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Original Article

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Correlation and Agreement Between the Occupational Vision Screener and Ophthalmologic Tests in Visual Performance Assessment of Surgical Health Professionals

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ABSTRACT

OBJECTIVE This study aims to evaluate the correlation and agreement between occupational vision tests and standard ophthalmological examinations across five dimensions of visual performance.

METHODS Fifty-three participants underwent assessments for visual acuity (VA), red-green color vision, stereoscopic depth, and phoria using both the Titmus occupational vision screener and ophthalmologist-administered tests, including the Early Treatment Diabetic Retinopathy Study (ETDRS) chart for VA, Farnsworth D-15 for color vision, Stereotest-Circles for stereoscopic depth, and the cover-uncover test for phoria. To compare the correlation or agreement of each parameter between the two methods, correlation coefficients were used to evaluate VA and stereoscopic depth perception, Kappa analysis for color blindness, phoria and astigmatism. Statistical significance was set at $p < 0.05$.

RESULTS Test results were finalized with 53 participants, mean age of 29.4 years. A majority of the participants (62.30%) reported a history of prior and/or present use of visual aids. The assessment of visual capacity demonstrated a good correlation between occupational stereoscopic depth and Stereotest-circles (0.5997, $p < 0.001$) and a moderate correlation between the Occupational best corrected VA and ETDRS best corrected VA (maximum 20/20) (0.4616, $p < 0.001$). Color vision screening showed a high level of statistical agreement with a kappa value of 1.00. However, the results for phoria and astigmatism were inconsistent with only left-eye astigmatism demonstrating statistical significance ($p = 0.047$), but with only a fair Kappa value (0.21).

CONCLUSIONS Occupational vision tests showed strong to moderate correlation for stereoacuity and visual acuity and high agreement of color with standard methods. These tests are useful for visual screening of surgical professionals. Further extensive examinations of other parameters and with a wider variety of participants are required for a more comprehensive assessment of visual capacity related to specific job tasks.

KEYWORDS stereo acuity, visual acuity, vision test, occupation, color vision

INTRODUCTION

Visual performance is one of the most important functions in work activities and daily life. Key aspects of eye performance include visual acuity (VA), which ensures clear vision in various job tasks and is essential for responding effectively in urgent situations. Stereoscopic depth is crucial for determining the distance to objects, such as when driving or operating a moving object or device. The perception of color plays a role in distinguishing and recognizing different shades and hues. Some careers require optimal visual performance across several areas to ensure fitness for duty, such as driving, fire-fighting, and airplane piloting (1-3).

Physicians encounter specific occupational risks (4) which could potentially impact the safety of both patients and healthcare personnel. The diverse range of medical specialties introduces unique job characteristics for each specialty. For example, surgically skilled physicians, e.g., surgeons, orthopedists, ophthalmologists, otolaryngologists, and obstetric gynecologists, rely heavily on visual capabilities (5). Their work involves activities that require sustained focus, visuospatial perception, and coordination (6). Their work also often demands sustained concentration and meticulous attention to detail. Evaluating visual capacity is crucial in determining an individual's preparedness for work (7). However, assessing the entire range of key factors related to their job performance can require significant time.

Ophthalmological assessments generally include evaluation of multiple ocular functions (8, 9). For example, VA is measured with a Snellen or ETDRS chart to quantify the smallest resolvable optotype by each eye. Phoria is evaluated using the cover-uncover test or prism bars to detect phoria or strabismus, both of which may cause eyestrain or diplopia during sustained focus. Depth perception is usually tested using the fly or butterfly stereotests, which use polarized images to assess 3D depth perception. Color vision is assessed with pseudoisochromatic plates like the Ishihara and Hardy-Rand-Rittler (HRR) tests. The Farnsworth D-15 test is additionally employed to evaluate both red-green and blue-yellow deficiencies and to grade their severity. Astigmatism is detected using an auto-refractometer for objective refractive error measurement. Visual field is measured by automated perimeters, e.g., a Humphrey visual field analyzer, to detect vision loss, crucial in visually demanding tasks.

