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Research Paper

Diurnal Variations of Exophoria in Subjects With Normal Vision

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Conflict of interest

The authors declare no conflict of interest.

ABSTRACT

Background and Objectives: We aimed to investigate the variation of heterophoria during a day in students with a normal visual system.

Methods: This cross-sectional observational study was conducted on 15 students aged 19 to 22 years with 20/20 visual acuity and normal binocular vision. Heterophoria was measured with a prism bar and alternate cover test at near and far distances (40 cm and 6 m). The measurement was performed from 8 to 10 PM in one day with 2 hours intervals.

Results: The Mean±SD age of students was 21.6±0.87 years (63% women and 37% men). The mean deviation in far and near order was 1.93 and 3.75 prism diopter, respectively. The Greenhouse-Geisser test concluded no significant difference between the measurements of distant heterophoria during the day (F=1.362, df=3.066, P=0.267). However, the near-distance results were significant (F=15.17, df=7, P<0.05). The paired t-test results showed that the highest amount of exophoria was observed near 4 PM, which was significantly different from the initial value, and the difference increases at the end of the day so that the mean difference of the initial near exophoria value from 4 to 10 PM reached from -1.254 to -3.508.

Conclusion: Changes in refractive error or high order aberration increase near work and decrease the illumination during a day can induce force on accommodation and vergence. So, at the end of the day, the exophoria increases. Thus, it is preferable to perform eye examinations at the end of the day to make more accurate decisions about the diagnosis and treatment of patients.

Keywords: Diurnal variations of exophoria, Heterophoria, Accommodation

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What is "already known" in this topic:

Exophoria is the most common type of heterophoria in young people. It may cause some symptoms in daily visual tasks, but usually it seems completely normal in conventional visual examination.

What this article adds:

Exophoria is an important clinical issue that is not the same in different times of day. It seems it can be significantly changed in different time of day. However, it is very important to consider and report the time of examination and time of most visual symptoms.

Introduction

Heterophoria is a deviation from the orthophoria position, defined as the intersection of visual axes relative to the desired target without a fusional response [1]. Measuring near and far heterophoria is a standard part of any optometric examination. Distance heterophoria is a function of tonic vergence. Near heterophoria depends on the tonic, accommodative, and proximal convergence as well as vergence adaptation [2]. Heterophoria is routinely measured by prism bar, alternating covert-test, Maddox Rod, using Bernell muscle imbalance card, Turner card, or Van Graaf methods [3-5]. Heterophoria causes asthenopia or eye strain in many people. Exophoria is the most common cause of eye discomfort, especially in close work. There is a feeling of heaviness of the eyelids, tension, stretching of the eye muscles, fatigue from close work, and headache [6]. The clinical examination of binocular vision evaluates the degree of binocular vision stress that can lead to symptoms or suppression. Symptoms related to binocular vision stress are reported more at the end of a working day than in the morning after a night's rest. Many common causes of asthenopia during the study are related to the condition of binocular vision along with the position of heterophoria of the eyes [7, 8]. Changes in heterophoria because of low light conditions, for example, in the evening and night, may cause asthenopia. Low-level light and heterophoria position are associated with eye strain [9, 10]. Because the dim light reduces contrast, reading in dim light causes eye strain [11].

A recent study of day length changes in tonic accommodation shows that the amount of accommodation decreases from the morning to the beginning of the evening and approaches the morning value near the evening, and subsequently, there is an increase in the late evening [12]. Also, the effect of lighting on phoria, tonic accommodation during the day, and the use of different tools in measuring phoria have been investigated. However, no study still documents the changes in exophoria during the day. The changes of heterophoria affect the range of fusional verges and then accommodation system because of special interactions between the vergence and this system [13]. Therefore, these changes affect refractive error and the level of binocular vision can change the results of examinations [14]. So, the results of this study can help know the changes of heterophoria, determine the best time of optometric examinations for the patient, and consequently have a better and more accurate prescription.

