR test had the highest sensitivity and PVN (100%), very high specificity and LR+ (96.5%) and (28.57) respectively, but poor PVP (58.33%) in the diagnosis of congenital colour blindness. The overall accuracy of HRR test in diagnosing colour vision defects was (96.67%). Conclusion: Richmond 4th edition HRR test is as good as Ishihara’s test in detecting congenital red-green colour deficiency, and have an advantage over Ishihara's of grading the severity of the defect.

Key words: Colour vision blindness.

Introduction

The retina of human eye contains about seven million cone cells and more than 120 million rod cells that enable normal vision. (1) Cones serve vision at high levels of illumination while rods function in low illumination. The majority of cone cells are located in the centre of retina. There are three populations of retinal cones each with specific sensitivities; blue (tritan) at 414-424nm, green (deuteran) 522-539 nm and red (protan) at 549-570 nm. (2,3) Rod cells have maximum density about 5° from the fovea. Both types of cell diminish in number towards the retinal periphery. (3) A normal person requires all these primary colours to match those within the spectrum. Any given cone pigment...
may be deficient (e.g. protanomaly-red weakness) or entirely absent (e.g.
protanopia- red blindness).
Trichromats possess all three types of
cones (although not necessarily
functioning perfectly), while absence
of one or two types of cones renders an
individual a dichromat or
monochromat respectively.\(^{(2, 3)}\)

Most individuals with congenital
colour defects are anomalous
trichromats and use abnormal
proportions of the three primary
colours to match those in the light
spectrum.\(^{(2)}\)

Those with red-green deficiency
caused by abnormality of red-sensitive
cones are protanomalous, those with
abnormality of green-sensitive cones
are deuteranomalous and those with
blue-green deficiency caused by
abnormality of blue-sensitive cones are
tritanomalous.\(^{(4)}\) Acquired macular
disease tends to produce blue-yellow
defects and optic nerve lesions red-
green defects.\(^{(2, 4)}\)

The importance of correct or normal
colour vision should not be
underestimated. Many times each day
we use our colour vision ability to
discern and evaluate objects, signs,
situations and other phenomena often
concerning matters of safety, worker
pleasure, and observation in general.\(^{(5)}\)

Pigments have the ability to absorb
some colours and to reflect others. An
object that appears blue actually
absorbs all the other colour
wavelengths except blue. The
unabsorbed wavelength is reflected
back to eye and brain interprets the
object as blue.\(^{(6)}\)

Colour vision tests are used clinically
to identify and differentiate congenital
and acquired colour deficiency and to
select personnel for occupations which
require good colour vision. Clinical
colour vision tests are based on
psychophysical methods but use
pigment colour instead of spectral
stimuli.\(^{(7, 8)}\)

Screening tests identify people with
normal or abnormal colour vision.
Grading tests estimate the severity of
colour deficiency. Some tests have
both screening and grading functions.
Most tests aim to classify protan,
deutan and tritan colour deficiency.\(^{(9,}
\textbf{10})\)

The original Hardy Rand Rittle (HRR)
colour vision test was developed sixty
years ago by Hardy, Rand and Rittle at
Columbia University and was first
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published by The American Optical Company in 1955. It had carefully designed plates to differentiate protan, deutan and tritan deficiencies and grade their severity. Richmond Products published a fourth edition in 2002, the colours of which have been carefully re-engineered with the assistance of Jay and Maureen Neitz and James Bailey. The aim of the present study is to determine the validity of Richmond 4th edition HRR test, as a screening test to detect congenital colour blindness, using Ishihara's test as a standard test and to do comparison between these two tests in the diagnosis of congenital colour blindness.

**Patients and methods**

This is a prospective study conducted on 154 subjects attending Ophthalmologic Out patient Clinic at Al-Jumhory Teaching Hospital in Mosul from the 1st of January till 30th of June 2012.

**Study participants:**

The inclusion criteria for the participants includes: age more than 13 years, healthy, neither diabetic nor hypertensive, did not have significant refractive errors, or exposed to previous ocular surgery or ocular trauma.

Out of 154 subjects who accept to participate in this study four had been excluded, two because of sever ocular allergy and another two because of significant refractive errors and previous ocular trauma respectively. All subjects had a visual acuity testing before enrolment in this research.

