THE EFFECT OF HETEROPHORIA ON THE SIZE OF DISTANCE AND NEAR FUSION VERGENCE

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SUMMARY

Aims: To demonstrate changes in distance and near fusional vergence measured with prism bars, while compensating for present heterophoria using current ametropia correction. In addition, to determine the differences in values of the AC/A ratio determined by the heterophoric (calculation) and gradient methods.

Material and methods: The basic sample includes 19 subjects with a mean age of 21.5 ±3.0 years (min. 18, max. 27). We used the Von Graefe technique for examination of distance and near phoria, and prism bars for examination of fusion vergences measured in prism diopters. We divided the basic cohort into six research sets according to the size of distance and near heterophoria. This was a cohort of patients with distance (D OR) and near orthophoria (N OR), a cohort of patients with distance (D EX) and near exophoria (N EX) and a set of patients with distance (D ES) and near esophoria (N ES).

Results: In the case of both groups with exophoria (distance, near) we found a statistically significant result only for negative fusion vergence (NFV). There was a statistically significant increase in NFV in the sample with distance and near exophoria (D EX, $p = 0.01$ and B EX, $p = 0.02$, respectively). In our study, we also demonstrated a statistically significant difference ($p < 0.001$) in the values of the AC/A ratio measured by the gradient and heterophoric methods. The values determined by the gradient method are lower (3.0 ±1.1 pD/D versus 5.8 ±0.9 pD/D) than by the heterophoric method.

Conclusion: By comparing fusion vergence values in patients with exophoria and orthophoria, we demonstrated that in the presence of distance or near exophoria there is an increase in ipsilateral fusion vergence. In the case of an increase in ipsilateral fusion vergence, the finding was statistically significant both distance and near ($p = 0.01$ and $p = 0.02$, respectively). By contrast, we were unable to prove this fact in the group of patients with esophoria. In our study, we also demonstrated a statistically significant difference ($p < 0.001$) in the values of the AC/A ratio measured by the gradient and heterophoric methods. The values determined by the gradient method are lower (3.0 ±1.1 pD/D versus 5.8 ±0.9 pD/D) than by the heterophoric method.

Key words: Heterophoria, fusion vergence, AC/A, Von Graefe method, Howell card, prism

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INTRODUCTION

Heterophoria or latent squint is defined as a relative deviation of the eyes, which is manifested in dissociation of visual perception, meaning in a situation when maximum separation of the visual perception of the right and left eyes occurs [1]. This concerns for example the Von Graefe prism test, Schober anaglyph test or a cross test with polarized filters (Fig.1).

In several previous studies it was determined that dissociated heterophoria (hereinafter referred to as heterophoria) is linked with the size of fusional vergences, as well as with refractive errors [3–5]. It was also determined that heterophoria may be caused by an uncorrected refractive error, accommodation-vergence anomalies, anatomical factors and also increasing demands in close-up work [6,7]. Heterophoria, fusional vergences and refractive errors are important clinical attributes which we should take into consideration during examination. Heterophoria may be clinically asymptomatic. It will be decompensated or symptomatic at the moment when the compensatory mechanism (contralateral fusional vergence) is reduced [5,7]. Symptoms in decompensated heterophoria include headache, photophobia, eye pain, and may also be manifested as a refusal of close-up work. Compensated and decompensated heterophoria may culminate in suppression and strabismus [5,7,8]. For a correct evaluation of the size of heterophoria it is very important also to examine distance and near heterophoria separately, as well as the ratio between accommodative convergence and accommodation (AC/A), and also distance and near fusional vergence separately. Due to the size of the AC/A ratio, we divide disorders of simple binocular vision into “simple heterophorias” and “insufficiencies”, or more precisely vergence excesses [9]. The method of determining the correct AC/A ratio to be used in practice is the subject of professional discussion [10]. From a practical perspective, the simplest and fastest method appears to be the gradient method of measuring the AC/A ratio. This technique is used to determine the change in vergence of the near system upon change of the patient’s accommodation. Change of accommodation is usually triggered by a stimulus in the form of binocular application of spherical eyeglasses lenses of +1.0 D or -1.0 D. The use of diverging lenses generates a larger accommodative response, which should trigger a change in vergence. According to the size of the resulting change in vergence, we determine the ratio between accommodative convergence and accommodation. By contrast, the use of converging lenses causes a relaxation of accommodation, and convergence at the same time. In practice this technique may fail in exceptional cases, whereupon the patient is unable to change the size of accommodation after stimulation. In this case we recommend calculation of the accommodative convergence and accommodation ratio, namely AC/Ah, from knowledge of the size of distance heterophoria, near heterophoria (HTFD, HTFN) pupillary distance in centimeters (PD) and distance of the main working point in meters (usually 0.3 m) according to the formula presented below. This is known as the heterophoric or calculation method, which however does not take into account the proximal component of vergence.

