Mashhad University of Medical Sciences (MUMS)

Reviews in Clinical Medicine

Clinical Research Development Center Ghaem Hospital

Comparison of objective and subjective techniques of ocular deviation measurement: A cross-sectional study

Sara Farsi[1], Monireh Mahjoob[2*], Neda Nakhjavanpoor[1], Farkhondeh Shahri[1], Hava Shafiee[1]

[1]Department of Optometry, School of Rehabilitation Sciences, Zahedan University of Medical Sciences, Zahedan, Iran.

[2]Health Promotion Research Center, Department of Optometry, School of Rehabilitation Sciences, Zahedan University of Medical Sciences, Zahedan, Iran.

ARTICLE INFO

Article type
Original article

Article history
Received: 12 Feb 2025
Accepted: 02 Dec 2025

Keywords
Heterophoria
Heterotropia
Exophoria
Esophoria

ABSTRACT

Introduction: Measuring eye deviations is one of the most important steps in evaluating binocular vision. Small amounts of eye deviation can cause headaches and asthenopia if not managed appropriately. The aim of this study was to compare the objective and subjective deviation measurement methods.

Methods: This cross-sectional study was carried out qon 110 students aged 18-30 years, from Zahedan University of Medical Sciences. Assessments included refraction, near-point convergence, near-point accommodation, fusional vergences and best-corrected visual acuity. Objective measurements of near and far deviation were done using the Alternate Prism Cover Test, while subjective measurements were performed using the Maddox Rod for far and the Maddox Wing for the near. The intra-class correlation coefficient was used to check the agreement between the objective and subjective deviation angle measurement methods.

Results: The 95% limits of agreement (LoA) between the subjective and objective methods were –3.07 to 2.25 PD at far and –7.17 to 5.50 PD at near, showing that the two techniques cannot be used interchangeably. While the intra-class correlation coefficients demonstrated good statistical agreement for far (ICC=0.849) and near (ICC=0.836) deviations (P<0.001), these correlations do not offset the poor clinical agreement indicated by the LoA.

Conclusion: According to the results of this study, the range of the 95% LoA revealed a large magnitude of deviation (>5 PD), indicating a poor clinical correlation between the angle of deviation measured by the objective and subjective methods for both distances.

Please cite this paper as:
Farsi S, Mahjoob M, Nakhjavanpoor N, Shahri F, Shafiee H. Comparison of objective and subjective techniques of ocular deviation measurement: A cross-sectional study. *Reviews in Clinical Medicine*. 2025;12(4): 131-135.

Introduction

Effective binocular vision, involving both sensory and motor components, is crucial for eye alignment. Sensory fusion merges the images from both eyes, while motor fusion ensures the eyes stay aligned to support this sensory integration (1). Heterophoria and heterotropia are the relative misalignment of the visual axes when one eye is purposely excluded from vision, leading to a breakdown in the sensory and motor fusion processes of binocular vision. Heterotropia is a visible misalignment, whereas heterophoria is a latent misalignment that only becomes apparent when normal fusion is disrupted (2).

Accurate assessment of the deviation in patients is important for proper diagnosis and effective treatment. Abnormalities in vergence measurements can result in symptoms such as blurred vision, eye fatigue, diplopia, eye strain, excessive tearing and headaches that are particularly aggravated by prolonged engagement in visually demanding tasks such as reading or computer tasks. Such discomfort

***Corresponding author**: Monireh Mahjoob*
Department of Optometry, School of Rehabilitation Sciences, Zahedan University of Medical Sciences, Zahedan, Iran
Email: mahjoob_opt@yahoo.com Tel: +989153105701

Doi: 10.22038/RCM.2025.86043.1527

This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

can impair performance in close-range tasks and negatively impact on child's education (3,4). Deviation measurement methods are broadly categorized into objective and subjective techniques. Objective methods commonly used by optometrists include the Simultaneous Prism and Cover Test (SPCT) and the Alternate Prism Cover Test (APCT) (5). The cover test is an objective technique because it is not influenced by the patient's responses, although it does depend on the examiner's criteria and proficiency (3,6,7). These procedures involve using a prism to neutralize the involuntary eye movements observed by the examiner during measurement (5,8). Subjective assessments are also commonly employed to diagnose and quantify deviation problems. Certain subjective methods employ a Maddox Rod (MR), which comprises high-powered cylindrical lenses. MR is used to subjectively assess vertical deviation when positioned horizontally and horizontal deviation when positioned vertically on a trial frame.[1] Previous research has identified inconsistencies in the reliability of various methods used to subjectively quantify heterophoria (3,6,8). Additionally, it has been observed that some subjective tests tend to measure greater deviations at both distance and near and are capable of detecting vertical deviations not identified by objective methodes (8).