The occupational vision test is one of the tools employed to evaluate preparedness for visual work which has become more widely available in occupational medicine clinics. The primary objective of this test is to match the job requirements with the job category (10). The tool is a compact portable device capable of evaluating seven aspect visual parameters: VA, phoria, stereoscopic depth perception, vertical and horizontal phoria, color blindness, astigmatism, visual field, and binocular vision (11). Each of these areas is crucial for assessing visual performance. Although standard ophthalmologic tools are often permanently installed in clinics and require time, trained personnel and a controlled environment to complete a full assessment, the occupational vision screener device is portable, making it practical for proactive screening in various settings such as communities, primary care clinics, and workplaces. It enables quick, one-stop screening of multiple visual parameters outside a hospital setting and requires fewer operators to run. Vision screening plays a vital role in assessing fitness for duty, e.g., professions such as dentistry and surgery require precise perceptual and visual skills to perform procedures effectively (12, 13). Similarly, motor vehicle driving demands adequate VA and visual field to ensure safety during both daytime and nighttime conditions. Previous studies have demonstrated that visual impairments are significantly associated with an increased risk of road traffic accidents (14). However, a knowledge gap persists regarding the consistency of these tools in evaluating job tasks that do not fit into existing categories. If occupational vision tests are shown to correlate well with standard vision tests, they might be adopted more broadly, thus reducing the time and resources needed for evaluating healthcare workers. Since no prior study has assessed the accuracy of this test or its agreement with standard examinations, the present study was conducted to determine the correlation and agreement between occupational vision tests and standard ophthalmological examinations across five dimensions of visual performance: VA, color vision, phoria, stereoscopic depth perception, and astigmatism among surgical health professionals.

METHODS

Study Design and Population

The cross-sectional study was conducted in June 2023 at the teaching hospital in Chiang Mai, Thailand. The sample size was determined using the n4Studies program, based on the infinite population proportion formula by Daniel (15) The parameters used included a prevalence (P) of 0.29, based on a study by Alhusuny et al. (16), a delta (d) of 0.2, an alpha (α) of 0.05, and a Z (0.975) value of 1.959964. The calculated minimum required sample size was 20 participants. To ensure adequate power and to account for potential dropouts or missing data, we increased the sample size by 150.00%, resulting in a final sample of 50 participants. We recruited a total of 57 newly trained first-year physicians whose jobs involved surgical procedures. The study included individuals who consented to participate and who could communicate verbally. The study enrollment flow diagram is shown in Figure 1.

Data collection

The study was divided into two parts. Part 1 involved a structured questionnaire for collecting general demographic data, e.g., age, sex, height, weight, underlying health conditions, and visual health-related information such as eyeglass use, history of eye surgery, and use of artificial tears. Part 2 involved visual performance screening and ophthalmologic diagnostics. The participants provided demographic information and underwent eye examinations to obtain data across five aspects: VA, color vision, phoria, stereoscopic depth perception, and total astigmatism. The data collection was conducted over two days. On the first day, occupational health screenings were performed, and on the second day, ophthalmologist examinations were conducted. This scheduling was designed to reduce eye fatigue from prolonged periods of eye examination. The Titmus V4 Vision Screener (Titmus LLC, Honeywell International Inc., Charlotte, NC, USA) was conducted by a single occupational medicine physician in a private examination room and included evaluation of phoria, depth perception ranges from 400 to 10 seconds of arc, VA (both far and near, binocular and monocular), color vision, and visual field in this sequence. Astigmatism was assessed separately using a Visiolite VT1 Vision Screener (Depisteo LLC, Atlanta, GA, USA). The interpretation for color vision, phoria, and total astigmatism followed the devices' instructions, with details provided in the supplementary file. After the evaluation using occupational eye health screening tools, an ophthalmologist evaluated the majority of the elements using standard methods, with the exception of binocular vision, visual field, and near VA. Ophthalmologist-standard tools were also used to examine the same five aspects: 1) VA assessments were conducted using an Early Treatment Diabetic Retinopathy Study (ETDRS) Chart, with data presented as decimal scores and converted to logMAR units. The ETDRS chart is the accepted benchmark in clinical trials owing to its logarithmic progression and high test-retest reliability (17). 2) Color blindness examinations were performed via the Farnsworth D15 test (Good-Lite Co., Elgin, IL, USA), a high specificity tool capable of distinguishing protan and deutan defects and grading mild to severe deficiency (18). Abnormal results were indicated

