Conventional and Simulated Vision Screening Among Students of Public Junior Secondary School in Osogbo Southwest Nigeria-A Comparative Study

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ABSTRACT

Purpose: To evaluate an innovative application using comparative vision screening tools in secondary students in Osogbo, Nigeria.

Methods: A descriptive cross-sectional study conducted among 496 secondary school students. A web application with the capacity of assessing visual acuity and colour vision was developed de-novo and used for simulation. The simulated approach was based on a programme designed to run on a computer. Conventional visual acuity (VA) testing was performed using Snellen chart and was taken as the line completed and read correctly. The sensitivity, specificity, positive and negative predictive values (PPV and NPV) of the simulated method in comparison with the conventional approach were determined. Kappa statistics was used to assess the level of agreement between the two approaches.

Results: The mean age of the respondents was 11.79 ± 1.50 years with a male:female ratio of 1.4:1. The prevalence of abnormal VA in the study participants was 7.9%. There was substantial agreement between the two approaches for the right eye VA measurements (Kappa = 0.773; $p < 0.001$). There was also substantial agreement between the two approaches for colour vision measurement in the right eye (Kappa = 0.764; $p < 0.001$). The simulated approach had a sensitivity of 98.5%, specificity 90.9%, PPV 99.34% and NPV of 81.08% for VA measurements. It had a sensitivity of 97.86%, specificity 92.86%, PPV 99.57% and NPV of 72.22% for colour vision.

Conclusion: The conventional and simulated approaches have a significant level of agreement in the test results for both visual acuity and colour vision.

Keywords: *conventional*, *colour vision*, *simulated*, *visual acuity*

INTRODUCTION

Maintaining good eye health through proper care of eyes is essential for the overall health and well-being of a person or child[1]. The school setting provides a public health environment for vision screening for children and it can serve as a platform for communicating about eye conditions. School nurses and teachers can play an important role in communicating with parents about a student's eye health needs[2]. This is especially important because of the shortage of ophthalmologists in low-and-middle-income-countries, which has been worsened by the recent massive emigration of health workers from countries like Nigeria.

For children, the role of vision in the learning process is fundamental and it is often a central contributor to academic success[1]. Visual problems such as inability to see clearly and colour blindness are considered major public health issues with adverse effects on learning and academic performance among school-going children[3,4].

Research shows that many children who experience problems in school may actually suffer from visual dysfunction, but may be erroneously diagnosed with learning disability or considered to have attention-deficit/hyperactivity disorder (ADHD)[5]. 'Prevent Blindness' - a USA volunteer Eye Health and Safety Organization, reports that one in four children has an undiagnosed vision problem[7].

The most prevalent disabling childhood vision disorders are refractive error, amblyopia and strabismus[7]. Signs and symptoms that may indicate that a child has vision problem include frequent eye rubbing or blinking, short attention span, avoiding reading and other close activities, frequent headaches, covering one eye; and tilting the head to one side when reading. Other signs include squinting, seeing double, losing his place while reading or using a finger to guide his eyes when reading, not being able to differentiate colours, complaining of tired eyes, receiving lower grades than usual and many more[8,9].

School vision screening is an important means for early detection and treatment of eye disorders among school children[8]. Eye screening as one of the prerequisites for entry into Junior Secondary School (JSS) is therefore essential. The aim of the study is to evaluate the effectiveness of an innovative approach using a web application as a screening tool for visual acuity and colour vision among school-going children in southwestern Nigeria.

MATERIALS AND METHODS

The study was carried out in Osogbo metropolis, the capital of Osun State. Osun State is located in the South-western part of Nigeria with an area of 9,251km^2 and a projected population of 4,705,600 for 2019[10]. The state has 1460 primary schools, 530 secondary schools and 24 technical colleges. Osogbo metropolis consists of Olorunda, Egbedore and Osogbo Local Government Areas (LGAs). Olorunda LGA has 23 registered private and 26 public junior secondary schools; Egbedore LGA has 16 registered private and 23 public junior secondary schools while Osogbo LGA has 14 registered private and 26 public junior secondary schools with a total student population of 48,766. Osogbo is predominantly populated by the Yoruba ethnic group while other ethnic groups such as the Hausa, Igbo, Edo also reside in the city. Other nationalities such as Ghanaians and Togolese are also found in the area. In the rural area, majority of the inhabitants are farmers while in the urban areas, they are mostly traders, artisans, cloth dyers and civil servants.

