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The distribution of near point of convergence, near horizontal heterophoria, and near vergence among myopic children in South Korea

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ABSTRACT

Background/Purpose: To assess the distribution of near point of convergence (NPC), near heterophoria, and near vergence among myopic school children in South Korea.

Methods: One hundred and thirty-six elementary school children, aged 8–13 years, were each given a thorough eye examination including binocular vision testing, NPC using standard push-up technique, horizontal heterophoria measurement by Von Graefe, distance, and near negative and positive vergence with a phoropter and phoropter replacement card.

Results: NPC break and recovery points were highest in the age 9 years group, but the mean values of NPC were within the normal range. Of 136 individuals, 52 presented with esophoria, 53 presented with 0–6 Δ exophoria, and 31 presented with $\geq 7\Delta$ exophoria. In the younger age groups (8 years and 10 years) 0–6 Δ exophoria was prevalent, whereas in the older age groups (11 years, 12 years, and 13 years) esophoria was prevalent. Near positive fusional vergence (break and recovery point) presented with statistically significant correlations with the participants' ages. Esophoria showed higher correlations with high myopia (8.00 ± 0.000) rather than with low myopia (3.36 ± 2.499) or medium myopia (3.42 ± 2.149). The mean value of 0–6 Δ exophoria was highest in medium myopia (4.04 ± 1.517), and of $\geq 7\Delta$ exophoria was the highest in high myopia (12.66 ± 1.154).

Conclusion: There were no statistically significant correlations between the school childrens' ages and NPC, near horizontal heterophoria, and near fusional vergence, except near positive fusional vergence. Also, unlike many studies, myopic magnitude did not present a significant correlation with near phoria and fusional vergence.

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1. Introduction

Binocular dysfunction is an anomaly in visual function system that both eyes cannot aim simultaneously at the same visual stimuli, thus binocular function develops inadequately. Previously, various studies were conducted to understand normative values of binocular function in different populations.^{1–5} In particular, near point of convergence (NPC), horizontal phoria, and fusional vergence are commonly measured during an eye examination to diagnose binocular anomalies.

Recently, the amount of near work including hours on computers has increased. By attending an elementary school, children start to spend longer hours studying and on near work. Activating an excessive accommodation and vergence at near work can cause a decrease in binocular functions, such as reduced fusional vergence, and it accompanies symptoms such as asthenopia,⁶ headache and eyestrain, loss of concentration, or intermittent diplopia. Asthenopia can be caused by uncorrected refractive errors and/or binocular dysfunctions such as horizontal phorias or anomalies of fusional vergences, and the symptoms can be stressed with near activities such as reading and studying.⁷ With the increased amount of near work given to elementary school children, it becomes more important to perform an accurate refractive and binocular function tests.⁸ Binocular function tests are related to each other by their testing conditions and methods, thus one test

Conflicts of interest: The authors have no conflicts of interest to declare.

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result can be used to predict the other test result. Understanding patients' binocular function systems also helps to analyze and prescribe what they need.⁹ Gallaway et al¹⁰ reported a phoria test among various binocular tests as a fundamental test to perform on symptomatic patients.

Heterophoria, deviation of the eyes, can appear when the fusional vergence is interrupted because the tendency of eye deviation is kept latent by fusion.¹¹ It can be overcome by fusional movement, thus the ability to fuse must be evaluated and can be measured by near positive and negative relative convergence. Goss and Jackson¹² found a correlation between myopic development and phoria status. Also, Goss and Rainey¹³ found near phorias are associated with the onset of myopia in children. NPC has been considered as an important factor in evaluating the vergence system, and in Chen et al's¹⁴ study NPC tends to increase with children's age.

Several authors have examined variables, such as NPC, near heterophorias, or fusional vergences in school children and adults. However, there is no study on Korean school children and in particular among myopic children since myopia has reached epidemic levels in certain Asian countries,¹⁵ especially in South Korea. Thus, the present study is to understand the distribution of NPC, near horizontal heterophoria, and near positive and negative fusional vergence among myopic school children in Korea, and to assess the influence of myopia on NPC, near heterophoria, and near fusional vergences.