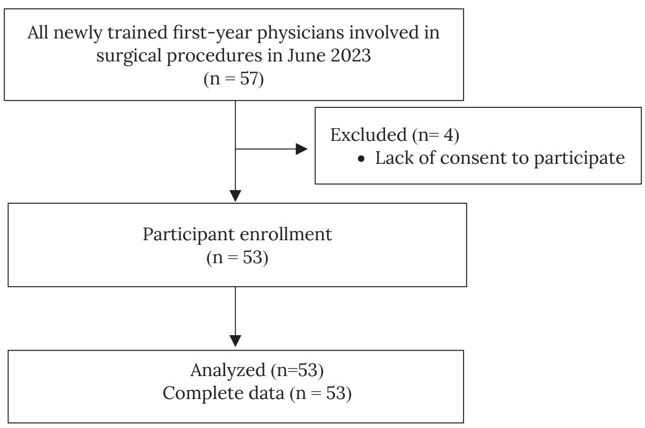

Figure 1. Study enrollment flow diagram

by more than 2 crossing lines in a diagram. 3) Stereoscopic depth perception was evaluated using stereotest circles (Stereo Optical Co., Inc., Ltd., Chicago, IL, USA), with results ranging from 800 to 40 seconds of arc. This tool was selected for its minimal monocular cues, validated sensitivity to sub-arc-second disparities, and widespread use in both research and clinical settings due to its high specificity (19). 4) Phoria was assessed using the ophthalmologist's cover-uncover test, which has demonstrated high specificity (20). Phoria was indicated when the occluded eye deviated and then returned to a straight position upon removal of the occlude. 5) Measurements for total astigmatism were conducted using an Auto-refractometer (Nidek Co. Ltd., Aichi, Japan) and categorized into four groups: none, direct astigmatism (vertical meridian is steeper), inverse astigmatism (horizontal meridian is steeper), and oblique astigmatism. Ophthalmological diagnostic tests were conducted at an ophthalmology clinic under standard clinical settings. All tests were conducted by trained personnel with experience in operating each device. To minimize operator bias and ensure standardization, the same examiner conducted the same test for all participants. Equipment setup and calibration followed clinic protocols and manufacturer recommendations.

Statistical analysis

Descriptive analysis was used to determine frequencies, mean averages, and proportions of categorical and continuous variables. To compare the results between the occupational health vision screening tools and those used by ophthalmologists, pairwise correlation analysis was employed to evaluate the correlation of best corrected VA and stereo depth values. A correlation coefficient close to +1 indicates a strong positive linear association, while a value near −1 signifies a strong negative linear association. Conventionally, values >0.7 are classified as 'strong,' 0.5–0.7 as 'good,' 0.3–0.5 as 'fair or moderate,' and <0.3 as a 'weak' correlation (21). The level of inter-rater agreement in color vision assessment, phoria, and astigmatism was evaluated using Cohen's Kappa to measure reliability for qualitative (categorical) items was interpreted as follows (22): < 0.00 was classified as 'poor', 0.00–0.20 as 'slight', 0.21–0.40 as 'fair', 0.41–0.60 as 'moderate', 0.61–0.80 as 'substantial', and 0.81–1.00 as almost perfect. The statistical significance level was set at a $p < 0.05$ and the confidence interval at 95%. STATA version 16.0 (StataCorp LLC, College Station, TX, USA) was used to assess and evaluate all the data.

Ethical considerations

This study was approved by the Research Ethics Committee, Faculty of Medicine, Chiang Mai university, Thailand (study approval code: COM-2565-09077). The study was reported according to the STROBE guidelines.