A cross-sectional descriptive survey research design was adopted. The study was carried out among JSS1 students in selected public junior secondary schools during the first term of the 2019/2020 academic session. The study duration was 4 months (September to December 2019).The study population consisted of class 1 students in selected public Junior Secondary Schools for whom consent had been given by their parents and assent by the students themselves.Students with deafness, mental disabilities and those with non-consenting parents.

Using the Fisher's formula cited by Araoye,[11] a sample size of 436 students was calculated assuming a 95% confidence interval (z=1.96), a prevalence of refractive error(p) at 6.9% reported in Ilorin by Ayanniyi *et al*[12] with precision level(d) set at 2.5% and an attrition rate of 10%

A multi-stage sampling technique was used. For the first stage, 12 of the 48 public JSS in the 3 LGAs in Osogbo metropolis were selected using systematic sampling and ballot methods. In the second stage, 3 arms of JSS1 in each of the chosen schools were selected using simple random sampling technique (balloting method). At the 3rd stage, the number selected in each of the 3 classes in each school was determined using proportional allocation and systematic samplingmethod.

The research team comprised of the principal investigator who administered the conventional and simulated approaches to the students and two volunteers (teachers in each school).

OPERATIONAL DEFINITIONS

For the purpose of this study the following definitions were applicable

Good visual acuity: presenting visual acuity(VA) of 6/6 or better.

Impaired visual acuity: presenting VA of 6/9 or worse.

Normal colour vision: Correctly identifying 6 of 6 Ishihara plates.

Colour vision deficiency: Identifying less than 6 Ishihara plates correctly.

Conventional approach: The traditional or paper-based method of visual acuity and colour vision tests.
Simulated approach: The computerized method of visual acuity and colour vision test.

Pre-Survey Activities

Advocacy: A letter of permission and consent was obtained from the Ministry of Education and schools' Parents Teachers Associations.
Two teachers in each school were trained by the researcher on the use of use of the conventional and simulated test in measuring VA and colour vision.
Fifty students in JSS1 in a public school outside Osogbo were recruited for the pilot study for a period of one week.

Data collection Procedure

Visual Acuity Assessment using Conventional Snellen Chart

This study deals with only distance vision testing. Unaided visual acuity was tested at 6 meters from the Snellen chart. The screening was done in a hall with normal daylight lighting. One eye was tested at a time starting with the right eye while the left eye was occluded. The student was told to read letters on the chart from top to bottom moving across each line left to right using a pointer. If any student failed to read a line, it was repeated in the reverse order. If the line was failed twice, the visual acuity was taken as the preceding line completed and read correctly. The procedure was repeated in left eye, with the right eye occluded. Subjects with visual acuity $\leq$ 6/9 in either eye were considered to have impaired vision.

Colour Vision Assessment using Conventional Ishihara Chart

This was the next step after the distant VA testing. The screening was done in a hall with normal daylight lighting. One eye was tested at a time. The researcher held the first plate at a distance of about 75cm from the subject. The plate was held up for about 3-5 seconds for the student to see the number. The instructions were read out and the student was shown the introductory plate (number 12) and five other colour plates. The student was told to say out loud the number they see and were allowed to ask questions if they had any difficulty reading the numbers. The procedure was repeated in the left eye, with the right eye occluded. The student then moved to do vision screening using the simulated computerized approach.

Visual Acuity and Colour Vision Assessments using the Simulated Approach System design model

