The Prevalence of Fusional Vergence Dysfunction in a Population in Iran

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Abstract

Purpose: To determine the prevalence of fusional vergence dysfunction (FVD) and its relationship with age, sex, and refractive errors in a population-based study.

Methods: In this cross-sectional study, all residents of Mashhad, northeast of Iran, aged >1 year were subjected to random stratified cluster sampling. After selecting the participants, they all underwent complete optometric examinations including the measurement of visual acuity and refraction, assessment of binocular vision and accommodative status, and slit-lamp biomicroscopy.

Results: Of 4453 invited individuals, 3132 participated in the study. After applying the exclusion criteria, statistical analysis was performed on the data of 1683 participants. The prevalence of FVD was 3.2% in all participants, 4.0% in men, and 2.9% in women ($P = 0.234$). The prevalence of FVD increased linearly with aging from 2.3% in the age group of 10–19 years to 5.4% in the age group of 40–49 years ($P = 0.034$). The prevalence of myopia, hyperopia, and emmetropia was 11.1%, 29.6%, and 59.3% in participants with FVD and 16.7%, 26.4%, and 57% in participants without FVD, respectively ($P = 0.570$). Multiple logistic regression analysis only showed a significant association between age and FVD (odds ratio =1.03 95% confidence interval: 1.02–1.05, $P = 0.031$).

Conclusion: The prevalence of FVD in this study was higher than most previous reports and increased significantly with aging. FVD had no significant association with sex and refractive errors.

Keywords: Fusional vergence dysfunction, Iran, Mashhad, Prevalence

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Introduction

Fusional vergence dysfunction (FVD) is a binocular vision disorder with an unknown etiology.[1] In this condition, accommodative convergence/accommodation (AC/A) ratio is normal, distance and near heterophorias are within the expected values, and accommodative function is intact, but fusional vergence findings are restricted in both positive and negative directions.[2,3] This binocular disorder is also known by other terms such as inefficient binocular vision and sensory fusion deficiency in older literature.[4-6] FVD is often associated with multiple symptoms, often during reading or other sustained near work.[7,8] Some patients with FVD avoid near-visual activities like reading to prevent these symptoms; therefore, it may interfere with the educational, athletic, and occupational performance of the patients, resulting in decreased quality of life.[2,3,9] Hence, diagnosis

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and effective treatment of this disorder are important issues in the optometric practice.[8]

FVD has received less attention than other binocular vision anomalies, and there is little information available about its different aspects in the literature.[3,10] This disorder is not included in Duane's classification of binocular vision disorders (as the most well-known classification system) and is also overlooked in other binocular vision classification approaches including the graphical analysis approach, analytical analysis approach proposed by the optometric extension program, and Morgan's system of clinical analysis.[3,11] Therefore, FVD is an important yet lesser-known diagnostic category that can be easily missed or dismissed by clinicians, and this can result in a lack of management or mismanagement of this disorder.[3,8]

Despite the importance of this anomaly and its diagnostic challenges, there is little information about its prevalence in the literature.[3,10,12] Few studies have investigated FVD, and its prevalence has been reported from 0.4% to 4.7% in different studies,[13-19] which is much lower than the prevalence rates reported for near binocular vision disorders, including convergence insufficiency and convergence excess.[1,18,20] It should be mentioned that most of these studies are not population-based and were done on a selected clinical population with a small sample size and limited age range. Therefore, their results cannot be generalized to the general population.[10,12] Moreover, considering limitations in the available literature, there is no information about the relationship of FVD with factors such as age, gender, and refractive errors. As a result, the nature of this anomaly and its risk factors are unknown.[10]

Knowledge of the prevalence of a disorder is important to form a clinical hypothesis about its possible diagnosis and decision regarding the process that should be followed.[12] Epidemiological data are also important for organizing proper screening programs, conducting research projects, and adopting visual health political strategies.[10,20] Therefore, the aim of the present research was to study the prevalence of FVD in a population-based study with large sample size and wide age range of participants. In addition to its prevalence, we also explored its association with factors such as age, sex, and refractive errors to achieve a clearer picture of the nature of this disorder and its risk factors.

Methods

The present cross-sectional study was part of the Mashhad Eye Study,[20,21] a multipurpose study designed to evaluate different aspects of refractive, accommodative/binocular, and ocular health status in a large sample of an Iranian population. The study population was all Mashhad (Khorasan Razavi province, northeast of Iran) residents >1 year of age. Random stratified cluster sampling was applied to select participants proportional to the population of different districts of the city (municipality districts were considered as strata). A number of clusters were selected in each district proportional to the number of households in that district. A total of 120 clusters were randomly selected from blocks determined by Khorasan Razavi Statistics Center, and the first house number of each cluster was considered the head cluster. In each cluster, sampling was continued systematically; if a household was not willing to participate in the study or was not present in the house, the next household was invited. All individuals were reimbursed for the cost of transportation to the clinic. In the clinic, demographic data and history of ocular examination, eye diseases, eye trauma, ocular surgery, and use of systemic and ophthalmic drugs were asked in face-to-face interviews and recorded.