Given the inconsistencies reported in previous studies, this research aims to provide a comparative analysis of heterophoria angles measured using three clinical methods; the APCT, Maddox Rod, and Maddox-Wing test (MWT). This comparison is crucial for improving the reliability of deviation measurements and consequently patient outcomes.

Methods

This cross-sectional study was in accordance with the principles of the Helsinki Declaration and was approved by the Ethics Committee of Zahedan University of Medical Sciences. All patients provided their written informed consent to participate in this study.

In this study, 113 students of Zahedan University of Medical Sciences (59 male and 54 female) were selected using convenience sampling. This study was conducted between October 2020 and September 2021 at the Optometry Clinic of Zahedan University of Medical Sciences. Sample size was determined using G power 3.1.9.4, with an effect size of 0.45 derived from the mean and standard deviation of phoria values reported in Azuamah Y's study,[9] alpha of 0.05 and power of 0.95.

A questionnaire was used to screen the participant's general health, followed by complete ocular examinations. Inclusion criteria included age 18 to 40 years, visual acuity of 10/10 or better, normal binocular vision, and normal ocular health. Any systemic and/or ocular diseases such as opacity in the ocular media, glaucoma, obvious ocular abnormalities, eye trauma history, eye surgery and manifest deviation were considered as exclusion criteria.

Refractive errors were also determined using Auto Refractometer (AR 8800, Topcon, Japan). Binocular vision was evaluated using the Titmus stereopsis test, near point of accommodation (NPA), near point of convergence (NPC), accommodation facility test, vergence facility, positive fusional reserve and negative fusional reserve tests. The amount of deviation was measured objectively using the alternate prism cover test at the far (6 meters) and near (40 centimeters) distances using an accommodative target.

The unilateral cover test was performed by covering one eye and watching the behavior of the uncovered eye. If the uncovered eye shifted to fixate on the target, this indicated a heterotropia. If no movement was observed, the examiner then covered the other eye and repeated the observation. After confirming that the uncovered eye showed no movement when either eye was occluded, a cover–uncover test was performed to check for a heterophoria. This test resembles the unilateral cover test, but in this case the examiner looked for movements of the covered eye once the occluder was removed. When a heterophoria existed, the occluded eye drifted to its phoric position during occlusion and then maked a corrective movement in the opposite direction upon uncovering to regain fixation. The alternate cover test was used to reveal the full extent of any ocular deviation, whether due to heterophoria or heterotropia. In this method, the occluder was rapidly switched between the eyes every one to three seconds, preventing any opportunity for binocular fixation. The angle of deviation was then measured using a prism bar. For distance testing at 6 meters, the fixation target was a letter approximately equal to the patient's visual acuity on the visual acuity chart. For near testing at 40 cm, the fixation target was a 6/12 letter on a reduced Snellen chart.

Maddox's cylinder, also known as a tangent scale, was used to subjectively estimate deviation at far distances. A red horizontal-axis Maddox rod was placed before the patient's right eye while they focused on a light positioned 6 cm away. Participants were asked to identify the exact position of the red Maddox streak relative to the light source. A horizontal prism was then applied to the left eye using the Risley prism attached to the trial frame until the patient reported that the red streak aligned with the light image. Subsequently, the degree of deviation was subjectively assessed at close range using the Maddox-Wing technique.

The Maddox wing test was administered at near, with the instrument positioned in a reading posture—tilted downward by about 15 degrees—and held approximately 33 cm from the patient. Participants were asked to hold the device and report the numbers indicated by the red and white arrows on their respective measurement scales. On the X-axis, the white arrow reflects horizontal misalignment: odd values correspond to eso deviations, while even values correspond to exo deviations. When no deviation is present, both arrows align at zero, signifying orthophoria. The patient's responses were recorded.