**Testing technique:**

All participants had a proper colour vision test instructions. The test done in a well illuminated optometry room, the plates were approximately perpendicular to the line of sight and the subjects viewed the plated binocularly from a fixed distance of 40cm. All subjects take Ishihara's test first; they were given about three seconds to respond to each page of the tests. Each symbol missed with Ishihara's test was counted as an error and the results fixed on the score sheet provided with the test, the same process repeated for HRR test with five minutes break between the two tests.

In this research Ishihara's colour vision screening test was used as a golden standard (reference) test to diagnose colour blindness in the participants.
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The design of Ishihara’s colour vision test is very simple. The numerals which are seen on plates 1-17 are stated and each answer should be given without more than three seconds delay. If the subject is unable to read numerals, plates 18-24 are used and the winding lines between two X’s are traced with the brush. Each tracing should be completed within ten seconds. The results recorded on the score sheet provided with this test. Figure (1 and 2)

The design of the HRR test is very simple as well, it based on very sound principles. It comprises 24 plates each displaying either one or two symbols, which can be a cross, a circle or a triangle. Figure (3) The symbols are constructed of coloured dots on a background of gray dots. The coloured dots have chromaticity co-ordinates that lie on or close to the protan, deutan or tritan dichromatic confusion loci that pass through the chromaticity co-ordinates of the gray background colours. There are six screening plates, four for the protan-deutan deficiencies and two for the tritan deficiencies. These are followed by 14 plates designed to grade the severity of deficiency and to differentiate protans, deutans (10 plates) and tritans (four plates). The principle is that those with a severe deficiency of colour vision will not see the symbols with colours lying on their confusion loci. Patients have their colour vision deficiency graded as mild, medium or sever, depending on whether they see or do not see the symbols on more saturated plates. There are 10 grading plates for the protan/ deutan defects: patients who make one or more errors in two plates with the most saturated colours are graded as sever, those who make an error in the next three most saturated plates are graded as medium. Those who make errors only with the five least saturated plates are graded as mild. The results recorded on the score sheet provided with this test. Figure (4)

Statistical analysis:

The sensitivity, specificity, predictive value positive (PVP), predictive value negative (PVN), likelihood ratio positive (LR+), likelihood ratio negative (LR-) and overall accuracy of HRR test were calculated against Ishihara’s test (reference test) for the diagnosis of colour blindness.
Results

A total of 150 subjects enrolled in this study: 130 males (86.67%) and 20 females (13.33%). Figure (5). The age of the participants ranged between 15 - 25 years with mean (20.67 ± 2.74) years.

Out of 150 subject who take Ishihara’s test, seven shown to have Red-green deficiency: six males and one female. On doing HRR test, all seven subjects who had red green colour deficiency using Ishihara’s test were also shown to have red-green colour deficiency using HRR test. On the other hand five subjects who had normal colour vision using Ishihara’s test, shown to have red-green colour deficiency using HRR test, all of them were male. The total number of patient shown to have red-green colour deficiency using HRR test is 12 subjects: 11 males and 1 female. Table (1)

<table>
<thead>
<tr>
<th>Grade</th>
<th>Number of Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderate</td>
<td>7 (58.33%)</td>
</tr>
<tr>
<td>Mild</td>
<td>3 (25%)</td>
</tr>
<tr>
<td>Severe</td>
<td>2 (16.67%)</td>
</tr>
</tbody>
</table>

No grading was possible using Ishihara’s test, because the test is not designated to grade the severity of congenital red-green blindness.

Table (3) represent the validity measures of the new HRR test in the diagnosis of colour blindness; the test had the highest sensitivity and PVN (100%), very high specificity and LR+ (96.5%) and (28.57) respectively, but poor PVP (58.33%) in the diagnosis of colour vision defects. The overall accuracy of the HRR test in diagnosing colour vision defects was (96.67%).

