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Comparison of near horizontal heterophoria tests in free space and with phoropter

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Background: Measurements of phoria at near are important elements of the optometric assessment of binocular vision. It is important to know if different methods of measuring a phoria are interchangeable. This study was designed to compare phoria measures using in-phoropter (von Graefe) and in free space methods (Howell card). *Methods*: The study was conducted with 70 pre-presbyopic subjects, aged 23–35 years. Both near the von Graefe and near Howell card horizontal dissociated phorias along and with gradient +1.00 D and –1.00 D phorias were measured for each technique. *Results*: The mean values of the near dissociated phoria, for both test conditions (von Graefe and Howell card) showed a slight deviation in the two measures with von Graefe measures being generally more exophoric. The mean value of the phoropter phoria was 1.97 Δ base-in and in free space, the value was 0.9 Δ base-in. The phoropter phoria with the +1.00 D gradient was 5.24 Δ base-in, and in free space, 2.73 Δ base-in. Measurements of the phorometric phoria with a gradient of –1.00 D gave a mean of 0.42 Δ base-out and 0.94 Δ base-out in free space. The near phoria measures were significantly different for the basic near measure ($p = 0.01$) and for the +1.00 D gradient ($p = 0.000002$) but not for the –1.00 D measure ($p = 0.36$). *Conclusion*: The results of the differences in the near horizontal phoria in free space and in- phoropter were significantly different for the basic measure and for the +1.00 D gradient. The findings between the two methods of testing should therefore not be treated as equivalent or convertible. Each test method should have separate means and ranges established.

Keywords: Howell phoria card, near horizontal heterophoria, phoropter, Von Graefe test.

1. Introduction

Correct phoric measures are an important factor affecting the potential comfort of a person when performing close visual work. Measurements of phorias at near are therefore

important elements in an optometric assessment of binocular vision. Indeed, these measures are often the basis for making decisions concerning the treatment of the patient [1, 2]. The disassociated phoria defines the direction and magnitude of the deviation of the visual axis of the other eye when fusion is disrupted. The visual system is considered to work harder to overcome a deviation, since theoretically, this measure impacts the maintenance of near fusion. This deviation is determined by assuming a reference point of parallel positioning (orthophoria) of the visual axis at near. The horizontal disassociated phoria is then the measured position of the eyes when the eyes are disassociated. The measure may be convergent (base-out; esophoria), or divergent (base-in; exophoria).

Depending on the direction of the deviation, one can distinguish: esophoria, exophoria, hyperphoria or hypophoria; a vertically non-parallel positioning of the visual axis. With a vertical phoria, one of the axes is directed higher in with respect to the second axis. Cyclophoria is a rotation of the eyeball around the visual axis [3, 4]. This study was confined to a study of the horizontal phorias.

Horizontal heterophoria is a condition commonly found in the population, but in most cases, under physiological conditions it does not adversely affect the visual process. Usually, small values of heterophoria do not involve differences in fixation. This, it is believed, means a higher probability that symptoms will not occur [5].

Subjective symptoms can be accompanied by uncompensated phorias; however, symptoms are not specific to phorias and can also be caused by other factors. Symptoms therefore must always be analyzed in conjunction with other clinical data obtained during the examination. Usually discomforts resulting from decompensated phorias are associated with excessive visual work. These symptoms tend to subside with rest, are less severe in the morning, and may become more severe during the day. Symptoms later in the day are more often associated with visual work at near [6]. The leading symptoms of decompensated heterophoria are believed to include headaches, eye pain, difficulty in changing focus from far to near or *vice versa*, difficulty in concentrating during visual tasks, blurry vision, “swimming” text, difficulties in maintaining single, comfortable binocular vision, transitional diplopia, asthenopia, motion sickness, photophobia and closing one eye during visual work [6–9].