Examinations included the measurement of visual acuity and refraction, accommodative and binocular vision tests, and ocular health examination. All optometric examinations were performed by two experienced optometrists (one optometrist was responsible for visual acuity measurement and refraction, and the other was responsible for binocular/accommodative examinations). First, uncorrected distance visual acuity was measured using a Snellen E chart at 6 meters (m). Then objective refraction was done to assess the refractive status using the Topcon KR-8000 auto refractometer (Paramus, New Jersey, USA), and the results were refined with the HEINE BETA 200 retinoscope (HEINE Optotechnik, Herrsching, Germany). Finally, subjective refraction was done to determine the best distance and near optical correction, and the best distance and near corrected visual acuities (BCVAs) were recorded.

In the next stage, binocular and accommodative examinations were done with the best optical correction according to standard clinical protocols of the tests.[3] Near tests were conducted through appropriate addition lenses – determined via near subjective refraction – for presbyopic individuals. First, unilateral and alternate cover tests were conducted to assess ocular alignment at far (6 m) and near (40 cm) using a prism bar, and the magnitude of distance and near heterophorias was measured and recorded in prism diopter (PD). The target used for the cover test was an accommodative target, including a single letter one line above the BCVA on the near and distance Snellen charts.

Then, the amplitude of positive and negative fusional vergences (PFV and NFV) were measured at far (6 m) and near (40 cm) by the step method using the base-out and base-in prisms of a prism bar, respectively. To prevent the impact of adaptation to the base-out prism on the NFV measurement, PFV was measured after NFV. The target used for this test was a column of 20/30 letters on the distance (to measure fusional vergences at far) or near (to measure fusional vergences at near) Snellen chart. During the test, a prism bar was held in front of the participant's right eye, and the subject was asked to keep the target as single and clear as possible and report when sustained blur or diplopia occurred as the prism bar was moved. The amount of prism increased at a constant rate of 2 PD per second until the person reported first sustained blur and then diplopia. The prism power was then decreased at a rate of 2 PD per second to reach recovery of binocular fusion. Finally, prism powers at the points of blurred vision, diplopia, and fusion recovery were recorded as blur/break/recovery.

In the next step, monocular accommodative amplitude (AA) was measured first for the right eye and then the left eye using the Donder's push-up method. The target (one line above the BCVA on the near Snellen chart) was slowly moved toward the person at a rate of 1–2 cm/s, and the subject was asked to keep the target as clear as possible and report first sustained blur. At this point, the distance from the target to the spectacle plane was measured and recorded as the near point of accommodation (NPA). NPA was measured three times, and the mean of three measurements was considered the final NPA. To convert NPA (cm) to AA in diopters (D), 100 was divided by the final NPA.

Then, binocular accommodative facility (BAF) was tested for indirect assessment of fusional vergence dynamics using +2 and -2 D flipper lenses and 20/30 letters of near Snellen chart as the target. The participant was instructed to try to get the target clear and single as quickly as possible as positive and negative lenses were alternately held before his/her eyes and report as soon as the target became clear by saying the word "clear." Each instance of clearing both plus and minus lenses was considered one cycle, and the number of cycles in 1 min (cpm) was recorded as BAF finding. Before measuring BAF, the test was performed once for demonstration. BAF testing was done using the amplitude scaled facility approach[3] in individuals >30 years, and the lens power and distance were adjusted accordingly. In amplitude scaled BAF testing, the test distance was calculated with the following formula: 100/0.45×AA. The power of each lens was selected as 15% of AA.[3] For example, in a patient with the measured AA of 5.00 D, the testing distance and lens power range would be 44.50 cm (100/0.45 × 5.00) and 1.50 D (0.30 × 5.00; 1.50/2 = ±0.75 flipper lenses), respectively.

Monocular accommodative facility (MAF) was tested first for the right eye and then the left eye using +2 and −2 D flipper lenses. A near Snellen chart was placed at 40 cm, and the participant was asked to look at the 20/30 line of letters. The patient was instructed to get the letters clear as quickly as possible as positive and negative lenses were placed before his/her eye alternately and report as soon as the letters became clear by saying the word "clear". Each instance of clearing both plus and minus lenses was considered one cycle, and the number of cpm was recorded as MAF finding. To measure MAF in individuals >30 years, the amplitude scaled facility approach was used, and the lens power and distance were adjusted accordingly.

Finally, slit-lamp examination was done by an ophthalmologist to evaluate ocular health. Posterior segment examination was done using +90 Volk lens.