Statistical analysis

Statistical analyses were analyzed using SPSS version 27 (SPSS Inc., Chicago, IL). The Kolmogorov–Smirnov test was applied first to evaluate whether the data followed a normal distribution. Descriptive results were presented as mean ± standard deviations and 95% confidence intervals. The intra-class correlation coefficient (ICC) was used to determine the agreement between the subjective and objective methods for measuring deviation angles, calculated. ICC values below 0.75 were interpreted as indicating poor agreement, values between 0.75 and 0.90 as moderate agreement, and values above 0.90 as strong agreement. The 95% limits of agreements (LoA) were also employed to further assess concordance between the methods. The 95% LoAs were computed as the mean difference ± 1.96 standard deviations. A clinical acceptance threshold for agreement was set at an LoA range within ±2.5 Δ (total range = 5 PD). Bland–Altman plots, along with their 95% confidence intervals, were created using Prism Graph software to visually demonstrate the agreement. P-value of less than 0.05 was considered to indicate statistical significance.

Results

This study was conducted on 113 students of Zahedan University of Medical Sciences (59 male and 54 female).

Three students were excluded due to the presence of systemic and/or eye diseases, and ultimately the results of 110 students (57 males) were analyzed.

The age of the participants was 21.90 ± 1.94 years (ranging from 18 to 30 years). The mean and standard deviation of the equivalent spherical refractive error were -1.33 ± 1.81 in the right eye and -1.31 ± 1.86 in the left eye. The paired t-test did not show a significant difference in equivalent spherical refractive error between the two eyes (P = 0.785). Also, there was no significant difference in the visual acuity between the right eye (decimal ± SD; 0.99±0.04) and the left eye (0.99±0.01, P=0.435).

''Table 1 and 2'' show the mean ± standard deviation of binocular vision tests and fusional reserve in all participants.

Table 1. The mean and standard deviation of binocular vision tests

	Titmus (sec/arc)	NPC (mm)	NPA (mm)	BVF(N) (cycle/min)	AF (cycle/min)
Mean± standard deviation (range)	50.09±23.90 (40-100)	7.75±4.27 (3-40)	9.35±2.47 (5-20)	10.30±4.86 (0-20)	8.58±5.93 (0-22)

Sec/arc: second of arc, NPC: near point of convergence, mm: millimeter, NPA: near point of accommodation, BVF: binocular vergence facility, AF: accommodation facility, cycle/min: cycle per minute, N: near

The mean and standard deviation of far and near deviation angles using the objective method were 1.22±3.10 and 4.22±4.62, respectively. Subjective far and near deviation angles were 0.45±2.17 and 3.39±4.14, respectively. Bland-Altman diagrams, ''Figure 1'' were used to check the agreement between subjective and objective methods. The 95% limits of agreement (LoA) between the subjective and objective techniques were wide and clinically unacceptable, ranging from –3.07 to 2.25 PD at far and –7.17 to 5.50 PD at near, with intervals exceeding 5 PD indicating that the two methods cannot be used interchangeably in clinical practice. Although the techniques showed good statistical agreement (far: ICC = 0.849, 95% CI: 0.77–0.89; near: ICC = 0.836, 95% CI: 0.75–0.88) and the ICC values were statistically significant (P < 0.001), these correlations do not compensate for the poor clinical agreement demonstrated by the LoA.

Table2. Mean and standard deviation of far and near fusion reserves

	FR (F)			FR (N)		
	Blur	Break	Recovery	Blur	Break	Recovery
Base in prism	0.07±0.76	7.37±2.76	5.16±2.54	10.31±4.65	15.70±5.54	12.20±14.39
Base out prism	9.98±5.40	16.00±7.84	12.06±6.67	14.72±6.42	21.42±9.76	16.28±7.68