Discussion

The key purpose of screening and testing for colour vision defect is to determine if the patient has normal or defective colour vision. If defective colour vision is present, further testing may needed to determine the type of deficiency (protan, deutan or tritan), whether congenital or acquired, and the extent (mild, moderate, sever). This because, in many cases, defective colour vision may have consequences for certain occupational abilities. (12, 13)

Effective evaluation of colour vision abnormalities remains an important task in steady demand by patients, their families and employers. Abnormalities of colour vision affects upwards of 5% of male population (as well as a very
small proportion of females), and thus constitutes one of the most prevalent visual disorders. Acquired dyschromatopsia is often tested for in clinical practice although generally a rare complaint.\(^{(14)}\)

Anomaloscope is acknowledged as the ‘gold standard’ for diagnosing colour vision defects. These instruments are expensive, not normally available for clinical use, and complex to use compared with pseudoisochromatic plate tests.\(^{(14)}\)

The ideal colour vision test will reliably detect, categorise and grade the severity of protan, deutan and tritan colour vision deficiencies. The Richmond HRR test attempts to do all these things. It must be pointed out that HRR test used in colour vision test, although its usage was relatively infrequent.\(^{(13)}\)

In the present research most of the diagnosed cases of congenital red-green colour defect were males (6 out of 7 in Ishihara’s test and 11 out of 12 in HRR test), with only one female double confirmed by both tests. This can be explained by the fact that congenital red-green colour deficiency is an X-linked recessive disorder affecting mainly males and females being affected only if the they are homozygous for the defect (usually rare).\(^{(15)}\)

In this study, we test the validity of Richmond HRR test in detecting red–green colour vision deficiencies using Ishihara’s test as a reference test. We found that Richmond HRR test is a good test at detecting red-green colour deficiencies with sensitivity of (100%) and specificity of (96.5%). This agree with the results of Cole BL et al.\(^{(16)}\) who calculated the validity of Richmond HRR test using Ishihara’s as a reference test, and found that the sensitivity of HRR in detecting red-green colour deficiency is (100%), but with higher specificity reach (97.5%).\(^{(16)}\) Bailey and his colleagues\(^{(14)}\) also reports a better specificity than that we found in our study (97.5%).

The present research calculate the likelihood ratio of HRR test in detecting colour vision defects. Likelihood ratios are alternative statistics for summarising diagnostic accuracy, which have several particularly powerful properties that make them more useful clinically than other statistics.\(^{(17)}\)
Likelihood ratio is the ratio of the probability of the specific test result in people who do have the disease to the probability in people who do not.\(^{18}\)

A likelihood ratio greater than 1 indicates that the test result is associated with the presence of the disease, whereas a likelihood ratio less than 1 indicates that the test result is associated with the absence of disease. The further the likelihood ratios are from 1 the stronger the evidence for the presence or absence of disease. Likelihood ratios above 10 and below 0.1 are considered to provide strong evidence to rule in or rule out diagnoses respectively in most circumstances.\(^{18}\)

Table(4) In this study the positive and negative likelihood ratios for HRR test was (28.57) and (0.01) respectively which means that this test is an excellent test in detecting congenital colour vision blindness.

The scope of Richmond 4\(^{th}\) edition HRR colour vision test not only involves the diagnosis of colour vision blindness but extends to grading of severity of colour vision defects. In this research 12 subjects diagnosed to have colour vision blindness using HRR test, three had mild defect, seven had moderate defect and two subjects had severe defect, such grading of severity is impossible when using the reference Ishihara's colour vision screening test.

Still further HRR test had the ability to detect rare congenital blue-yellow colour blindness and acquired colour vision defect, but these two categories were not included in our study.\(^{14}\)

The Richmond HRR can be used confidently to detect red-green colour vision deficiency. It will detect tritan deficiencies, which the Ishihara's dose not, a paediatric version of HRR test also available.\(^{13}\) Table (5) The HRR is not as well known as the Ishihara, so the risk of persons learning the correct answers to enable them to pass the test is very small and in any case the HRR can be presented upside down to confound those who have been industrious enough to learn the correct answer.

**Conclusion**

Richmond 4\(^{th}\) edition HRR test is as good as Ishihara’s test in detecting congenital red-green colour deficiency, and have an advantages over Ishihara's of grading the severity of the defect.
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Figure (1): Ishihara’s plates for colour deficiency.

Figure (2): Ishihara’s score sheet of colour
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Figure (3): Richmond 4th edition HRR plates.
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Figure (4): Score sheet of HRR 4th edition of colour vision test.

Figure (5): Sex distribution of the study participants.

Table (1): Comparison between Ishihara’s and Richmond 4th HRR test in diagnosis of colour vision defects.

<table>
<thead>
<tr>
<th></th>
<th>Reference test (Ishihara’s)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>positive</td>
<td>negative</td>
</tr>
<tr>
<td>HRR test</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>138</td>
</tr>
<tr>
<td>Total</td>
<td>7</td>
<td>143</td>
</tr>
</tbody>
</table>
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Table (2): Grading of severity of red-green colour defects using HRR test.