Being able to compare different phoria studies is based upon the concept that phorias derived from different measurement methods are interchangeable. In practice, different techniques are used to measure a heterophoria. Several have been compared by different authors in terms of the reliability of the results obtained. In clinical practice, the most frequently used phoria tests are the von Graefe method, the Maddox method, the cover test or the modified Thorington test [1, 10–12]. A clinically popular, modified Thorington technique is the Howell card, wherein a base down 6.0 Δ is placed over dominant eye as subject looks at the card positioned 33 cm away (Fig. 1). The subject is asked to keep the top row of numbers on the card clear and to report the position of the bottom arrow in relationship to the down row of numbers.

Phoria measures may be affected by the test conditions and indeed may be statistically different and not comparable [1, 10].

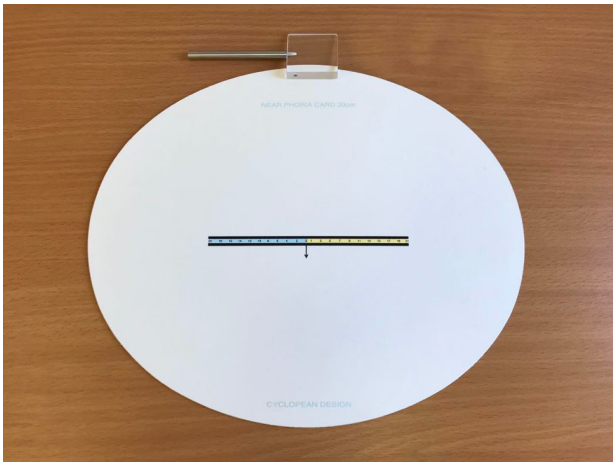

Fig. 1. The near Howell card.

To obtain information on heterophoria measures, it is reasonable to think that the test conditions should be as close as possible to the actual conditions of their visual work. Free space phoria testing therefore is assumed to be more closely related to real life conditions than phorias measured in a phoropter.

The aim of this research was to compare the measurement results of near phorias with the von Graefe and Howell card.

2. Methods

The investigation was conducted in accordance with the Declaration of Helsinki of 1975 and was approved by an institutional ethics committee. Seventy pre-presbyopic individuals (aged 23–35 years) were subjects of the study. The study group consisted of 36 women and 34 men. For each subject all tests were performed in correction of refraction. The mean visual acuity for distance in the right eye was 1.26 and in the left eye 1.25. The study of 36 people began with von Graefe testing, and the other 34 subjects started with the Howell card. The near phoria and the +1.00 D and –1.00 D gradient phorias was measured with both techniques.

The von Graefe was performed in a standard manner with a 6 Δ base-down prism placed before the right eye while base-in prism was placed before the other eye. A vertical row of letters (size 0.5 logMAR) placed at 33 cm, was the target and the subjects were instructed to keep the lower letters clear and report when the two targets were aligned, one over the other.

The Howell phoria card was held by the examiner at 33 cm. A 6 Δ base-down prism was place over the dominant eye. The subject was asked to keep the bottom numbers (size 0.5 logMAR) on the card clear and report the position of the upper arrow in relation to the upper row of numbers (reveals both direction and amount of the phoria). The same measurements were made for both the +1.00 D and –1.00 D gradient phorias. The plus

and minus gradient lenses were inserted binocularly in the phoropter, (von Graefe). With the Howell card, a trial frame was used to place the correction and the gradient lenses before the eyes of the subject. For each parameter, the measurement was performed three times, taking as the result the average of these values.

The statistical analysis used Student's *t*-tests, the Kolmogorov–Smirnov test and the Bland–Altman analysis.

3. Results

The mean values of the near phoria through the habitual correction, for both test conditions, showed a slight exophoria. The mean value of the near phoria with von Graefe was 1.97 (±4.22) Δ exophoria and with the Howell card, 0.9 (±2.93) Δ exophoria. The phoria with the +1.00 D gradient, which reduces accommodative demand, measured higher exophoric values in both cases. The phoropter +1.00 D gradient was 5.24 (±5.03) Δ exophoria, and in free space as 2.73 (±2.86) Δ exophoria. Measurements of the phoria with a gradient of –1.00 D, increasing accommodation demand, gave an average of 0.42 (±6.02) Δ esophoria with the von Graefe and 0.94 (±2.73) Δ esophoria for the Howell card. In each of the test conditions the phoropter results were more divergent than the free space condition.