Materials and Methods

This cross-sectional observational study was conducted on 15 students of the Faculty of Rehabilitation of Iran University of Medical Sciences with an age range of 19 to 22 years. The sampling method was simple and non-random. This study followed the principles of the Helsinki Declaration, and informed consent was obtained from all subjects. The inclusion criteria were the absence of tropia, symptoms such as headache and eye pain during near working, pathologic ocular diseases, and the presence of normal fusion reserves mentioned in a reference [15]. Also, uncorrected visual acuity was 20/20. Refractive states less than 0.5 diopters in all types of refractive errors, including myopia, hypermetropia, and astigmatism, were determined as emmetropia. Before the examinations, the amount of accommodation and convergence of the subjects were measured by the pencil push-up method, and if the values were normal, the subjects were included in the study. The normal range of convergence was obtained with a breakpoint of at least 6 cm or less and a recovery point of up to 9 cm. The mean amplitude of accommodation is considered at least 10 diopters or more. The refraction was done with the phoropter device (Hovitz HDR 7000) and retinoscopy method (Heine Beta 200), and visual acuity was measured in decimal form and with Snellen's vision chart at a distance of 6 m.

In the same clinical conditions, the heterophoria of people was done at 8 different times with an interval of 2 hours during the day. The measurement started at 8 AM and continued until 10 PM. The demand of heterophoria was measured by the alternating cover test and prism bar at two distances of 40 cm and 6 m while the person looked at the appropriate fusion target (line of 20/30 Snellen acuity chart). Next, the data were entered into SPSS version 24 software (IBM Corp, Armonk, NY, USA). The normality of the data was checked with the Shapiro-Wilk test. The paired t-test was used to compare heterophoria between each pair measurement, and the ANOVA test was used to check the heterophoria differences along the day. P<0.05 values were considered as a criterion for significant differences.

Results

The Mean±SD age of students was 21.6±0.87 years (63% women and 37% men). The most common heterophoria near and far are exophoria and orthophoria, respectively. Their mean deviation in far and near order was 1.93±0.36 and 3.75±0.48 prism diopter. The results of ANOVA, which was carried out to investigate the changes of heterophoria during the day, showed a lack of sphericity in the data (Mauchly's test of sphericity), and the results of the Greenhouse-Geisser test were as follows: F=1.362, df=3.066, P=0.267. Thus, there is no significant difference between the measurements of distant heterophoria during the day. The paired t-test results also confirmed this, and there was no difference between the initially measured deviation value and other measurements in the following hours (P>0.05) (Table 1). Only at 4 and 6 PM the highest amount of exophoria was observed, but this value was similar to the amount of heterophoria at 8 AM (P<0.05).

Regarding the amount of near heterophoria, the results of ANOVA showed the presence of sphericity in the data (P>0.05). According to the sphericity assumed test, there is a significant difference between near heterophoria measurements in the early hours of the morning and other hours of the day (F=15.17, df=7, P<0.05). According to the results of the paired t-test, the value of the difference of the near phoria at 4 PM is significantly different from the initial value, and the difference increases at the end of the day. Actually, at the end of the day, the amount of exophoria and the difference from the initial amount increases (Table 1). The average difference between the

Table 1. Results of difference between heterophoria from 8 AM to 10 PM (paired t-test)

Difference Time	Mean±SD	P
Far1 - Far2	-0.067±0.458	0.582
Far1 - Far3	0.067±0.799	0.751
Far1 - Far4	-0.133±0.834	0.546
Far1 - Far5	-0.533±0.915	0.041
Far1 - Far6	-0.333±1.234	0.313
Far1 - Far7	-0.267±1.163	0.389
Far1 - Far8	-0.200±1.207	0.531
Near1 - Near2	-0.200±1.146	0.510
Near1 - Near3	0.067±1.335	0.849
Near1 - Near4	-0.533±1.302	0.135
Near1 - Near5	-1.200±1.207	0.002*
Near1 - Near6	-1.667±1.234	0.000*
Near1 - Near7	-1.667±0.976	0.000*
Near1 - Near8	-2.600±1.639	0.000*

*P<0.05

initial near exophoria value between 4 PM and 10 PM has reached from -1.254 to -3.508.

Discussion

This study investigated the changes in heterophoria during the day. The results show that the amount of heterophoria at a far distance was almost constant throughout the day, but the amount of near exophoria increased from 6.27 prisms at 8 AM to 8.87 prisms at 10 AM. From 4 PM, exophoria gradually increased until the day's final hours. Although an increase in exotropia was seen before 4 PM, it was still not significant. These results are similar to Palomo Álvarez et al., in which the mean exophoria is 0.3 to 0.6, and this value does not change significantly during the person's life and is stable [16]. However, the type of heterophoria often changes from exophoria in the near to orthophoria at a distance.