2. Methods

2.1. Participants

A population of 136 individuals, aged 8–13 years, were recruited from two different elementary schools in Muan-gun, South Jeolla Province between September 2014 and February 2015. All participants' parents provided written agreement forms. All of the participants presented with symptoms of binocular dysfunctions, such as asthenopia, headache and fatigue at near work, intermittent blurriness, or diplopia. The school children had no history of ocular and physical pathology, or strabismus. Individuals with amblyopia were not selected.

2.2. Eye examination

To select the participants, the same exam environment, such as the same intensity of illumination, was provided. A classroom of an elementary school with blackout curtains was selected. To reduce errors, the same examiner performed all examinations over 2 days. The examination included the following tests. (1) A case-history: full scope of questionnaires about symptoms was asked. (2) Assessment of refractive error: refractive error was determined with an auto-refractor (HRK-8000A; Huvitz, Gunpo, Korea), and subjective refraction using a phoropter (DU-7000; Dongyang, Korea) and auto chart projector (CCP-3100; Huvitz). Subjective refraction was performed with the monocular fogging method using a cross-cylinder, followed by binocular balancing to a standard endpoint of maximum plus for the best visual acuity. Myopia was defined as the spherical equivalent of -0.50 D or greater in one or both eyes. Myopia was categorized into low myopia (from -0.50 D to -2.99 D), medium myopia (from -3.00 D to -5.99 D), or high myopia (-6.00 D or greater). (3) Accommodative and binocular vision system. (i) NPC: NPC was evaluated with the standard push-up technique using a fixation stick (Bernell, Mishawaka, IN, USA). The patient was seated and requested to follow the approaching target. For the test, the ruler was held at the center of patient's forehead at the level of the brow and the target was moved toward

the patient at 2–3 cm/s. The break value was measured as the average of three measurements in which the examiner detects one eye deviation or the patient announced diplopia. The recovery value was measured as the average of three measurements in which the examiner detects that the patient's eyes appear to be realigned or the patient announced single vision. (ii) Distance and near horizontal heterophoria: to assess the quality of general binocular vision system, the tests were performed with the best refractive correction in place. The von Graefe technique was used to determine distance and near horizontal heterophoria. A 6- Δ base-up dissociating prism was placed in front of right eye, and a Risley rotary prism with 12- Δ base-in was placed in front of the left eye. For the near horizontal heterophoria, a near chart (Phoropter replacement card, Hahn-medical, Seoul, Korea) was placed in the phoropter. A single column of letters of 20/30 equivalent at 40 cm was used as a target. Base-in prisms were reduced (2 Δ /s) until the participant reported vertical alignment of the target. (iii) Distance and near fusional vergence: distance and near positive and negative fusional vergence was measured using a phoropter (HDR-7000; Huvitz) and near chart. For distance positive and negative fusional vergence, Risley rotary prisms were used and approximately equal amounts of prism were slowly added in front of each eye at a constant velocity (2 Δ /s) until the patient reported horizontal diplopia (break point). The amounts of prism were then reduced until the patient reported that the images were fused again (recovery point). For near negative fusional vergence, Risley prisms on both eyes with the zero in the vertical position was placed and equal amounts of base-in prism were added at the same rate to both eyes. When the patient reported diplopia (break) the prism was reduced in the opposite direction until the patient reported a single image (recovery). The total amount of prism for the right eye and left eye for negative fusional reserve was recorded. For near positive fusional vergence, the same procedure as near negative fusional vergence except base-out prism was used.

All tests for the horizontal heterophoria and fusional vergence were done three times and recorded and the average value was analyzed.

2.3. Statistical analysis

Completed examination data were collected and analyzed. Analysis was conducted, calculated with 95% confidence intervals, followed by frequency analysis, and independent *t* test using SPSS (version 20.0 for Windows; SPSS Inc., Chicago, IL, USA). All confidence intervals presented are 95% confidence intervals and the significance level was set at 0.05 in all analyses.

2.4. Informed consent and ethical approval of procedures

The local administration of the Education and School Board were contacted to request their cooperation. After securing permission to perform the study, approval was obtained by the appropriate university Ethical Advisory Committee. Completed consent forms were obtained from the parents or guardians of all children before the examination.

3. Results

In order to assess parameters in accordance with the participants' ages, 136 school children, aged 8–13 years, were divided into six subgroups. The mean with the corresponding standard deviation of parameters were then calculated for each group. Table 1 presents general parameters in the mean and standard deviation in each age group. In this table, distance values of heterophoria and fusional vergence are included because distance values set up the

Table 1

General distribution of parameters in mean and standard deviation for each age group.