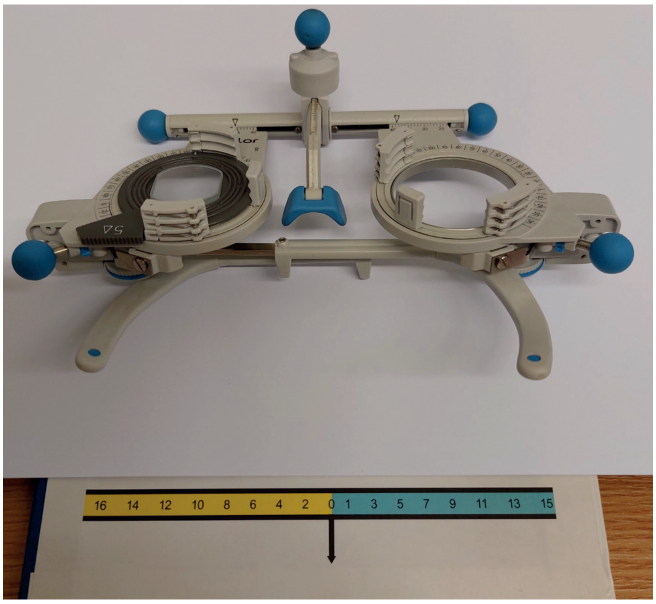

Figure 1. Von Graefe test with vertical prism and Howell card for testing horizontal near heterophoria

$$AC/A_h = PD[cm] \pm (0.3(HTF_D - HTF_N))$$

For example, a patient with pupillary distance of 7 cm, distance orthophoria and near exophoria of -10 pD will have an AC/A ratio calculated by this method equal to 4/1, which corresponds to a normal value. According to information from the domestic and foreign literature, a normal AC/A value is within the range from 3 to 5 pD per 1 D of accommodation [11,12]. It is not entirely clear from the literature as to whether the AC/A ratio is determined by heredity, and whether it is constant. An anomalous AC/A ratio is compensated for by fusion and fusional vergences. These decide whether any potential asthenopic complaints or diplopia will be manifested.

From a clinical perspective, heterophoria is a very common phenomenon, which appears overall in 70–80% of the population [5,7]. According to a study conducted by the authors Apke et al. [13], in children aged 5 to 19 years the prevalence of distance heterophoria is 23% and near heterophoria 53.6%. In a study by the authors Mathebula et al. [14], in the population of children aged 6 to 13 years the mean measured size of heterophoria was 2.5 ±2.3 pD of near exophoria. In another study conducted by the same author [15] in the population aged 20 to 36 years the mean measured size of near heterophoria was 2.1 ±6.2 pD of exophoria.

The aim of our study was to measure distance and near heterophoria in a population of young individuals, followed by fusional vergences at both distances, and to determine the AC/A ratio by the heterophoric (calculation) and gradient methods. We expected that the presence of heterophoria would mean a weakened component of both distance and near fusional vergence in accordance with Sheard’s criterion [11,12]. We were also interested in the resulting difference between the AC/A ratio stipulated by the heterophoric and by the gradient method.

MATERIAL AND METHODS

In our prospective study we had data from 19 probands with an average age of 21.5 ±3.0 years (min. 18, max. 27). They comprised 18 women and one man without any currently significant systemic or ocular pathology. We conducted an examination of horizontal distance and near heterophoria with the aid of a Von Graefe vertical dissociation prism test with accurate correction of the present refractive error. This was followed by measurement of distance and near fusion vergences with the aid of prism bars. In the measurement of fusion vergences it is possible to record the point of defocusing which occurs upon exhaustion of accommodation vergence. As part of the statistical processing of data, we decided to assess the values of the bifurcation point, which is easier to evaluate for the patients. We also calculated the AC/A ratio using the heterophoric method. The size of accommodative convergence per one diopter of accommodation is calculated as the difference of pupillary distance in centimeters and the value which ensues from the difference of the size of distance and near heterophoria in brackets multiplied by the near examination distance in meters (see formula 1). Using the gradient method, when determining near heterophoria we inserted +1 D or -1 D binocularly and measured the change in vergence to this examination distance. The size of the change in vergence therefore corresponds directly to the ratio of accommodative convergence per 1 D of accommodation.

We divided the basic cohort into six research groups according to the size of distance or near heterophoria. Specifically, this concerned a group of patients with distance orthophoria (D OR, n = 10) and near orthophoria (N OR, n = 9), a group of patients with distance exophoria (D EX, n = 3) and near exophoria (N EX, n = 5) and a group of patients with distance esophoria (D ES, n = 6) and near esophoria (N ES, n = 5).