Nevertheless, due to the significant changes in near exophoria during the day, changes in the visual system or the people's lifestyle can affect heterophoria. As observed in previous articles, during the day, the amount of refractive error of the eyes tends to myopia, which is caused by changes in the curvature of the cornea. Furthermore, this issue can cause less accommodation in the near and then increase the amount of exophoria [17]. Another hypothesis can be accommodation changes during the day and their effect on near heterophoria. Studies have shown that during the day, high-order ocular aberrations, especially coma and fourth-order spherical or Z24 (vertical secondary astigmatism), increase accommodation response dysfunction [18, 19]. Due to the interactions between the vergence and accommodation system, increasing these errors can disturb the vergence responses indirectly and increase the near exotropia. According to Park et al., the accommodation decreases in the afternoon compared to the morning, and the lowest amount has been seen from 3 PM to 4 PM, which is the same current study that the difference near exophoria between primary and 4 hours has become significant [20].

By reducing the accommodation range during the day, the amount of convergence of the eyes decreases at near, and more exophoria is observed [20]. Low brightness is another hypothesis. Research shows that this decrease in brightness can change the value of accommodation demand from 6.34 diopters to 4.35 diopters. The main cause of this is not only the increase in depth of focus caused by pupil meiosis, but the low brightness also causes a decrease in the retina's brightness, which affects the neural pathway of accommodation [21]. It can be said that by reducing accommodation stimuli at close distances and at the end of the day, the amount of convergence is also reduced and creates more exophoria. Although in this research, the measurements of heterophoria were in the same light and clinical conditions, the activities and light conditions that the person did and were in other times can affect measurements.

From another point of view, increased close work during the day, accommodation fatigue and changes in the vergence system cause a higher amount of exophoria at the near distance. Lee et al. investigated the relationship between visual discomfort and visual system responses in students [22]. They showed that long-term near work could affect increasing the accommodative lag and near exophoria. So the near point of convergence decreases after doing near work. The amount of exophoria after 30 minutes near work reaches from 4.70 to 5.2 prism diopters, which was statistically significant. This is caused by insufficient light in the work environment and the pressures on the visual system. Studies indicate changes in the vergence system and accommodation after close work during the day [23-26]. So even the use of small screens such as mobile phones have a greater effect on increasing exophoria, near point of convergence, and accommodative lag [27]. This study was conducted on students that read books and used electronic devices more. Also, with the advancement of technology and the increasing use of mobile phones, more stress on the visual system is induced, which causes fatigue and reduces the mean accommodation and its responses, as well as an increase in exophoria at near. In the early morning and after, the visual system is at a level of refreshment, and the possibility of visual dysfunction in these people is low. However, the visual system is under stress during the day, and this stress increases in the final hours of the day because of the decreasing brightness of the surrounding environment, and eventually, exophoria increases at a near distance. Therefore, it is preferable to perform eye examinations at the end of the day to make accurate decisions regarding the diagnosis and treatment of patients.

The number of samples and the lack of accommodation and refractive error measurement, which can play a role as interfering factors, were the limitation of this study. If these variables were investigated, we could find more specific reasons for increasing near exophoria.

Conclusion

According to the results of this article, which show an increase in near exophoria during the day, it is preferable to perform eye examinations at the end of the day so that we can make more accurate decisions regarding the diagnosis and treatment of patients.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Ethics Committee of the University of Iran University of Medical Sciences (Code: IR IUMS.REC.1498902 – 118/4/95).

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Authors' contributions

Conceptualization, Supervision: Leyla Mirzaee Saba, Ebrahim Jafarzadehpur, and Neda Aleshi; Investigation, Writing – review & editing: All authors. Writing – original draft: Farzaneh Dehghanian Nasrabad, Ebrahim Jafarzadehpur, and Neda Aleshi, Funding acquisition, Resources: Leyla Mirzaee Saba, Ebrahim Jafarzadehpur, and Farzaneh Dehghanian Nasrabad.