FR: fusional reserves, F: far, N: near

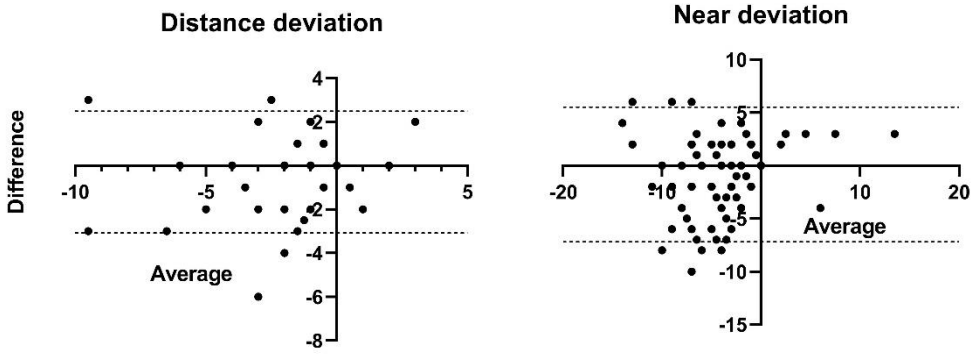

Figure 1: Bland-Altman plot of deviation angles obtained by subjective and objective methods. (The horizontal axis shows the mean values obtained for each subject, and the vertical axis shows the differences between the two values obtained for each subject)

Discussion

Heterophoria is a binocular misalignment that occurs during monocular viewing or when binocular vision is disrupted. Abnormal heterophoria can result in fatigue, headaches, and double vision, making its evaluation necessary in clinical examination.[2,4,10] There are both subjective and objective methods for assessing heterophoria.[8]

This study measured the angle of deviation both objectively and subjectively, revealing a poor agreement between objective and subjective methods. However, Bitner et al[8] measured strabismus in near and distance objectively with alternate prism cover test and subjectively with red glasses test methods and reported no statistically significant difference between the two methods. One possible reason for the difference between the results of Bitner's study and the current study can be in the type of deviation. They measured the angle of deviation in people with strabismus, which is less affected by the accommodation factors, unlike heterophoria.

In our study, the range of the upper and lower the 95% of LoA between subjective and objective methods was 5.32 PD for far distances and 12.67 PD for near distances. The two measurement methods showed less difference for far distance, but the near heterophoria values may have been infected by factors such as refractive errors, vergence and accommodation anomalies. These factors have a greater impact when measuring using the Maddox wing.[11] Dweyer et.al,[11] measured near heterophoria using objective and subjective (Maddox wing) methods and reported that the Maddox wing results were underestimated, similar to the findings in our study. This is likely due to the peripheral cues to fusion provided by the lower corners of the instrument.[11] When comparing the cover test and Maddox techniques, it is important to note that the intensity of the adaptive stimulus differs. The Maddox test uses a matching stimulus from a light source that does not adequately stimulate fusion,[12] whereas the cover test uses an accommodative stimulus under sufficient lighting condition.[13] Additionally, the two methods use different dissociation mechanisms: the alternate cover test produces complete motor dissociation, whereas the Maddox Rod test induces only sensory dissociation and does not achieve full dissociation.

Calvine et al[14] assessed the amount of deviation by the alternate prism cover test and von Graefe method, indicating a difference of 11 PD between the two methods at 40 cm, with the cover test displaying less heterophoria than the Von Graefe method. This finding contrasts with the result of our study as in the alternate cover test, the fusion is disrupted completely, allowing for the measurement of the total deviation angle. In another study similar to our results, a significant difference was found between the amount of deviation measured by the cover test and the Maddox cylinder. They emphasized that the coverage test is the gold standard for measuring deviation.[15]

One of the limitations of this study was the measurement of heterophoria alone, so it is recommended including strabismic patients in future research.

Conclusion

This study showed a significant clinically difference between subjective and objective deviation measurement methods. Therefore, when measuring deviation, it is recommended to perform both subjective and objective tests. The wide range of 95% LoA between subjective and objective methods can potentially cause problems in clinical management, especially for prisms prescribed for patients treated optically.

Acknowledgement: The authors gratefully acknowledge the Vice Chancellor of Research and Technology at Zahedan University of Medical Sciences for providing valuable support and facilities.

Ethical issues: The authors declare that this study was in accordance with the principles of Helsinki

Declaration and was approved by the Ethics Committee of Zahedan University of Medical Sciences (Ethics Code: IR.ZAUMS.REC.1396.8). Written informed consent was obtained from all participates to participate in the study.

Competing interests: The authors declare that they have no conflict of interests.

Author Contribution:
Conceptualization: F.Sh, M.M
Methodology: F.Sh, M.M
Software: N.N, M.M
Validation: H.Sh, M.M
Formal analysis: M.M
Investigation: S.F, M.M
Resources: N.N, H.Sh
Data curation: F.Sh
Writing-original draft: S.F, M.M
Writing- review and editing: S.F, M.M
Visualization: S.F, M.M
Supervision: F.Sh, M.M
Project administratiom: N.N

Funding: The study has not any the source of funding for the research and/or publication.