RESULTS

A total of 53 first-year physicians who had recently started their employment at the medical school participated in the study, representing a 92.98% response rate. Most participants (92.40%) reported no evidence of any underlying health problems before taking part in this study. The majority of participants (49.00%) relied solely on glasses to correct their vision, followed by contact lenses (7.60%), and a combination of both glasses and contact lenses (5.70%). Of the participants,

Table 1. The Characteristics of the participants (N = 53)

Characteristics	n (%)
Age (years), mean±SD	29.4±2.8
Weight (kg), mean± SD	66.9±2.8
Height (cm), mean±SD	168.6±9.7
Gender	
Female	18 (34.0)
Male	35 (66.0)
Underlying health conditions[a]	
Yes	4 (7.6)
No	49 (92.4)
Current Use Visual aids	
No	20 (37.7)
Glasses only	26 (49.0)
Contact lens only	4 (7.6)
Glasses and contact lens	3 (5.7)
Use of artificial tears	
Yes	16 (30.2)
No	37 (69.8)
History of refractive surgery	
No	43 (81.0)
Laser *In situ* keratomileusis (LASIK)	3 (5.7)
Photorefractive keratectomy (PRK)	2 (3.8)
Refractive lenticule extraction (ReLEx)/ small incision lenticule Extraction (SMILE)	3 (5.7)
Implantable collamer lens	2 (3.8)

[a]Underlying health conditions: 3 cases of allergic rhinitis and 1 case of dyslipidemia

Table 2. Compared visual performance assessments (N = 53)

Parameters	Occupational health vision exams n (%)	Ophthalmologist n (%)
Color vision		
Normal	52 (98.1)	52 (98.1)
Abnormal	1 (1.9)	1 (1.9)
Phoria		
Far horizontal phoria		
No phoria	31 (58.5)	51 (96.2)
Phoria is present	22 (41.5)	2 (3.8)
Far vertical phoria		
No phoria	51 (96.2)	53 (100.0)
Phoria is present	2 (3.8)	0 (0.0)
Near horizontal phoria		
No phoria	40 (75.5)	50 (94.3)
Phoria is present	13 (24.53)	3 (5.7)
Near vertical phoria		
No phoria	49 (92.45)	53 (100.0)
Phoria is present	4 (7.55)	0 (0.0)
Astigmatism, left eye		
None	19 (35.8)	31 (58.5)
Direct astigmatism	9 (17.0)	1 (1.9)
Inverse astigmatism	15 (28.3)	20 (37.7)
Oblique astigmatism	10 (18.9)	1 (1.9)
Astigmatism, right eye		
None	25 (47.2)	16 (30.2)
Direct astigmatism	10 (18.9)	1 (1.9)
Inverse astigmatism	11 (20.7)	34 (64.1)
Oblique astigmatism	7 (13.2)	2 (3.8)
Parameters	**Occupational health vision exams (Mean±SD)**	**Ophthalmologist (Mean±SD)**
Best-Corrected Visual Acuity		
Distance logMAR VA, both eyes	0.1061±0.1779	N/A
Distance logMAR VA, left eye	0.1235±0.1515	0.0150±0.0507
Distance logMAR VA, right eye	0.1504±0.2063	0.0215±0.0778
Near logMAR VA, both eyes	0.0447±0.1101	N/A
Near logMAR VA, left eye	0.1205±0.1701	N/A
Near logMAR VA right eye	0.1232±0.1446	N/A
Stereoscopic depth		
Seconds of arc	84.3±98.6	43.6±9.4
Seconds of arc (median, P25, P75)	50, 20,100	40, 40,40

N/A, not applicable; SD, standard deviation

37.70% required no visual aids. A high proportion of participants (69.80%) needed no artificial tears and denied a history of refractive surgery (81.00%). Additional information regarding participant characteristics is provided in Table 1. Table 2 shows details of the visual performance assessments of the individuals who underwent evaluations for each test parameter.