The median and standard deviations for the respective measurements (phoropter and free space) are shown in the Table. The median and standard deviation values were both less for the Howell card data than was the von Graefe.

Statistical analysis of the Student *t*-test compared the average difference between the phoropter and free space results. A similar analysis was carried out with the near dissociated horizontal phoria data with the +1.00 D and –1.00 D. Statistically significant differences of coefficient $p < 0.05$ were obtained for the mean differences of the near dissociated horizontal phoria ($p = 0.01$) and for near dissociated horizontal phoria with the +1.00 D gradient ($p = 0.000002$). There was no statistically significant difference between the mean differences between the two phoria measurements with the

T a b l e. Mean, median, and standard deviation of values for near dissociated horizontal phoria, with gradients +1.00 D and –1.00 D near dissociated horizontal phoria measured with phoropter and in free space.

Parameter	Mean value	Median	Standard deviation
	With phoropter tests		
Phoria mean value	1.97 BI	2.00 BI	4.22
Phoria with +1.00 mean value	5.24 BI	5.00 BI	5.03
Phoria with –1.00 mean value	0.42 BO	1.00 BO	6.02
	Free space tests		
Phoria mean value	0.90 BI	0.33 BI	2.93
Phoria with +1.00 mean value	2.73 BI	2.00 BI	2.86
Phoria with –1.00 mean value	0.94 BO	0.75 BO	2.73

–1.00 D (p = 0.36). The normality of the distribution for the results of individual measurement series was checked by the Kolmogorov–Smirnov test. The values of the near dissociated horizontal phoria to both gradients of +1.00 D and –1.00 D demonstrated normal distributions.

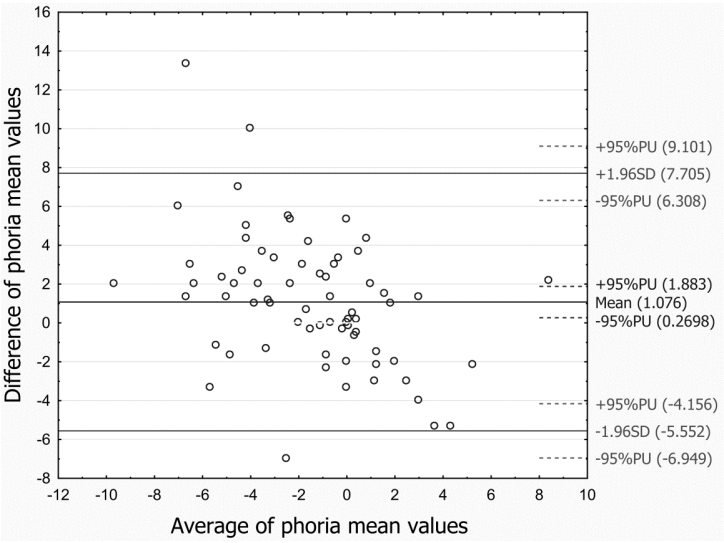

Fig. 2. Bland–Altman chart presents the distribution of differences for the mean values of the near dissociated phoria measured with the use of the phoropter and in free space.