The results of the examinations were recorded in an MS EXCEL table and subsequently statistically evaluated with the aid of the statistical program Statistika version 12 from the company STATSOFT and MedCalc. The statistical level of significance was selected at p = 0.05. In all cases we used a two-sample Student t-test, which serves for a comparison of the median value of the two groups upon a normal distribution of the examined data. The normality of the data was tested with the aid of a Shapiro-Wilk test and a Kolmogorov-Smirnov test.

RESULTS

The basic cohort contained a total of 19 subjects with a mean value of distance heterophoria (HTF D) of 0 ±3.2 pD, positive distance fusional vergence (PFV D) of 24.1 ±6.7 pD, and negative distance fusional vergence (NFV D) of 10.5 ±3.9 pD. We measured a mean value of near heterophoria (HTF N) of -1.1 ±5.0 pD, mean positive near fusional vergence (PFV N) of 28.6 ±8.3 pD and mean negative near fusional vergence (NFV N) of 15.5 ±7.6 pD. The mean value of the AC/A ratio determined by the heterophoric method (AC/Ah) was 5.8 ±0.9 pD/D and by the gradient method (AC/Ag) 3.0 ±1.1 pD/D. According to the Student t-test a statistically significant difference was found between these two variables (p < 0.001).

Table 1 presents the mean values of fusional vergences in all six observed groups. For easier orientation, the red box illustrates the reduction of the value in comparison with the control group, and the green box illustrates the increase of the measured value. In both groups with exophoria (distance, near) there was a reduction of the mean value of positive fusional vergence in comparison with the mean value of PFV in orthophoria. However, the difference was not statistically significant (PFV D, p = 0.55 and PFV N, p = 0.96). We found a statistically significant difference in these groups only in the case of negative fusional vergence (red numbers on grey background). We can therefore confirm that a statistically significant increase of NFV took place in the group with distance exophoria (D EX, p = 0.01) and in the group with near exophoria (N EX, p = 0.02).

In the groups with esophoria, there was a reduction of the mean values of both fusional vergences in the group with distance esophoria (D ES), but the result was not statistically significant (PFV D, p = 0.89 and NFV D, p = 0.07). By contrast, in the group with near esophoria there was an increase in the mean values of both fusional vergences, but again the result was not significant on the designated statistical level (PFV B, p = 0.83 and NFV B, p = 0.89).

At the same time, Table 1 also presents normal mean values of distance and near fusional vergences. It is assumed that distance PFV should be at least 20 pD and NFV at least 10 pD. The mean values of near fusional vergences should be slightly higher. In the case that distance and near orthophoria is identified in a patient, the AC/A ratio is normal and we have measured reduced anomalous values of fusional vergences, we classify this defect of simple binocular vision according to Scheiman and Wick [9] as a fusional vergence defect.

DISCUSSION

The main contribution of our study is that with the aid of our results we have supported a fact known from practice

Table 1. Average sizes of fusion reserves when the group is divided into 6 groups according to the type of heterophoria in the distance and in the nearby. Red boxes show a decrease in the magnitude of the mean value relative to the orthophoric group, and green boxes show the opposite. Red p-value numbers (or stars) indicate a statistically significant difference according to the Student's test

	D OR			D EX			p-value	D ES			p-value
	Average	Standard deviation	Range	Average	Standard deviation	Range		Average	Standard deviation	Range	
PFV D [pD]	24.7	6.6	16–35	22.0	6.7	18–30	0.55	24.2	7.0	14–35	0.89
NFV D [pD]	10.8	3.9	6–18	15.3*	4.8	12–20	0.01	7.7	4.4	6–12	0.07
	B OR			**B EX**			**p-value**	**B ES**			**p-value**
	Average	Standard deviation	Range	Average	Standard deviation	Range		Average	Standard deviation	Range	
PFV B [pD]	28.4	8.2	16–40	28.2	8.4	16–45	0.96	29.4	6.4	20–35	0.83
NFV B [pD]	12.0	4.8	8–18	22.6*	8.1	16–40	0.02	14.8	4.3	10–20	0.89

PFV D/B – Positive fusion vergence far/near, NFV D/B – Negative fusion vergence far/near, D/B OR – far/near orthophoria, D/B EX – far/near exophoria, D/B ES – far/near esophoria [pD] and other scientific studies [16,17]. In the case of presence of heterophoria, compensatory mechanisms are very often manifested depending on the direction of heterophoria, primarily towards a weakening of contralateral fusional vergence and an increase of ipsilateral fusional vergence. We also demonstrated an increase of ipsilateral fusional vergence in our study. Unfortunately, we did not succeed in confirming a weakening of contralateral fusional vergence, probably due to the small number of probands in the groups. In addition, the patient becomes restricted in activity performed at a distance, where heterophoria is manifested most strongly. In more extreme situations the patient has to cover one eye in order to prevent double vision.