The data was used to compare assessments performed by ophthalmologists to those carried out during occupational health vision examinations, as presented in Table 3 and Table 4. Color vision screening showed a high level of agreement between the two measurements, with a kappa value of 1.00 and 100.00% agreement. Phoria assessment using the occupational health vision exam showed poor, non-significant agreement. For astigmatism, only left-eye astigmatism demonstrated fair agreement, with a Kappa value of 0.21 and a statistically significant p-value of

Table 3. The agreement of outcomes in each visual performance assessment

Occupational health vision exams	Visual capacity assessments by ophthalmologists				
	Abnormal	Normal	Total	% Agreement	Kappa (p-value)
Farnsworth Test					
Color vision screening[+]					
Abnormal	1	5	1	100%	1.000
Normal	0	52	52		(<0.001)
Total	1	52	53		
Cover-uncover test					
Far phoria[+]					
Abnormal	1	15	16	69.81%	0.050
Normal	1	36	67		(0.267)
Total	2	51	53		
Near phoria[+]					
Abnormal	1	4	5	88.68%	0.190
Normal	2	46	48		(0.072)
Total	3	50	53		
Right astigmatism					
Astigmatism, right eye[+]					
Abnormal	20	8	28	25.83%	0.035
Normal	17	8	25		(0.393)
Total	37	16	53		
Left astigmatism					
Astigmatism, left eye[+]					
Abnormal	15	17	34	58.49%	0.210
Normal	5	14	19		(0.047)
Total	22	31	53		

[+]Analyzed by kappa analysis

0.047. Table 4 shows the correlation analysis of visual capacity, examining the association between variables evaluated using the occupational vision test and the standard techniques performed by ophthalmologists. Correlations that demonstrated statistical significance were seen between occupational stereoscopic depth and stereotest-circles test (0.5997, $p < 0.001$), indicating a good correlation. Additionally, a moderate correlation was found between occupational VA and ETDTS VA (maximum 20/20) (0.4616, $p < 0.001$).

Table 4. Correlations of visual performance between the assessments by Occupational health vision examination and ophthalmologist

	Correlation	p-value
Occupational stereoscopic depth vs. stereotest-circles	0.5997	< 0.001
Occupational best corrected VA vs. ETDRS best corrected VA (maximum 20/20)	0.4616	< 0.001

ETDRS, Early Treatment Diabetic Retinopathy Study

DISCUSSION

The studies indicated statistically significant correlation in visual performance between assessments conducted using occupational health vision examinations and conducted by ophthalmologists. Specifically, correlations were observed in stereoscopic depth and the stereotest circles, as well as occupational best-corrected visual acuity and ETDRS best-corrected VA (maximum 20/20), demonstrating strong and moderate correlation strengths of 0.5997 and 0.4616, respectively. The evaluation of stereoscopic depth in minutes of arc revealed median measurements of 50 seconds of arc with the occupational health vision assessment and 40 seconds of arc with the stereotest-circles performed by the ophthalmologist. Participants demonstrated superior stereoacuity with both tools, surpassing the threshold of less than 60 seconds of arc observed in prior studies (23, 24). Based on the significant correlation, the occupational vision test can provide good correlation results to assess stereoacuity and to determine the level of stereoscopic depth. However, the use of stereotest-circles was restricted to the best stereoacuity measurement of 40 seconds of arc (25). Additionally, monocular cues in the easier test items may have partially influenced stereoscopic depth perception, allowing participants to respond without truly perceiving depth (26). The occupational vision screening tool offers an extensive assessment of depth perception, reaching up to 10 seconds of arc, and may be less affected by monocular cues. Although our results do not determine the appropriate passing threshold for the occupational health vision test in surgical professionals, meeting the minimum stereoscopic depth criteria in this test suggests a high level of stereoscopic depth perception. A good stereo depth function could enhance surgical skills, despite ongoing debates regarding the level of stereopsis required for satisfactory performance (23, 27).