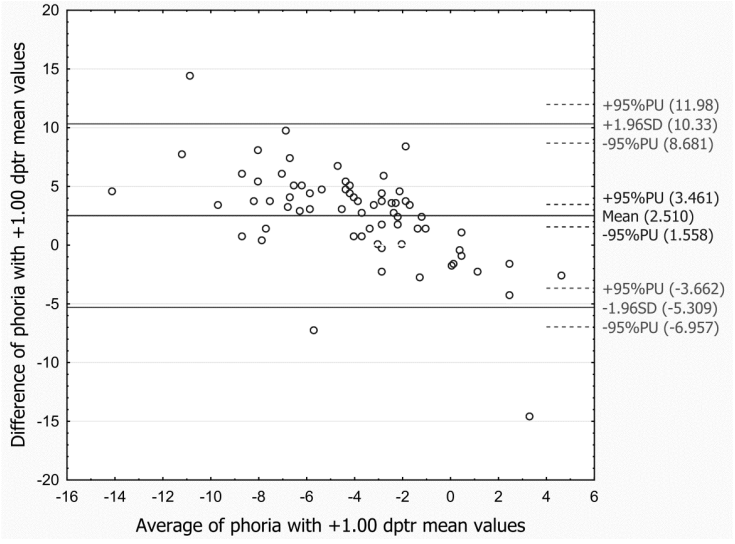

Fig. 3. Bland–Altman chart – presenting the distribution of differences for the mean values of the near dissociated phoria for +1.00 D with the use of the phoropter and in free space.

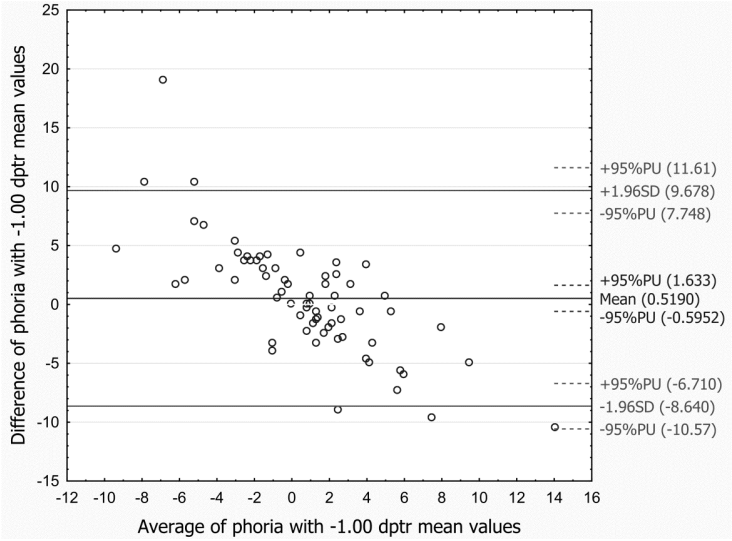

Fig. 4. Bland–Altman chart – showing the distribution of differences for the mean values of the near dissociated phoria with –1.00 D gradient measured with the use of the phoropter and in free space.

Figures 2 to 4 show the Bland–Altman plots for differences of near horizontal phoria and with gradients +1.00 D and –1.00 D with both methods.

The mean differences and the limits of agreement, that is, the ranges where between 95 percent of results lie, are also indicated in the plots.

For near dissociated horizontal phoria, average difference was 1.08 Δ with a spread of results from 7.71 BO to 5.56 BI Δ, the range in where 95% of the obtained results are contained. For the near dissociated horizontal phoria with gradient +1.00 D the average difference was 2.51 Δ with a range of results between 10.33 BO Δ and 5.31 BI Δ. For the near dissociated horizontal phoria gradient of –1.00 D, the average difference of results is 0.52 Δ, with a range of from 9.68 BO Δ to 8.64 BI Δ.

4. Discussion

Many different measurement methods are used by clinicians to determine the near phoria. The most frequently used tests are the von Graefe, cover test, Maddox test and modified Thorington test [1, 10, 13, 14].

The modified Thorington test is considered as a simple and repeatable method [1, 10–13]. SCHROEDER *et al*. reported the reliability of the modified Thorington test was greater than the von Graefe test. Moreover, found the credibility of von Graefe's dissociated phoria measurements better than that of the Maddox measurements [10]. However, CASILLAS and ROSENFIELD state that tests performed in free space using both the modified Thorington method and the Maddox test gave more reproducible results than the von Graefe method [13].