Reference

1-Akbari MR, Alghurab A, Khorrami-Nejad M, Azizi E, Masoomian B. Sensory exotropia versus sensory esotropia: A comparative clinical features study. J Optom. 2024;17(3):100516. **doi:** 10.1016/j.optom.2024.100516
2-Paula VC, Tsunoda TD, Pires PF, Andraus RA, Alves OB, de Oliveira GA, et al. Intra-and inter-rater reliability of ocular phoria tests: Reliability of eye strength tests. Man Ther, Posturology Rehabil J. 2024;14;22:1-7. **doi:** 10.17784/mtprehabjournal.2024.22.1374
3-Anderson HA, Manny RE, Cotter SA, Mitchell GL, Irani JA. Effect of examiner experience and technique on the alternate cover test. Optom Vis Sci. 2010;87(3):168-75. **doi:** 10.1097/opx.0b013e3181d1d954
4-Nguyen E, Inger H, Jordan C, Rogers D. Ocular Causes for Headache. Semin Pediatr Neurol. 2021;40:100925. **doi:** 10.1016/j.spen.2021.100925
5-Yeh, PH., Liu, CH., Sun, MH. *et al.* To measure the amount of ocular deviation in strabismus patients with an eye-tracking virtual reality headset. *BMC Ophthalmol* 21, 246 (2021). **doi:**10.1186/s12886-021-02016-z
6-Johns HA, Manny RE, Fern K, Hu YS. The intraexaminer and interexaminer repeatability of the alternate cover test using different prism neutralization endpoints. Optom Vis Sci. 2004 Dec;81(12):939-46. Erratum in: Optom Vis Sci. 2005 Feb;82(2):159. **PMID:** 15592119.
7-Hrynchak PK, Herriot C, Irving EL. Comparison of alternate cover test reliability at near in non-strabismus between experienced and novice examiners. Ophthalmic Physiol Opt. 2010;30(3):304-9. **doi:**10.1111/j.1475-1313.2010.00723.x
8-Bitner DP, Adesina O-OO, Ding K, Farris BK, Michael Siatkowski R. Comparison of objective and subjective techniques of strabismus measurement in adults with normal retinal correspondence. Journal of Pediatric Ophthalmology & Strabismus. 2017;54(4):216-20. **doi:**10.3928/01913913-20170322-02
9-Azuamah Y, Ukonu S, Esenwah E, Ikoro N, Megwas A. A Comparative Study of Near Lateral Phoria of Young Adults Using the Von Graefe Technique and Maddox Wing. International Journal of Research and Review. 2022;9(5):367.٧٢- **doi:**10.52403/ijrr.20220543
10- Gantz L, Stiebel-Kalish H. Convergence insufficiency: Review of clinical diagnostic signs. J Optom. 2022;15(4):256-70. **doi:**10.1016/j.optom.2021.11.002
11- Dwyer P. A Comparison of Near Phoria Measurements by the Maddox Wing and the Keystone Telebinocular Stereoscope. The Australian Journal of Optometry. 1981;64(1):28-9. **doi:**10.1111/j.1475-1313.2005.00303.x
12- Garber N. Evaluating diplopia with the Maddox rod, Risley's prism, and red glass. J Ophthalmic Nurs Technol. 1995 Sep-Oct;14(5):224-8. **PMID:** 7473795.
13- Clark TE, Reynolds W, Coffey B. The effects of varying examiner position on alternating cover test results. Optometry. 2003 Apr;74(4):233-9. **PMID:** 12703688.
14- Calvin H, Rupnow P, Grosvenor T. How good is the estimated cover test at predicting the von Graefe phoria measurement? Optom Vis Sci. 1996;73(11):701-6. DOI: **doi:**10.1097/00006324-199611000-00005.
15- Momeni-Moghaddam H, Asgarizadeh F, Ehsani M, Ansari H, Haghighi B. The comparison of measured heterophoria with objective and subjective methods with attention to motor eye dominancy. Zahedan J Res Med Sci. 2011; 13(7): 28-33. **Link**