The idea for the simulated approach was conceived by the lead author and developed by a software engineer. The simulated approach is a web application (https://drive.google.com/file/d/10UHDUN5cw8Ikv0xiGdNEpdg09m3YZlRg/view?usp=drive web), which on installation provides opportunities for user registration and testing. The system is based on a computer programme designed by the principal investigator using Winnersworld Technologies (winner worldtech@gmail.com) to run on any personal computer running on Microsoft Windows. The eventual aim is for the programme to be used by school nurses, teachers or other suitable personnel. The programme interface has been carefully designed to allow vision screening to be carried out by those with minimal computer skills. The simulated vision test application was downloaded and installed on a Hewlett Packard (HP), Windows 8 laptop. The home page was displayed and had options of user registration, start test and user information. On clicking on user registration and entering name, date of birth and gender; a user identification number is generated. The test was performed with or without glasses and one eye was tested at a time. In order for the test to be performed correctly, the computer automatically detects the screen size and display instruction to allow for the distances between the subject and screen. The type of computer used (HP) allowed a standard computer resolution of the application at 1440 x 900mm. At this resolution, the appropriate distance for assessing distant visual acuity was 3 meters and colour vision testing distance was 75cm.

Procedure for administering the Simulated Approach System: Test plates were programmed to display optotypes from which the student read out loud. There were fourteen diagnostic plates for presentation during testing. The first 8 plates were for testing visual acuity and remaining 6 plates for testing colour vision.

Visual Acuity Testing: To test the right eye, the left eye was covered with an occluder and subject was at a distance of 3 meters. Thereafter, the left eye was tested while the right eye was covered. After this, the student immediately started the colour vision test.

Colour Vision Testing: To perform the test, the subject was seated 75cm from the computer screen according to system instruction, and each eye was tested separately. Six test plates were presented; the first plate was the introductory plate which was number 12. The system made its diagnosis based on the number of plates read correctly. When a student correctly identified all the optotypes in a section was, the software ended the testing and presented a simplified scoring with a diagnosis of the test along with the total number of plates correctly identified out of the total number of plates. When the student did correctly identify the optotypes, the software immediately began further tests to quantify the defect. The system automatically gave the result of the visual acuity test. If a student read all 6 plates correctly, a score of 6/6 (6 out of 6 plates) was recorded i.e. normal colour vision but anything less than 6 plates was scored accordingly, and recorded as colour vision deficiency, such a student was referred to an ophthalmologist for further evaluation.

Ethical Approval

This study followed the Helsinki Declaration on study involving human subjects. Approval for the study was obtained from the Ethical Review Committee, Ladoke Akintola University of Technology Teaching Hospital, Osogbo (LTH/EC/2019/03/401) and Osun State Ministry of Education. Written consent was obtained from parents/guardians of the students and assent from the students.

Data Management

The data was manually sorted, entered into the statistical software - Statistical Package for Social Sciences (SPSS) version 22. Bio-data of the students were presented using descriptive statistics such as frequencies and percentages. The assessment and comparison of conventional and simulated approaches on the degree of visual acuity and colour vision deficiencies was analyzed using descriptive statistics and inferential statistics using Kappa. The sensitivity, specificity, positive predictive value and negative predictive value of the simulated approach as a screening tool was calculated.

RESULTS

A total of 496 students were examined. Their age range was 8-16 years with a mean of 11.79 ±1.50 years. The age and sex distribution of the respondents are presented in Table 1. Majority (71%) were within the age group of 11-13years while male:female ratio was 1.4:1. The prevalence of abnormal VA in the study participants was 7.9%. There was substantial agreement between the two approaches for the right eye VA measurements (Kappa = 0.773; $p < 0.001$). Tables 2 and 3 show the comparison between the visual acuity tests using conventional and simulated approaches in the right and left eyes respectively. There was also substantial agreement between the two approaches for colour vision measurement in the right eye (Kappa= 0.764; $p< 0.001$). Tables 4 and 5 show the comparison between colour vision tests using conventional and simulated methods in the right and left eyes respectively.

Table 1: Age and Sex distribution of the Respondents

Variable	Frequency	Percentage (%)
Age Group		
8-10years	92	18.5
11-13years	352	71.0
14-16years	52	10.5
Total	496	100.0
Mean age (±SD)	11.79 ± 1.50 years	
Gender		
Male	285	57.5
Female	211	42.5
Total	496	100.0

The sensitivity of measuring VA and colour vision using the simulated approach compared to the conventional approach showed ranged between 97-99% while the specificity ranged between 90-97%. See Table 6.