During the testing of the near dissociated horizontal phoria most respondents measured exophoria. With the phoropter (42 out of 70 subjects), and during in free space testing 36 out of 70 subjects. Orthophoria using the phoropter was shown in 7 subjects, while in free space 6 subjects. Similar observations were noted by Sanker *et al*. and Lam *et al*. [1, 15].

The free space data showed less exophoria or more esophoria compared to the phoropter results. This was true for both the basic near phoria through the habitual prescription as well as with the additional +1.00 D or –1.00 D lens. A higher mean divergent deviation was found with the von Graefe method than with the Howell card. These results have also been demonstrated in studies by Casillas *et al*., Goss *et al*. and Maples *et al*. [13, 14, 16]. Conversely, different observations were obtained by Lam *et al*., whose study showed a tendency to shift results towards smaller exophoria (or higher esophoria) using the phoropter as compared to free space phoria testing. In the latter study they used a conventional muscle balance card, and the conventional Maddox rod technique [15].

According to Maples *et al*., a larger percentage of patients are classified as biased towards having a binocular vision anomaly when the von Graefe method is used to study the phoria, rather than when using the Howell phoria card. The von Graefe method also gives a wider range of results and which are shifted more towards exophoria than when measured using the Howell card for the same patient for both far and near [16].

Studies by several authors and by our own observations would indicate various phoria test methods are sensitive to variants of visual dissociation and other factors between tests. The results of the dissociated heterophoria measurements cannot therefore be regarded as identical.

Care should be taken in considering the "interchangeability" of methods for measuring a near heterophoria [1, 10].

The Bland–Altman graph was also used for the clinical analysis of the obtained results. The graphically illustrated results show differences obtained in the near dissociated horizontal phoria measures, in free space and behind a phoropter. It can be assumed that differences of up to 3 Δ are clinically acceptable [1]. In this case, the different test methods can be considered as equivalent and possible to be used interchangeably with the adoption of identical ranges of standards. However, in all three comparisons, the results obtained show a much wider range of differences between the obtained results. Hence, the comparison of the near dissociated horizontal phoria in the phoropter to free space cannot be considered as equivalent methods to each other. Other authors also point to the discrepancy in the results obtained depending on the adopted measurement method to determine the near horizontal dissociated phoria. These differences among test results may be caused by variations in test technique, different dissociation methods, examiner bias, subject response skill, control of accommodation, or other factors [1, 10]. The contribution of the peripheral retinal information to spatial stability is known. The phoropter clearly is at a detriment to spatial stability, since it reduces the spatial sensory information. This can explain the differ-

ences in results between different tests. Therefore a higher mean divergent deviation was found with the von Graefe method than with the Howell card. Another possible contribution beside the peripheral vision contribution when measuring the phorias would be conditions related to the stimulation or non-stimulation of accommodation between the two test conditions. Although the different phoria measurement methods cannot be considered equivalent, they are nevertheless used interchangeably in clinical practices. It was beyond the scope of this study to consider the occurrence of symptoms for each test method. A future study should investigate the quantity and severity of symptoms between the two methods. If there are differences in the number of symptoms and severity of symptoms between the two methods, this information would guide the clinician to the method which is clinically superior. In conclusion, it is important to note the method of measurement of the near dissociated horizontal phoria when reporting the clinical data.

5. Conclusion

The test conditions, in free space or in-phoropter, significantly affect the obtained results of the horizontal near phoria and should not be treated as equivalent or convertible.

Measurement of near dissociated horizontal phoria within the gradient of +1.00 D, using the Howell phoria card in free space gives results which are statistically significantly shifted towards esophoria (lower exophoria, greater esophoria), compared to the results obtained for the phoropter.

Due to the significant differences between the results of this near dissociated horizontal phoria study, the method and measurement conditions are significant. The conclusion of this study is that for each method, separate ranges of standards should be established.

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