Age, y (N)	8 (16)	9 (16)	10 (36)	11 (17)	12 (28)	13 (23)	F	p
NPCBP (cm)	6.06 ± 1.24	6.44 ± 1.90	6.07 ± 1.78	6.29 ± 1.65	5.64 ± 0.99	5.74 ± 1.95	0.752	0.586
NPCRP (cm)	8.44 ± 1.26	9.25 ± 2.08	8.94 ± 1.72	8.94 ± 1.78	8.11 ± 1.13	8.39 ± 2.23	1.396	0.230
HD (Δ)	1.69 ± 2.12	3.25 ± 1.91	2.83 ± 2.82	2.59 ± 2.57	2.93 ± 2.59	3.17 ± 1.58	0.961	0.444
HN (Δ)	3.81 ± 3.60	2.87 ± 5.45	4.22 ± 5.077	3.82 ± 4.35	2.57 ± 4.51	3.43 ± 4.27	0.489	0.784
FNFVB (Δ)	12.53 ± 5.40	10.37 ± 3.59	10.86 ± 3.65	11.47 ± 4.11	10.43 ± 4.21	9.65 ± 3.02	1.200	0.313
FNFVR (Δ)	8.69 ± 4.08	7.81 ± 4.44	7.611 ± 3.64	7.76 ± 6.65	7.03 ± 3.32	6.48 ± 2.21	0.889	0.490
FPFVB (Δ)	15.12 ± 5.87	15.56 ± 7.58	16.08 ± 4.52	15.00 ± 4.90	15.60 ± 4.32	13.70 ± 5.95	0.601	0.700
FPFVR (Δ)	10.06 ± 5.37	11.19 ± 6.10	11.53 ± 5.37	9.53 ± 5.01	11.57 ± 3.74	9.30 ± 3.65	1.080	0.375
NNFVB (Δ)	16.94 ± 4.67	16.50 ± 3.97	17.50 ± 3.15	16.47 ± 2.79	16.21 ± 3.54	18.04 ± 3.11	0.986	0.429
NNFVR (Δ)	12.75 ± 3.79	12.00 ± 2.83	12.83 ± 3.26	11.41 ± 1.84	12.43 ± 2.95	13.65 ± 2.67	1.317	0.261
NPFVB (Δ)	17.25 ± 4.55	18.13 ± 3.81	20.22 ± 5.05	17.53 ± 4.43	17.79 ± 4.08	20.83 ± 4.30	2.690	0.024
NPFVR (Δ)	12.13 ± 4.10	12.88 ± 4.06	15.83 ± 5.13	13.76 ± 3.73	13.21 ± 3.54	15.87 ± 4.59	3.051	0.012

FNFVR = far negative fusional vergence recovery point; FPFVB = far positive fusional vergence break point; FPFVR = far positive fusional vergence recovery point; HD = heterophoria at distance; HN = heterophoria at near; NNFVB = Near Negative Fusional Vergence Break Point; NNFVR = near negative fusional vergence recovery point; NPCBP = near point of convergence break point; NPCRP = near point of convergence recovery point; NPFVB = near negative fusional vergence break point; NPFVRP = near negative fusional vergence recovery point.

standards for the comparison. The mean values of NPC break and recovery points were farthest in the age 9 years group (6.44 ± 1.90 and 9.25 ± 2.08 , respectively) and shortest in the age 12 years group (5.64 ± 0.989 and 8.11 ± 1.13 , respectively). However, the mean NPC value was around 6 cm, and did not reveal significant differences between age groups. Distance heterophoria value was at its highest in the age 9 years group (3.25 ± 1.91) and near heterophoria value was its highest in the age 10 years group (4.22 ± 5.077). In the age 8 years group, distance negative fusional vergence break and recovery point values were highest (12.53 ± 5.40 and 8.69 ± 4.08 , respectively), whereas distance positive fusional vergence break point value was highest in the age 10 years group (16.08 ± 4.52) and recovery point value was the highest in the age 12 years group (11.57 ± 3.74). Near negative and positive fusional vergence break and recovery point values were highest in the age 13 years group (18.04 ± 3.11 , 13.65 ± 2.67 , 20.83 ± 4.30 , and 15.87 ± 4.59 , respectively). Results show that there were no statistically significant differences in NPC, heterophoria at distance and near, and far negative and positive fusional vergences. The near negative and positive fusional vergences were statistically significant in both break point and recovery point. Table 2 shows distribution of near heterophoria by subjects' age. Of 136 subjects, 52 presented with esophoria, 53 presented with 0–6Δ exophoria and 31 subjects presented with $\geq 7\Delta$ exophoria. In age 8 and 10 groups, 0–6Δ exophoria was the most prevalent. In age 11 and 12, occurrence of esophoria was prevalent. In age 13 group, esophoria, 0–6Δ exophoria, and $\geq 7\Delta$ exophoria were evenly distributed.

