Abstract

**Purpose:** To determine the fusional amplitudes and the frequency of heterophoria, in our patients

**Methods:** In this cross sectional study, 111 adults with mean age of 25.6 years were included. All participants had best corrected visual acuity (BCVA) better than 20/25, more than 60 sec of arc stereopsis and had no heterotropia or other significant eye disorders. Fusional amplitudes were measured at far (6 meters) and near (40 centimeters) by rotary prism and heterophoria was evaluated by Maddox wing.

**Results:** The total frequency of heterophoria was 57.7%, and exophoria, esophoria, hyperphoria and cyclophoria were 51.4%, 0.9%, 3.6% and 9.9% respectively. The mean of convergence fusional amplitudes for far and near were 11 prism diopters (PD) and 16 PD and for divergence fusional amplitudes were 7 PD and 14 PD respectively. There were correlations between convergence and divergence fusional amplitudes at far and near.

**Conclusion:** The amount of exophoria had not affected the fusional reserves and the presence of heterophoria was not related to the visual complaints like asthenopia and transient diplopia.

**Keywords:** Fusional Amplitude, Heterophoria, Rotary Prism


Introduction

Patients often manifest symptoms that appear to be related to binocular distress. Many of these patients may have normal heterophoria at distance and near, making the etiology of such symptoms more complex. The presence of abnormality in vergence system could result in variety of symptoms. For assessing the vergence system there are different parameters as near and far horizontal and vertical phoria, near and far positive and negative fusional vergence (PFV and NFV), vergence facility and near point of convergence (NPC). Nowadays binocular abnormalities following keratorefractive surgery (KRS), is one of the major concerns. Some of these abnormalities could result in persistence complaints after KRS.

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Thus knowing the normative value of such parameters for assessing the binocular function could help us to detect the high risk people for developing such problems after KRS, and to select patients for KRS. Furthermore these values help us to manage the patients with symptoms which may be related to binocular disorders.

The starting point for evaluation of binocularity is assessment of vertical and horizontal phoria in far and near.\(^5\)

For assessment of binocularity, measuring the fusional vergence amplitude, provides useful information.\(^3\) The fusional reflex compensates the phoria so the amount of vergence amplitude which was used for compensating the phoria is important for normal binocular function.

For measuring PFV and NFV, rotary prism and prism bar could be used.\(^4\)

When measuring the fusional vergence we encounter 3 points:

1) **The blur point: the amount of vergence when no accommodation is used**

2) **The break point: the total fusional vergence when the individual declines diplopia.**

3) **The recovery point: the amount of vergence when the individual regains single vision after diplopia.**

We aimed to record normative value of parameters such as PFV and NFV for far and near and prevalence and amount of heterophoria at near among target group for KRS (20-40 years old) in our community.

**Methods**

The participants were between 20 and 40-year-old. Since we desired to have cases with normal binocularity our inclusion criteria were: best corrected visual acuity (BCVA)\(>20/25\), stereopsis\(\leq 60\) second of arc, no heterotropia, or any significant ocular disorders, including high refractive error [myopia\(\leq 6\) diopters (D) & hyperopia\(\geq +6\) D] and anisometropia (more than 2 D). We have selected our cases from medical students, staff and nurses of Khatam-Al-Anbia hospital who have participated in our study voluntarily.

The presence of any visual complaints during longtime near work like asthenopia, transient diplopia and blurred vision were asked from all participants. At first intensity the BCVA was measured for all participants, before any other examination to exclude fusion disruption. We excluded heterotropia by cover-uncover test at far and near. Other ocular abnormalities were ruled out by a complete anterior and posterior segment examinations. Then the Maddox wing was used to record the presence of any heterophoria. For this reason, Maddox was held by the individual and he was asked to fix the black and red flashes on the Maddox. Then the individual read the number faced on each flash. Also the movement directions of flashes were reported (left or right for red flash and up or down for black one). In this way, the examiner could achieve the amount of eso or exo and hyper or hypo phoria, according to the explanation on Maddox. Cyclophoria was also evaluated by asking the individual to look at the movable needle on Maddox. He was requested to moving along the needle until it faced its indicator on Maddox body. Thus examiner was able to record the amount and type of cyclophoria, according to the explanation on the Maddox. All the tests were done between 9-11 AM to reduce the effect of daytime and fatigue on measurements. Stereopsis was measured by Titmus stereotest at near. The results of examinations of participants were reviewed and if they had the defined criteria for our study they were asked to come back again for further examinations in the coming days. At the next visit, the participants with VA of \(>20/25\), the PFV and NFV at 6 meters and 40 Centimeters were measured by rotary prism, with their BCVA. The rotary prism was put in front of the right eye of the patient and he was asked to fix at Snellen chart, 2 lines below his BCVA at 6 m. The patient was asked to declare when the target gets blurred (Blur point), doubled (Break point) and again singled (Recovery point). Then the prism was slowly rotated laterally (Base out prism) and blur point and break point of PFV were recorded. After this measure the rotary prism was rotated to the opposite direction until the individual saw again the single target (Recovery point of PFV). These steps were repeated with rotating the prism medially (Base-in prism) to record the Blur, break and recovery points of NFV at far.