<table>
<thead>
<tr>
<th>Severity of colour vision defect</th>
<th>Sex</th>
<th>Male No. (%)</th>
<th>Female No. (%)</th>
<th>Total No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild</td>
<td>Male</td>
<td>2 (16.67)</td>
<td>1 (8.33)</td>
<td>3 (25.00)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>1 (8.33)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>Male</td>
<td>7 (58.33)</td>
<td>0 (0.00)</td>
<td>7 (58.33)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>0 (0.00)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sever</td>
<td>Male</td>
<td>2 (16.67)</td>
<td>0 (0.00)</td>
<td>2 (16.67)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>0 (0.00)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>Male</td>
<td>11 (91.67)</td>
<td>1 (8.33)</td>
<td>12 (100.00)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>1 (8.33)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table (3): The validity measures of HRR test in diagnosis of colour vision defects.

<table>
<thead>
<tr>
<th>Validity measure</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>100%</td>
</tr>
<tr>
<td>Specificity</td>
<td>96.5%</td>
</tr>
<tr>
<td>PVP</td>
<td>58.33%</td>
</tr>
<tr>
<td>PVN</td>
<td>100%</td>
</tr>
<tr>
<td>Accuracy</td>
<td>96.67%</td>
</tr>
<tr>
<td>LR+</td>
<td>28.57</td>
</tr>
<tr>
<td>LR-</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Table (4): Strength of diagnostic test by likelihood ratios.

<table>
<thead>
<tr>
<th>Qualitative strength</th>
<th>LR +</th>
<th>LR -</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>10</td>
<td>0.1</td>
</tr>
<tr>
<td>Very good</td>
<td>6</td>
<td>0.2</td>
</tr>
<tr>
<td>Fair</td>
<td>2</td>
<td>0.5</td>
</tr>
<tr>
<td>useless</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Table (5): Comparison of Richmond 4th edition HRR and Ishihara’s test capabilities.

<table>
<thead>
<tr>
<th>Product</th>
<th>Screening</th>
<th>Congenital</th>
<th>Acquired</th>
<th>Ability to classify</th>
<th>Determine extent</th>
<th>Number of plates</th>
<th>Paediatric version</th>
</tr>
</thead>
<tbody>
<tr>
<td>HRR 4th Edition</td>
<td>yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>24</td>
<td>Yes</td>
</tr>
<tr>
<td>Ishihara’s</td>
<td>yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>24</td>
<td>Separate</td>
</tr>
</tbody>
</table>
References


مقارنة بين فحصين مستخدمين حالياً لتشخيص عمي الألوان في طب العيون

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الخلاصه:

الهدف من الدراسة: هو تحديد صلاحية الطبقة الرابعة من فحص HRR (فحص قياسي) و المقارنة ما بين هذين الفحصين في تشخيص عمي الألوان.

المرضى وطرق العمل: في اصشاء دساصت عهٗ 051 شخض فٙ ْزِ انذساست, حٛذ حشأحج أعَّاس عٛادة انعٌٕٖٛ. يٍ الأٔل يٍ كإٌَ الأٔلٔنغاٚات انزلارٍٛ يٍ حًٕص 2102. النتائج: تم إدراج 150 شخصاً في هذه الدراسة، حيث تراوحت أعمار المشاركين بين 25-65 سنة وبمعدل عمر (20،6) سنة. استعملت الدراسة على 123 شخصاً (77.2%) من الذكور و 20 شخصاً (22.8%) من الإناث. تم تشخيص عمي الألوان الوراثي لدى 131 شخصاً فقط باستخدام فحص HRR، و تم تحديد حالة الإصابة باستخدام HHR، حيث أن ثلاث أشخاص كان لديهم أصابه خفيفة، و سبعة أشخاص لديهم درجة إصابة متوسطة، و هو انثان فقط لديهم إصابة شديدة. كما بنينت النتائج ان فحص HRR ذو حساسية و نسبة احتمالية موجبة عالية (96.5% و 72.5%) على التوالي. أما بالنسبة للقيمة التنبيهية الموجبة فكانت عالٍ (35.6%) والدقة الكلية للفحص كانت عالية (96.7%). الاستنتاج: فحص HHR المستخدم في تشخيص عمي الألوان هو فحص جيد كفحص Ishihara's.