Of 136 patients, 86 presented with low myopia, 41 presented with medium myopia, and nine presented with high myopia (Table 3). Table 4 presents the general distribution of myopia, NPC, near heterophoria, and near vergence. The mean values of break and recovery points of NPC were highest in medium myopia (6.37 ± 1.933 and 8.93 ± 2.102 , respectively), and lowest in high

Table 3

Distribution of near heterophoria by degree of myopia.

	Low myopia (N)	Medium myopia (N)	High myopia (N)
Esophoria	28	13	1
0–6 Δ Exophoria	46	19	5
$\geq 7\Delta$ Exophoria	12	9	3
Total	86	41	9

myopia (5.56 ± 0.882 and 8.00 ± 1.000 , respectively). Esophoria showed a higher correlation with high myopia (8.00 ± 0.000) rather than with low myopia (3.36 ± 2.499) or medium myopia (3.42 ± 2.149). A 0–6Δ exophoria value was highest in medium myopia (4.04 ± 1.517) and $\geq 7\Delta$ exophoria value was highest in high myopia (12.66 ± 1.154). However, the number of patients for high myopia was much smaller given the definition of high myopia was ≥ -6.00 , thus the raw data pool was much smaller in this group to compare with other groups.

Table 5 shows the correlation of low myopia with NPC, near heterophoria, and near fusional vergence. In low myopic patients, the mean value of the break and recovery points were highest in $\geq 7\Delta$ exophoria (6.03 ± 1.674 and 9.00 ± 1.464 , respectively). However, regardless of the direction of phoria the mean value of NPC was within the normal limits. As the value of exophoria increased, break point of near negative fusional vergence decreased; however, recovery point did not present a significant correlation. The mean values of break points of near negative and positive fusional vergence were highest in esophoria (17.10 ± 3.275 and 19.80 ± 5.227 , respectively). Break and recovery points of NPC, near negative, and positive fusional vergences values were lowest in 0–6Δ exophoria. Figure 1 shows the correlation of near point of convergence (cm) and near convergence (Δ) in low myopia ($r^2 = 0.0654$).

Table 6 presents the correlation of medium myopia with NPC, near heterophoria, and near vergence. In medium myopia, the mean NPC value was larger than in low myopia. Similar to low myopia, break point of near negative fusional vergence was lowest in $\geq 7\Delta$ exophoria, as well as recovery point (16.44 ± 4.333 and 12.22 ± 2.108 , respectively). In esophoria, break and recovery points of near negative and positive fusional vergence values were highest. Figure 2 presents the correlation between NPC (cm) and near convergence (Δ; $r^2 = 0.013$).

Table 7 presents the correlation of high myopia with NPC, near heterophoria, and near fusional vergence. In high myopia, the mean value of NPC was highest in $\geq 7\Delta$ exophoria (6.33 ± 0.577), compared with in 0–6Δ exophoria (5.00 ± 0.707). In 0–6Δ

Table 2

Distribution of near heterophoria by the age of the participants in percentage.

Age (y)	Heterophoria at near		
	Esophoria	0–6 Δ Exophoria	$\geq 7\Delta$ Exophoria
8	3 (2.20)	11 (8.09)	2 (1.47)
9	5 (3.68)	5 (3.68)	6 (4.41)
10	12 (8.82)	18 (13.23)	6 (4.41)
11	13 (9.56)	4 (2.94)	2 (1.47)
12	11 (8.09)	9 (6.62)	8 (5.88)
13	8 (5.88)	6 (4.41)	7 (5.15)
Total	52 (38.24)	53 (38.97)	31 (22.79)

Data are presented as n (%).

Table 4

General distribution of myopia and near point of convergence, near heterophoria, and near vergence.