The six previously defined points (Blur, break and recovery points of PFV and NFV) were...
also recorded at near distance (40 cm). We considered the break point as fusional vergence in our study.

We used SPSS 11.5 to analyse our data. Correlation test and $\chi^2$ were used for assessing relationships between variables and T-test for comparison of means between groups.

**Results**

111 participants were included in our study with mean age of 25.6±3.6 years (45 males, 66 females).

The mean amount of stereopsis was 37.5±18 second of arc.

The prevalence of hetrophoria is presented in table 1. The mean value of horizontal phoria was -2.2±3 prism diopters (PD) for near with Maddox wing test. 57.7% of our cases had exophoria and 9.9% cyclophoria, 3.6% hyperphoria and only 0.9% had esophoria. The frequency of visual complaints in hetrophoric individuals was 20.3%. There was no relationship between the presence of hetrophoria and visual complaints such as asthenopia, transient diplopia and reading problems ($\chi^2$, P=0.37). The frequency of visual complaints in exophoric individuals was 15.8% ($\chi^2$, P=0.051) and there was no complaint in exophoric cases ($\chi^2$, P=0.03).

The values of fusional vergence are indicated in table 2. We didn’t find any relationship between PFV and exophoria ($P_{PFV \text{ near}}=0.52$ and $r=0.09$, $P_{PFV \text{ far}}=0.83$ and $r=0.03$). The mean of PFV in exophoric individuals in near and far were 15.25±6.3 PD and 11.04±4.54 PD, respectively.

Also, there was no correlation between the age of our cases for fusional amplitudes and spherical equivalents (SEs).

There was no correlation between SE, exophoria and fusional amplitudes.

The mean values of right and left eyes SE were -0.57±1.25D and -0.56±1.35 D, respectively. SE was the same for females and males (P=0.56) and SE of the two eyes of each individual were correlated (Correlation: 0.94, P=0).

There were statistically significant relationship between PFV far & near ($r=0.41$, P=0), NFV far & near ($r=0.29$, P=0.002), NFV & PFV far ($r=0.28$, P=0.005) and NFV & PFV near ($r=0.52$, P=0). So we could concluded that the convergence and divergence amplitudes at far and near are not independent and they correlated to each others.

**Table 1.** The frequency of heterophoria

<table>
<thead>
<tr>
<th>Heterophoria</th>
<th>57.7% (Mean horizontal phoria = -2.2±3 PD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exophoria</td>
<td>51.4%</td>
</tr>
<tr>
<td>Esophoria</td>
<td>0.9%</td>
</tr>
<tr>
<td>Hyperphoria</td>
<td>3.6%</td>
</tr>
<tr>
<td>Cyclophoria</td>
<td>9.9%</td>
</tr>
</tbody>
</table>

PD: Prism diopter

**Table 2.** The values of fusional vergence

<table>
<thead>
<tr>
<th>Distance</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>NFV brk</td>
<td>7.95</td>
<td>3.78</td>
</tr>
<tr>
<td>NFV rec</td>
<td>10.55</td>
<td>4.52</td>
</tr>
<tr>
<td>NFV blr</td>
<td>9.21</td>
<td>4.12</td>
</tr>
<tr>
<td>NFV brk</td>
<td>15.53</td>
<td>6.24</td>
</tr>
<tr>
<td>NFV rec</td>
<td>12.40</td>
<td>6.15</td>
</tr>
</tbody>
</table>

NFV: Negative fusional vergence (Divergence)
PFV: Positive fusional vergence (Convergence)
bl: Blue point
br: Break point
rec: Recovery point
SD: Standard deviation

**Discussion**

In this investigation we have defined the normal values of NFV and PFV among the 20 to 40-year-old people in our society. Several studies revealed normative values of parameters of binocular function.\(^5\)\(^9\) Scheiman and Wick, established for far distance reference values of 7±3 PD for the break point NFV, 4±2 PD for the recovery point NFV, 11±7 PD for the break point PFV and 7±2 PD for the recovery point for the general population.\(^6\) In NFV Jiménez recorded the same results.\(^2\)
Our results for the negative vergence were quite similar to those of the above mentioned authors. On the contrary, for the PFV, our results are considerably lower. This could be due to the fact that the great range of accommodation observed in children involves an increase in the amount of accommodative vergence.\(^2\) It has also been noted, however, that results are less reliable in children and that inter-examiner variation is high.\(^4\) In other hand, people with high refractive errors were excluded from our study due to the action of prismatic effect of these high power lenses. Also participants with high anisometropia were excluded because of anisocoria effect on fusional vergence. Maybe the participation of these groups of people by the use of contact lenses could solve this prismatic problem. There are many other studies which have recorded normative values of fusional vergence that were not considered here. As a matter of fact most of them are out dated or are performed in children. Our aim in this study was to record the normative values of fusional vergence amplitudes in target group of KRS. So it is not comparable with many other findings.