Conflict of interest

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References

[1] Lantz MW, Tea DM. Evaluation of heterophoria after sustained near work under varying illuminances [PhD dissertation]. Grand Rapids: Ferris State University; 2008. [Link]

[2] Han SJ, Guo Y, Granger-Donetti B, Vicci VR, Alvarez TL. Quantification of heterophoria and phoria adaptation using an automated objective system compared to clinical methods. Ophthalmic Physiol Opt. 2010; 30(1):95-107. [DOI:10.1111/j.1475-1313.2009.00681.x] [PMID]

[3] Lam AK, Lam A, Charm J, Wong Km. Comparison of near heterophoria tests under varying conditions on an adult sample. Ophthalmic Physiol Opt. 2005; 25(2):162-7. [DOI:10.1111/j.1475-1313.2005.00270.x] [PMID]

[4] Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet. 1986; 327(8476):307-10. [DOI:10.1016/S0140-6736(86)90837-8] [PMID]

[5] 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:10.1097/00006324-199611000-00005] [PMID]

[6] MacDonald AE. Exophoria and esophoria. Can Med Assoc J. 1931; 25(3):306-8. [PMID] [PMCID]

[7] Sheedy JE. Reading performance and visual comfort on a high-resolution large monitor compared to a VGA monitor. J Electron Imaging. 1992; 1(4):405-10. [DOI:10.1117/12.61063]

[8] Sheedy JE, McCarthy M. Reading performance and visual comfort with scale to grey compared with black-and-white scanned print. Displays. 1994; 15(1):27-30. [DOI:10.1016/0141-9382(94)90040-X]

[9] Sheedy JE, Saladin JJ. Phoria, vergence, and fixation disparity in oculomotor problems. Am J Optom Physiol Opt. 1977; 54(7):474-8. [DOI:10.1097/00006324-197707000-00008] [PMID]

[10] Sheedy JE, Saladin JJ. Association of symptoms with measures of oculomotor deficiencies. Am J Optom Physiol Opt. 1978; 55(10):670-6. [DOI:10.1097/00006324-197810000-00002] [PMID]

[11] Sheedy JE, Hayes J, Engle, Jon. Is all asthenopia the same? Optom Vis Sci. 2003; 80(11):732-9. [DOI:10.1097/00006324-200311000-00008] [PMID]

[12] Amerson TL, Mershon DH. Time-of-day variations in oculomotor function: 1. Tonic accommodation and tonic vergence. Optom Vis Sci. 1988; 8(4):415-22. [DOI:10.1111/j.1475-1313.1988.tb01178.x] [PMID]

[13] Costa Lança C, Rowe FJ. Variability of fusion vergence measurements in heterophoria. Strabismus. 2016; 24(2):63-9. [DOI:10.3109/09273972.2016.1159234] [PMID]

[14] Evans BJ. Pickwell's binocular vision anomalies. Amsterdam: Elsevier Health Sciences; 2021. [Link]

[15] Block SS. Clinical procedures in primary eye care. Optom Vis Sci. 2021; 98(2):175. [DOI:10.1097/OPX.0000000000001646]

[16] Palomo Alvarez C, Puell MC, Sánchez-Ramos C, Villena C. Normal values of distance heterophoria and fusional vergence ranges and effects of age. Graefes Arch Clin Exp Ophthalmol. 2006; 244(7):821-4. [DOI:10.1007/s00417-005-0166-5] [PMID]

[17] Chakraborty R, Read SA, Collins MJ. Diurnal variations in ocular aberrations of human eyes. Curr Eye Res. 2014; 39(3):271-81. [DOI:10.3109/02713683.2013.841257] [PMID]

[18] Srivannaboon S, Reinstein DZ, Archer TJ. Diurnal variation of higher order aberrations in human eyes. J Refract Surg. 2007; 23(5):442-6. [DOI:10.3928/1081-597X-20070501-04] [PMID]

[19] Del Águila-Carrasco AJ, Kruger PB, Lara F, López-Gil N. Aberrations and accommodation. Clin Exp Optom. 2020; 103(1):95-103. [DOI:10.1111/cxo.12938] [PMID] [PMCID]

[20] Park SM, Moon BY, Kim SY, Yu DS. Diurnal variations of amplitude of accommodation in different age groups. Plos One. 2019; 14(11):e0225754. [DOI:10.1371/journal.pone.0225754] [PMID] [PMCID]

[21] Lara F, Del Águila-Carrasco AJ, Marín-Franch I, Riquelme-Nicolás R, López-Gil N. The effect of retinal illuminance on the subjective amplitude of accommodation. Optom Vis Sci. 2020; 97(8):641-7. [DOI:10.1097/OPX.0000000000001544] [PMID]

[22] Lee JW, Cho HG, Moon BY, Kim SY, Yu DS. Effects of prolonged continuous computer gaming on physical and ocular symptoms and binocular vision functions in young healthy individuals. PeerJ. 2019; 7:e7050. [DOI:10.7717/peerj.7050] [PMID] [PMCID]