Myopia	NPCBP (cm)	NPCRP (cm)	Esophoria	0–6 Δ Exophoria	≥7 Δ Exophoria	NNFVBP (Δ)	NNFVRP (Δ)	NPFVBP (Δ)	NPFVRP (Δ)
≤−2.99 D	5.87 ± 1.486	8.59 ± 1.597	3.36 ± 2.499	3.71 ± 1.684	9.40 ± 2.063	15.52 ± 3.946	12.26 ± 2.723	18.63 ± 4.648	13.79 ± 4.358
−3.00 to −5.99	6.37 ± 1.933	8.93 ± 2.102	3.42 ± 2.149	4.04 ± 1.517	8.60 ± 1.9550	16.93 ± 3.608	13.02 ± 3.198	18.63 ± 4.306	14.11 ± 4.701
≥−6.00	5.56 ± 0.882	8.00 ± 1.000	8.00 ± 0.000	3.20 ± 1.303	12.66 ± 1.154	18.11 ± 4.755	14.00 ± 4.123	22.56 ± 4.362	17.89 ± 3.480

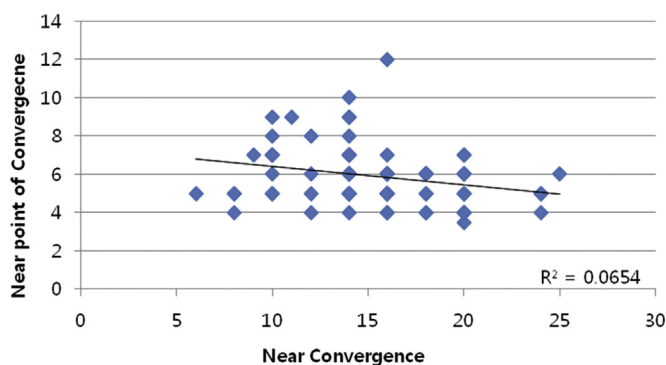
NNFVBP = near negative fusional vergence break point; NNFVRP = near negative fusional vergence recovery point; NPCBP = near point of convergence break point; NPCRP = near point of convergence recovery point; NPFVBP = near negative fusional vergence break point; NPFVRP = near negative fusional vergence recovery point.

Table 5

Correlation of heterophoria versus near point of convergence and vergence range in low myopia.

Low myopia	NPCBP (cm)	NPCRP (cm)	NNFVBP (Δ)	NNFVRP (Δ)	NPFVBP (Δ)	NPFVRP (Δ)
Esophoria	5.85 ± 1.694	8.65 ± 1.843	17.10 ± 3.275	12.70 ± 3.262	19.80 ± 5.227	14.25 ± 5.250
0–6 Δ Exophoria	5.82 ± 1.367	8.45 ± 1.540	15.08 ± 4.151	12.04 ± 2.638	17.92 ± 4.185	13.18 ± 3.713
≥7 Δ Exophoria	6.03 ± 1.674	9.00 ± 1.464	14.93 ± 3.712	12.40 ± 2.293	19.47 ± 5.194	15.27 ± 4.964

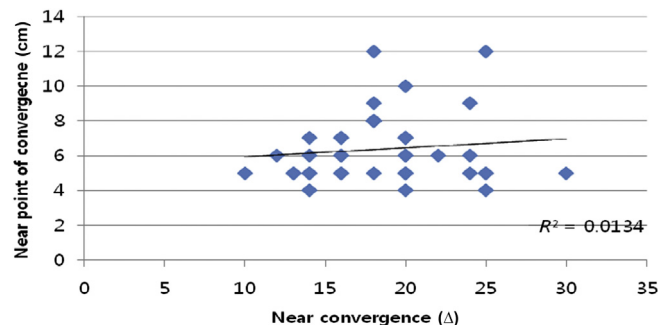
NNFVBP = near negative fusional vergence break point; NNFVRP = near negative fusional vergence recovery point; NPCBP = near point of convergence break point; NPCRP = near point of convergence recovery point; NPFVBP = near negative fusional vergence break point; NPFVRP = near negative fusional vergence recovery point.