DISCUSSION

Table 2: Visual Acuity Measurement using the Conventional and Simulated Approaches (Right Eye)

Conventional Method (%)								Statistics
	6/6	6/9	6/12	6/18	6/24	6/36	6/60	
Simulated Method								Kappa=0.773 **p<0.001***
6/6	457(99.3)	2(0.4)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	1(0.2)	
6/9	3(21.4)	11(78.6)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	
6/12	2(50.0)	0(0.0)	2(50.0)	0(0.0)	0 (0.0)	0(0.0)	0(0.0)	
6/18	0(0.0)	2(25.0)	0(0.0)	5(62.5)	1(12.5)	0(0.0)	0(0.0)	
6/24	1(14.3)	1(14.3)	2(28.6)	0(0.0)	3(42.9)	0(0.0)	0(0.0)	
6/36	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	1(100.0)	0(0.0)	
6/60	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	2(100.0)	

**Statistically significant (p<0.001)*

Table 3: Visual Acuity Measurement using the Conventional and Simulated Approaches (Left Eye)

Conventional Method (%)								Statistics
	6/6	6/9	6/12	6/18	6/24	6/36	6/60	
Simulated Method								Kappa=0.872 **p<0.001***
6/6	457(99.8)	1(0.2)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	
6/9	1(5.6)	17(94.4)	0(0.0)	0 (0.0)	0(0.0)	0(0.0)	0(0.0)	
6/12	2(40.0)	2(40.0)	1(20.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	
6/18	0(0.0)	0(0.0)	0(0.0)	5(83.3)	1(16.7)	0(0.0)	0(0.0)	
6/24	0(0.0)	0(0.0)	1(25.0)	0(0.0)	3(75.0)	0(0.0)	0(0.0)	
6/36	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	1(100.0)	0(0.0)	
6/60	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	1(25.0)	3(75.0)	

**Statistically significant (p<0.001)*

Table 4: Colour Vision Measurement using the Conventional and Simulated Approaches (Right Eye)

Conventional Method (%)							Statistics
	6/6	5/6	4/6	3/6	2/6	1/6	
Simulated Method							Kappa=0.764 **p<0.001***
6/6	459(99.6)	2(0.4)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	
5/6	9(47.4)	10(52.6)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	
4/6	1(12.5)	1(12.5)	6(75.0)	0(0.0)	0(0.0)	0(0.0)	
3/6	0(0.0)	1(33.3)	0(0.0)	2(66.7)	0(0.0)	0(0.0)	
2/6	0(0.0)	0(0.0)	0(0.0)	0(0.0)	2(100)	0(0.0)	
1/6	0(0.0)	0(0.0)	0(0.0)	0 (0.0)	0(0.0)	3(100.0)	

**Statistically significant (p<0.001)*

Table 5: Colour Vision Measurement using the Conventional and Simulated Approaches (Left Eye)

Conventional Method (%)							Statistics
	6/6	5/6	4/6	3/6	2/6	1/6	
Simulated Method							Kappa=0.957 **p< 0.001***
6/6	471(100.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	
5/6	2(16.7)	10(83.3)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	
4/6	0(0.0)	0(0.0)	6(100.0)	0(0.0)	0(0.0)	0(0.0)	
3/6	0(0.0)	0(0.0)	0(0.0)	3(100.0)	0(0.0)	0(0.0)	
2/6	0(0.0)	0(0.0)	0(0.0)	0(0.0)	1(100.0)	0(0.0)	
1/6	0(0.0)	0(0.0)	0(0.0)	0 (0.0)	0(0.0)	3(100.0)	

**Statistically significant (p<0.001)*

Table 6: Sensitivity and Specificity of Simulated Approach compared with conventional method for testing visual acuity and colour vision

	Sensitivity	Specificity	PPV	NPV
Visual Acuity (Right)	98.49%	90.91%	99.34%	81.08%
Visual Acuity (Left)	99.13%	97.22%	99.78%	89.74%
Colour Vision (Right)	97.86%	92.86%	99.57%	72.22%
Colour Vision(Left)	99.36%	95.83%	99.79%	88.46%

Generally, there is an inadequate number of ophthalmologists in Nigeria, which has markedly reduced the ophthalmologist to patient ratio required by the World Health Organisation (WHO). This has been worsened with the massive emigration of health professionals. There is therefore a need for innovative approaches to solving common ophthalmic problems without ophthalmologists in Nigeria, hence this study. The evolution of modern technology has led to the development of numerous mobile computing applications that demonstrate efficacy in screening vision skills.[13] A vision screening test needs to be simple, fast, valid and effective. The most important initial consideration is the accuracy of the screening tools which is assessed through sensitivity and specificity. In this study, sensitivity was greater than 90% for visual acuity and colour vision as compared with the conventional method. Specificity was also greater than 90%. A high specificity is desirable for screening tests that seek to confirm "disease" because the number of false-positive results is reduced in such tests.