[23] Leung TW, Chan CT, Lam CH, Tong YK, Kee CS. Changes in corneal astigmatism and near heterophoria after smartphone use while walking and sitting. Plos One. 2020; 15(12):e0243072. [DOI:10.1371/journal.pone.0243072] [PMID] [PMCID]

[24] Morse SE, Jiang BC. Oculomotor function after virtual reality use differentiates symptomatic from asymptomatic individuals. Optom Vis Sci. 1999; 76(9):637-42. [DOI:10.1097/00006324-199909000-00021] [PMID]

[25] Choy CK, Siu AW, Lam FY, Tse JT, Lau SY. Addition lens alleviates reading-induced ocular stress. Clin Exp Optom. 2000; 83(1):12-5. [DOI:10.1111/j.1444-0938.2000.tb05070.x] [PMID]

[26] Pickwell D, Jenkins T, Yekta A. The effect on fixation disparity and associated heterophoria of reading at an abnormally close distance. Ophthalmic Physiol Opt. 1987; 7(4):345-7. [DOI:10.1111/j.1475-1313.1987.tb00758.x] [PMID]

[27] Kang JW, Chun YS, Moon NJ. A comparison of accommodation and ocular discomfort change according to display size of smart devices. BMC Ophthalmol. 2021; 21(1):1-9. [DOI:10.1186/s12886-020-01789-z] [PMID] [PMCID]

تغییرات روزانه اگزوفوریا در افراد با بینایی طبیعی

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چکیده

مقدمه این مطالعه با هدف بررسی تغییرات اگزوفوریا در طول روز بر روی دانشجویان با سیستم بینایی نرمال انجام شده است.

مواد و روش‌ها در این مطالعه مشاهده‌ای مقطعی ۱۵ دانشجو با رنج سنی ۱۹ تا ۲۲ سال مورد بررسی قرار گرفتند. افراد وارد شده به این مطالعه دارای حدت بینایی ۲۰/۲۰ و وضعیت دید دوچشمی نرمال بودند. دامنه هتروفوریا به کمک پریزم و روش آلترنیت کار تست در دو فاصله دور و نزدیک اندازه گیری شد. به منظور بررسی تغییرات هتروفوریا در طول روز، جلسات اندازه‌گیری انحراف از ساعت ۸ صبح تا ۱۰ شب با فاصله زمانی ۲ ساعت انجام شد.

یافته‌ها متوسط سن افراد برابر با ۰/۸۷، ۲۱/۶ سال بوده است (%۶۳ زن و %۳۷ مرد). متوسط انحراف دور و نزدیک به ترتیب برابر با ۱٫۹۳ و ۳٫۷۵ دیوپتر اگزوفوریا بوده است. نتایج آزمون گیسر نشان داد تغییرات هتروفوریا در فاصله دور در طول روز معنادار نبوده است (f= ۱٫۳۶۲, df= ۳٫۰۶۶, P= ۰٫۲۶۷). این در حالی است که این تغییرات در فاصله نزدیک از لحاظ آماری قابل ملاحظه بود (f=۱۵٫۱۷ , P<۰٫۰۵,df=۷). نتایج آزمون T زوجی به منظور مقایسه دو به دو اندازه‌گیری‌های انجام شده نشان می‌دهد که اگزوفوریا نزدیک در ساعت ۴ عصر به نسبت مقدار آن در ساعات اولیه صبح تفاوت قابل ملاحظه‌ای داشته است و هرچه به ساعات پایانی روز نزدیک می‌شویم این تفاوت بیشتر می‌شود. به طوری که تفاوت هتروفوریا نزدیک در ساعت ۴ عصر و ۱۰ شب به نسبت مقدارآن در ۸ صبح به ترتیب برابر ۱٫۲۵۴- و ۳٫۵۰۸- پریزم دیوپتر بوده است.

نتیجه گیری تغییرات عیب انکساری و ابیراهی‌ها، افزایش کار نزدیک در طول روز و کاهش روشنایی محیط میتواند بر روی تطابق و سیستم ورجنسی اثر بگذارد. تغییرات ایجاد شده در سیستم تطابقی و ورجنسی منجر به مقدار اگزوفوریا در ساعات پایانی روز خواهد شد. لذا پیشنهاد می‌شود به منظور داشتن نتایج دقیقتر، معاینات چشمی در ساعات پایانی روز انجام شوند.

کلیدواژه‌ها:
تغییرات روزانه
اگزوفوریا، هتروفوریا،
تطابق

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