The size of fusional vergence is of fundamental significance for the compensation of present heterophoria. Normal values of fusional vergences are described for example in the study by [18], who determined the following normative values of fusional vergences with the aid of measurement by prism bars. For the group aged 21–30 let years, positive distance fusional vergence is 19.3 ±8.2 pD, and negative distance fusional vergence is 9.5 ±2.8 pD. For the group aged over 70 years, positive distance fusional vergence is 16.7 ±7.3 pD, negative distance fusional vergence is 8.6 ±2.3 pD. No statistically significant difference was found upon a comparison between individual age groups. Our values of measurement of fusional vergences correspond very strongly with these values.

The influence of heterophoria on the size of near fusional vergences has also been demonstrated, for example in the study by Lanca [19], which was conducted on pediatric patients with an average age of 7.6 ±1.2 years. In the group of patients with exophoria, a statistically significant decrease in the value of positive fusional vergence was demonstrated in comparison with the groups with orthophoria and esophoria. This study also demonstrated that patients with lower fusional vergences had a tendency to have a larger size of heterophoria ($r = -0.848$, $p < 0.001$), while conversely patients with higher values of fusional vergence had lower values of near heterophoria ($r = -0.115$, $p = 0.008$).

Another correlation, which though weak is statistically significant, was demonstrated by Radakovič [20] in a study conducted on 152 children aged 6–7 years. The correlation coefficient between the size of heterophoria and distance fusional vergences was $r = 0.18$ ($p < 0.05$) and near fusional vergences -0.26 ($p < 0.05$). The mean value of distance heterophoria was 0 pD and for near heterophoria -2 pD exophoria, which was very similar to the case in our basic cohort. Most of the studies that evaluate the size of near heterophoria state the average result of heterophoria as slight exophoria, especially due to the presence of fusional vergence, which supplements accommodation vergence.

The ratio of accommodative convergence and accommodation plays a significant role in the classification of non-strabismic defects of simple binocular vision. Normal values of AC/A are stated similarly in various sources, from 3 pD to 5 pD of vergence per 1 D of accommodation [11,12]. The results of our measurement using the gradient method show that only 3 individuals (15.7%) had an AC/A ratio lower than 2 pD/D and only one individual had this ratio higher than 5 pD/D (5.2%). The majority of the subjects had this ratio within the limits of the norm (78.9%).

In accordance with Schieman and Wick [9], we divide defects of simple binocular vision according to the size of the AC/A ratio. If the AC/A ratio is normal (3–5 pD/1 D) and approximately the same value of exophoria is measured in distance and near vision, this concerns so-called basic exophoria, and in the opposite case basic esophoria. If distance and near orthophoria is measured and fusional vergences are weakened, this concerns a defect of fusional vergence. If the AC/A ratio is high (more than 6 pD/1 D), this most often concerns an excess of convergence or divergence. In the opposite case (AC/A less than 2 pD/1 D), it concerns an insufficiency of convergence or divergence.

A study conducted by Wajuihian [21] analyzed simple binocular vision (SBV) in 1201 high school students aged 13–19 years, with the aim of detecting defects of SBV. Within the cohort 4.3% of individuals were identified with convergence insufficiency, and 5.6% of patients with convergence excess. A total of 3.3% of individuals had a defect of fusional vergence. The study also demonstrated a statistically significant difference in the prevalence of convergence insufficiency ($p = 0.01$) upon a comparison between the group of subjects from a city and from a village. In the case of convergence excess, a statistically significant larger prevalence ($p = 0.02$) was demonstrated in the group of younger individuals in comparison with a group of older subjects.

In our cohort we identified one proband with convergence insufficiency (5.2%), one with convergence excess (5.2%), two probands with basic exophoria (10.5%) and one proband each with convergence excess and defect of fusional vergence (5.2% each). In clinical practice the subjective symptoms of the individual in question should also correlate with this classification. We classify these symptoms into groups of so-called asthenopic complaints, which include for example, eye pain, headache, stinging of eyes, lacrimation, jumping over letters or rows, doubling thereof and other symptoms. We may detect individuals' subjective symptoms either by means of anamnesis or using a questionnaire. Structured and complicated questionnaires are mostly highly demanding on patients, and for this reason we recommend rather shorter and simpler questionnaires such as CVS-Q [22]. In our study we did not conduct testing of subjective symptoms, which from a certain perspective may limit the results of this study. Another limiting factor of our study was the small extent of certain groups of patients and the imbalance of the range of these patients. The predicative value of the results is therefore reduced in this sense.

CONCLUSION

Through a comparison of the values of fusion vergences in patients with exophoria and orthophoria, we demonstrated that the presence of distance or near exophoria leads to an increase of ipsilateral fusional vergence. In the case of