This simulated approach is similar to the Visual Efficiency Rating Acuity (VERA) which is a computer software created for school nurses to screen for vision problems that could interfere with reading and school performance.[13] In the VERA study, sensitivity was fair at only 45%, but increased to 56% in children with reading delays. Specificity was considerably better than sensitivity, at 83%, which increased to 92% in children with reading delays. Consistent finding was reported by Hatch,[14] who compared the results of VERA screener with the outcome of an eye examination and found it to have a sensitivity of 75% and specificity of 93%. In the same vein, results obtained in the United Kingdom[15] where the computer programme was operated by experienced clinicians was similar to this study even though the simulated approach was operated by school teachers. Some studies carried out in Auckland and Phillipines have demonstrated that measurements of visual acuity using a software device can provide similar results with standard charts.[16,17] Moreover, results from a recent study showed that the Portable Eye Examination Kit (PEEK) Acuity application is just as accurate as Snellen chart for testing visual acuity.[18,19]

Another study showed there was a difference between visual acuity test using the standard conventional method and a software,[17] though

glare was not eliminated from the screen before this was done. This aforementioned finding differs from another study on conventional approach versus simulated approach done in the United States where there was no difference reported on distance visual acuity test using the two approaches.[20]

Inconsistencies in appropriate vision screening methods still exist especially with the booming market of computer software programmes which still needs validation.[14,21] Hence the need for evaluation of the two approaches in the study location. In this study, the sensitivity in both eyes using the simulated approach for colour vision test was greater than 96% while the specificity was greater than 92% compared to the conventional method. This finding further supports previously documented reports in Toronto, Canada where computer emulations of Ishihara test on colour vision test gave high specificity and sensitivity comparable to the conventional method.[22] Therefore, the simulated approach of testing can be used for screening of colour vision deficiency with similar results as the conventional approach. Comparing the performance of students diagnosed as normal or colour vision deficient by both tests resulted in statistically significant relationship, adding to their liability of the computer-based test. This is similar to a study in Egypt where the computer-based test gave 100% sensitivity and 99% specificity.[23] Several other studies have shown a high reliability of Ishihara test to detect congenital colour vision deficiency.[24,25]

Integration of visual acuity and colour vision tests to human sensory function using computer can improve the quality of the result, reduce the required resources and decrease the time to analyze results. Marey *et al*[26] in their study evaluated the use of computer software for colour vision deficiency testing compared to Ishihara test and reported that the computer-based testgave 100% sensitivity and 98.78% specificity, thereby making the computer-based test convenient for screening for congenital colour vision deficiency.

As shown in this study, a simulated computer application can detect visual acuity defects in a manner comparable to conventional tests. The implication of using the simulated approach in terms of its high specificity will lead to low false positive results. It will also reduce the percentage of wrong student referrals and by so doing, help to avert unnecessary financial burden.

LIMITATIONS OF STUDY

The tests for visual acuity and colour vision were subjective and dependent on the participant's cooperation and have to be accepted as they were stated. However, the research assistants were well trained to minimize reporting bias during data collection.

CONCLUSION

Using the conventional and simulated approaches for the assessment of visual acuity and colour vision was found to be effective as screening tools and can be used for vision screening. Therefore, simulated approach is recommended for mass screening of students in this environment.

Declarations

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analyzed during the current study are available from corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

All the authors were involved in the conception of the research idea and topic. AOO, COA and MAI wrote the background of the study, AOO and AAA wrote the methodology section. AOO and AAA were involved in data collection and data entry. AOO and AAA analyzed the data and together with COA, MAI and BGK wrote the results and discussion sessions. All authors read and approved the final version of the manuscript.

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