There are different reports of frequency of heterophoria at near distance in different populations.\(^{10-12}\) For East Asian children it was reported 58.3% at 6 years and 52.2% at 12 years of age.\(^{13}\) Our finding was 58.7% among adults (20-40 year-old). The mean value for near horizontal phoria was -2.2±3 PD in our study. In the table 3 we have indicated the mean values of horizontal phoria at near distance in different studies.

There are some statements concerning the correlation between the refractive errors and heterophoria. It has been reported that hyperopia is associated with esophoria at near and distance fixation and myopia is associated with exophoria at near and distance fixation.\(^{13}\) Exophoria was reported significantly more frequent in myopic subjects in another study.\(^{14}\) It is also reported that hyperopia could result in exotropia.\(^{15}\) But special studies which were designed to evaluate this matter, disagreed with such statement and they did not find relationships between refractive errors and heterophoria.\(^{17,16}\) We also did not find such relationship in our investigation.

<table>
<thead>
<tr>
<th>Study</th>
<th>Method</th>
<th>Age (year)</th>
<th>Mean of Horizontal phoria at near (PD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frier</td>
<td>Maddox</td>
<td>5-74</td>
<td>-0.34 to -3.83</td>
</tr>
<tr>
<td>Letourneau</td>
<td>Maddox</td>
<td>6-13</td>
<td>-0.78±4.51</td>
</tr>
<tr>
<td>Jackson</td>
<td>Von Graefe</td>
<td>8-16</td>
<td>-3±4</td>
</tr>
<tr>
<td>Chin and Abidin</td>
<td>Howell Card</td>
<td>7-12</td>
<td>-1.84±3.94</td>
</tr>
<tr>
<td>Jimenez</td>
<td>Modified thornton</td>
<td>6-12</td>
<td>-0.4±3</td>
</tr>
<tr>
<td>Present study</td>
<td>Maddox</td>
<td>20-40</td>
<td>-2.2±3</td>
</tr>
</tbody>
</table>

Vertical and horizontal phoria show no relationship with age.\(^{10,12,17,18}\) Our findings showed the same result. We did not find any relationship between horizontal phoria at near distance and aging.

Positive and negative lenses can be used for management of convergence and divergence insufficiency.\(^{19}\) We have sought the effect of SE on fusional amplitudes in our study but we have seen no effect. This may be explained by the difference of our patient’s age which ranged between 20 and 40 years and not including children with high accommodative power.

Because of the need to converge to compensate exophoria, we expected to find correlation between the convergence amplitudes at far and near distance and the amount of exophoria, but interestingly we did not find any correlation between the amount of exophoria and PFV at far and near distance. We could conclude that the amount of exophoria dose not have effect on PFV and when exophoria is more than fusional amplitude changes to exotropia. It is possible to increase vergence ability by orthoptics.\(^{20,21}\) But exophoria did not have such effect on PVF in our study.

There are rare investigations on parameters which were evaluated in our study, as relationships between SE by heterophoria in adults and relationships between fusional amplitudes by age and heterophoria in healthy binocular people. Furthermore most of the studies in these fields are limited to children such as intermittent exotropia and convergence insufficiency.\(^{22-25}\) We have selected the healthy adults for our study to find out normative values of fusional vergence in these cases.
Conclusion

In conclusion we could record the normative values of fusional vergence amplitudes in binocular healthy adults who are targeted group for refractive surgery. According to our knowledge there was not such study done in Iranian societies before. So all of our results in fusional amplitudes could be used in different subjects of that age with or without vergence dysfunction. Such normative values could help the ophthalmologist to select the patient for KRS and could explain some of the visual complaints of the patients. Further studies must be applied for assessment of effect of KRS on fusional vergence amplitudes and phorias, but indeed the first step in such investigations is to know the normative values of these parameters. It is important to know that is possible to have normal fusional vergence amplitudes and still have dysfunction of vergence system. Thus additional test must be used for evaluating binocularity such as vergence facility and near point of convergence (NPC) before and after KRS.

References