We computed VA for both eyes and compared it with the best-corrected VA as per the ETDRS standard, with a maximum of 20/20. The correlation between the two tests demonstrated statistical significance, but with moderate strength. A previous study which developed a new VA test and compared it with standard tools, found that the new VA test demonstrated higher correlation and lower error rates in right eyes (28). A previous study found that occupational health vision exams had a positive predictive value of 20.40% and a specificity level of 64.30% for visual impairment screening, suggesting that there may be many false positives which require additional investigation (29). In addition, other studies have indicated that VA often provides worsen results when used with the Landolt C chart, commonly employed in occupational health vision examinations, compared to the Snellen chart. However, the observed discrepancies were minimal (30-33). In our study, the majority of the participants did not use artificial tears (69.80%) and currently used visual aids (62.30%). The use of glasses or contact lenses to correct refractive errors may affect accommodative and binocular visual functions (34), potentially affecting test outcomes. Additionally, tear film instability caused by dry eye can lead to a decline in VA. Artificial tears, as a modifiable intervention, may offer both immediate and long-term benefits for VA improvement (35).

The color vision assessment in the occupational health vision examination demonstrated a high level of agreement. This result was expected, as the assessment details of this test were a condensed version of the Ishihara color vision test. Although the color vision assessment in the occupational health vision examination is limited to detecting congenital red-green color blindness, it is sufficient for pre-placement screening. In addition, nearly all Thai physicians have had color vision examinations before beginning their medical study (36). Based on our results, this color vision assessment might be used as a screening confirmation test for color vision problems among interns, especially, as in the present study, physicians with surgical skills. Other more-specific tools, such as the Hardy-Rand-Rittler (HRR) pseudoisochromatic test, Farnsworth arrangement test, and L'Anthony test D-15 test (37, 38), may help to identify more specific details of color blindness and its severity.

The inconsistent results for phoria and astigmatism found in this study may be partly due to chance. One possible explanation for the non-significant result for phoria is that the occupational health vision screener requires fixed convergence to engage with the screen, which may influence phoria adaptation (39). Future studies should consider alternative designs to minimize this effect.

This study demonstrated strength as a pioneering study intended to support the practical application of occupational vision tests by evaluating the correlation between these tests and standard tests performed by ophthalmologists. Stereo depth as measured by the device may serve as a reliable standard for screening fine binocular function and as rule-out tests for subtle binocular abnormalities. In contrast, VA and color vision measurements are most effective for ruling out gross deficits prior to confirmation with further standard assessments.

This study does, however, have certain limitations. Although the study attempted to reduce operator bias by having the same examiner conduct all tests, the lack of blinding could still have introduced observer bias, where prior knowledge of a participant's status may have unintentionally influenced the assessment. Another limitation is the study design, as the cross-sectional study was conducted in the specific context of a teaching hospital. The recruitment of participants may have led to a healthy participant effect due to selection bias, despite exceeding the calculated required study population size. As a pilot study, it is appropriate only for pre-placement assessments of newly trained interns in departments requiring surgical skills. Future studies should include more diverse participants, be conducted over longer periods of employment, and focus on specific surgical procedures that may influence visual fatigue. Healthcare professionals may experience visual fatigue not only during conventional surgery but also during specialized procedures such as robotic surgery (40). Establishing visual performance standards for more specialized surgical procedures will? require additional research.

CONCLUSIONS

The applicability of the Occupational Vision Test appears to depend on which specific parameters are being evaluated. Phoria exhibited high specificity, whereas stereoscopic depth and the best-corrected VA test for both eyes showed strong and moderate correlation with standard methods, respectively. The color blindness test demonstrated high agreement with standard tests. These findings highlight its potential for optimizing visual assessment of surgical health professionals. Future studies that include more diverse participant populations and which provide more information about specific surgical procedures could improve understanding of how suitable different occupational vision tests are for various surgical uses and clinical applications.

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CONFLICT OF INTEREST

The authors have no conflict of interest to report.

ADDITIONAL INFORMATION

Author contributions

P.A.: conceptualization, formal analysis, investigation, methodology, resources, visualization, writing - original draft, writing - review & editing; J.P.: conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, supervision, validation, visualization, writing - original draft, writing - review & editing; P.U.: conceptualization, data curation, formal analysis, investigation, methodology, resources, supervision, validation, writing - review & editing; W.S.: formal analysis, methodology, software, validation, writing - review & editing.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used ChatGPT 3.0 in order to improve the language. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Availability of data and materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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