**Figure 1.** Correlation of near point of convergence (cm) and near convergence (Δ) on low Myopia Refractive state.

exophoria, break point of near negative fusional vergence was largest (19.80 ± 4.381); however, in ≥ 7 -Δ exophoria, near positive fusional vergence break point was largest (23.0 ± 2.645). In low and high myopia, NPC was shortened as the amount of near convergence was increased, whereas in medium myopia, NPC value was lengthened as the amount of near convergence was increased. In high myopia, there was only one patient with esophoria (data not shown), thus there was a limitation to assess the correlation of high myopia and esophoria, NPC, and near fusional vergence. Figure 3 presents the correlation between NPC (cm) and near convergence (Δ; $r^2 = 0.2628$).

4. Discussion

This study was to assess the characteristics of NPC, near heterophoria, and near vergence and was performed on school children who were beginning to spend longer hours on near work. We also studied the correlations of NPC, near heterophoria, and near fusional vergences in accordance with the degree of myopia. Our

**Figure 2.** Correlation of near point of convergence (cm) and near convergence (Δ) in medium myopia.

patients' NPC was within the normal limits. Several studies have evaluated the relationship between NPC and the patients' ages. Hayes et al.¹⁶ compared the NPC break point by patients' ages and concluded that kindergartners presented with a significantly smaller NPC break point than third and sixth graders. Also, in Chen et al.'s¹⁴ study, the age of the study participants ranged from 2 years to 17 years, and NPC increased significantly with age. Recently, in Abraham et al.'s¹⁷ study, the participants' ages that ranged from 10 years to 35 year, presented receded NPC with age. Also, Duane¹⁸ and von Noorden¹⁹ presented receded NPC with age. In our study, there was no significant correlation found in the sampled subgroups. However, in Scheiman et al.'s¹ study, they compiled data from various studies on the normative range for the NPC break and recovery point (5–17.5 cm and 8–11 cm, respectively) and our results were within this range.

In our study, 52 patients presented with near esophoria, and 84 patients presented with near exophoria. Among the patients with exophoria, 53 patients presented with 0–6-Δ exophoria, which is considered as the normal range. According to many researchers, normative finding for near horizontal heterophoria is 0–6 prism diopters exophoria.^{20–22} Thus, we used three different categories to

Table 6

Correlation of heterophoria versus near point of convergence and vergence range in medium myopia.

Medium myopia	NPCBP (cm)	NPCRP (cm)	NNFVBP (Δ)	NNFVRP (Δ)	NPFVBP (Δ)	NPFVRP (Δ)
Esophoria	6.42 ± 2.760	9.14 ± 2.911	17.42 ± 5.380	13.42 ± 5.126	19.71 ± 5.707	16.00 ± 6.531
0–6 Δ Exophoria	6.20 ± 1.802	8.76 ± 1.942	16.96 ± 2.835	13.20 ± 2.943	18.40 ± 4.301	14.30 ± 4.497
≥7 Δ Exophoria	6.77 ± 1.715	9.22 ± 2.048	16.44 ± 4.333	12.22 ± 2.108	18.44 ± 3.395	13.55 ± 3.8441

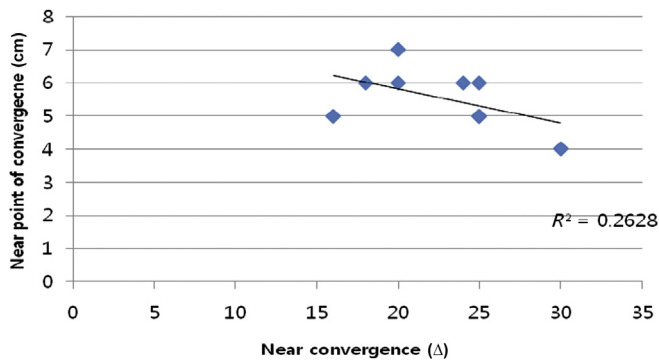
NNFVBP = near negative fusional vergence break point; NNFVRP = near negative fusional vergence recovery point; NPCBP = near point of convergence break point; NPCRP = near point of convergence recovery point; NPFVBP = near negative fusional vergence break point; NPFVRP = near negative fusional vergence recovery point.

Table 7

Correlation of heterophoria versus near point of convergence and vergence range in high myopia.

High myopia	NPCBP (cm)	NPCRP (cm)	NNFVBP (Δ)	NNFVRP (Δ)	NPFVBP (Δ)	NPFVRP (Δ)
Esophoria	6	8	14	12	20	16
0–6 Δ Exophoria	5.00 \pm 0.707	7.40 \pm 0.894	19.80 \pm 4.381	15.20 \pm 4.604	22.8 \pm 5.718	18.20 \pm 4.604
$\geq 7 \Delta$ Exophoria	6.33 \pm 0.577	9.00 \pm 0.00	16.66 \pm 5.773	12.66 \pm 4.163	23.0 \pm 2.645	18.0 \pm 2.000

NNFVBP = near negative fusional vergence break point; NNFVRP = near negative fusional vergence recovery point; NPCBP = near point of convergence break point; NPCRP = near point of convergence recovery point; NPFVBP = near negative fusional vergence break point; NPFVRP = near negative fusional vergence recovery point.

**Figure 3.** Correlation of near point of convergence (cm) and near convergence (Δ) in high myopia.

classify horizontal heterophorias, such as esophoria, 0–6 Δ exophoria, and $\geq 7\Delta$ exophoria. Previous studies reported the greater incidence of horizontal heterophoria, either esophoria or exophoria, from 6 years of age.^{2,14,17} In our study, the prevalence of esophoria increased with age of the patients, especially from age 11–13 years. This tendency can be related to the increased amount of near work and stress since the children started school,¹⁴ and the presence of heterophoria can affect children's performance at school. Various studies compared the mean values of near phoria with slightly different age groups.^{11,14,23} Walline et al²³ compared the mean values of near phoria between kindergarteners and fifth graders and found that the older group presented more convergent in near phoria. This result was backed up with Chen et al's¹⁴ and Leone et al's¹¹ study. In our study, the mean values of near phorias showed the tendency of convergent as well. However, the mean values of near phoria were much larger than other studies and we think this is because of a different study method that most of studies used, modified Thorington, whereas we used the von Graefe method.

Many studies were conducted on the mean values of negative and positive fusional vergences with different patients and techniques. Wesson²⁴ measured fusional vergence with prism bar with children aged 7–12 years, and concluded there was no significant relationship between the children's age and fusional vergence. However, Jiménez et al² used prism bar with patients aged 6–12 years, and concluded there were statistically significant differences between the 6–7 years group and the 8–12 year group. Interestingly in our study, only near positive fusional vergences (break and recovery point) were statistically significant, yet we used Risley prism. Our mean values on negative fusional vergence are much higher compares with other studies with prism bar, and we think this is because of the limitation on ease of application of the Risley prism method on elementary school children.

According to Chew et al,²⁵ esophoria is more prevalent in Western countries, whereas exophoria is more prevalent in Eastern countries. Esophoria at near is mainly related to hyperopia, whereas exophoria at near is mainly related to myopia, thus correcting refractive errors should be able to provide the least support

for the heterophoria. In terms of prescribing for the heterophoria, adjusting spherical refractive power without prescribing prism can help to change the amount of the heterophoria.²⁶ Therefore, when determining the prescription of the refractive errors, the impact of corrective power should be considered. Chew et al²⁵ reported that twice as much of fusional reserve than the amount of heterophoria is necessary to maintain comfortable binocular function. In other words, asthenopia caused by heterophoria is closely correlated with fusional reserves. Therefore, it is necessary to measure positive and negative relative convergence to relieve asthenopia.

Several studies agreed that the onset and progression of myopia is associated esophoria at near.^{12,13,27,28} and with a higher degree of myopia.²⁹ In Leone et al's¹¹ study, more 6-year-old children presented with lower myopia than those aged 12 years, and they found the significant association between myopia and near heterophoria. However, in our study, the degree of myopia and near fusional vergence did not present the significant association. In general, esophores present a divergent shift at near and it is necessary to increase the fusional divergence while exophores present convergent shift and it is necessary to increase fusional convergence. Thus, it is important to perform the study on the correlation between myopia and the fusional reverse in future study. Chen and Abidin³⁰ investigated the fusional reserve and concluded the fusional reserve component of vergence varied with children's age. In the present study, there was no correlation between myopia and near fusional vergence, and we think this is possible because even with a higher refractive error convergence and divergence reserves improve with age.

5. Conclusion

In this study, there was no statistically significant correlation between participant's age and NPC, near horizontal heterophoria, and near fusional vergence, except near positive fusional vergence. Also, unlike many studies, myopic magnitude did not present a significant correlation with near phoria and fusional vergence. In the future, it could be useful to perform the study with different techniques, such as modified Thorington and prism bar, to compare with the current study.

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