The exclusion criteria included manifest strabismus, amblyopia, BCVA <20/30 in either eye, history of ocular trauma and intraocular surgery, any systemic or ocular pathology affecting binocular vision and accommodation, and the use of systemic or ophthalmic drugs affecting binocular vision and accommodation. The age group <10 years and over 49 years was excluded from the analysis due to the small sample size and possible poor reliability of the subjective data.

Myopia and hyperopia were defined as the spherical equivalent of subjective refraction ≤−0.5 D and >+0.5 D, respectively. Clinically significant near heterophoria was defined as exophoria more than 6 PD or any esophoria at 40 cm.[3] Clinically significant distance heterophoria was defined as distance exophoria more than 3 PD or distance esophoria >1 PD.[3] The following criteria were used to diagnose FVD according to the guideline proposed by Scheiman and Wick.[3] These criteria have also been used in other epidemiological studies[16] and are considered a valid reference in binocular epidemiological studies. To diagnose FVD, the presence of items 1 and 2 and one of the items 3 or 4 was necessary.

1. Lack of clinically significant distance or near heterophoria
2. Normal MAF ≥8 cpm
3. Deficient both NFV and PFV at both near and far distances (break value <10 and 15 PD at near and <6 and 10 PD at far for NFV and PFV, respectively)
4. BAF <8 cpm with the patient having problems with both positive and negative lenses.

Statistical analysis

The prevalence of FVD is reported as a percentage and 95% confidence interval (CI) in all subjects as well as the age groups 10–19, 20–29, 30–39, and 40–49 years. The effect of cluster sampling was considered in the calculation of standard error. Simple and multiple logistic regression was applied to evaluate the relationship between FVD and other factors.

Ethical issues

The Ethics Committee of Mashhad University of Medical Sciences approved the study protocol, which was conducted in accordance with the tenets of the Declaration of Helsinki. All participants signed a written informed consent (Ethics Code: 86170).

Results

In this study, 3132 of the 4453 invitees participated in the study (response rate = 70.4%). After applying the exclusion criteria, the final analysis was performed on the data of 1683 participants. The mean age of the participants was 27.8 ± 11.9 years (range, 10–49), and 1156 of the participants were female (68.7%).

The overall prevalence of FVD was 3.24% (95% CI: 2.24–4.24). The prevalence of FVD was 4.02% (95% CI: 2.22–5.82) in men and 2.89% (95% CI: 1.83–3.95) in women. Simple logistic regression analysis showed no significant difference in FVD prevalence between men and women ($P = 0.219$). Table 1 shows the prevalence of FVD in different age groups. According to Table 1, the prevalence of FVD showed a linear increase from 2.35% in the age group 10–19 years to 5.4% in the age group 40–49 years. Chi-square test showed a significant association between age and the prevalence of FVD ($P = 0.034$). The prevalence of myopia, hyperopia, and emmetropia was 11.1%, 29.6%, and 59.3% in participants with FVD and 16.7%, 26.4%, and 57% in participants without FVD, respectively ($P = 0.570$). Multiple logistic regression in the presence of age, sex, and refractive error showed that only age had a significant association with FVD (OR =1.03 95% CI: 1.02–1.05, $P = 0.031$). Table 2 shows the distribution of near and far phoria, NFV, PFV, MAF, BAF, AA, and SE in participants with and without FVD. Table 3 shows the results of multiple linear regression models for the NFV, PFV, MAF, and BAF in the presence of age and sex. According to Table 3, statistically significant negative associations were found between age with near PFV break, BAF, and MAF. There were also statistically significant relationships between sex with near NFV blur and near NFV break so that these two parameters were higher in women than men.

Table 1: Prevalence of fusional vergence dysfunction by age and gender

	n	Percentage (95%CI)
Total	1683	3.24 (2.24-4.24)
Gender		
Male	527	4.02 (2.22-5.82)
Female	1156	2.89 (1.83-3.95)
Age		
10-19	521	2.35 (1.00-3.70)
20-29	409	2.18 (0.54-3.82)
30-39	385	3.47 (0.70-6.24)
40-49	367	5.45 (2.65-8.26)

CI: Confidence interval

Discussion

In this population-based study, we evaluated the prevalence of FVD in a large sample size with a wide age range. According to the results, the overall prevalence of this disorder was 3.2%. According to the results of previous studies, which are presented in Table 4, the prevalence of FVD varies from 0.4% to 4.7%, indicating a relatively high prevalence in our study.

Different factors, such as differences in the study design, sampling method, study population, measurement method, and diagnostic criteria may contribute to this difference in prevalence rates. As for the study design and sampling method, it should be noted that most previous studies were not population-based and were done on small selected clinical samples; therefore, their findings could not be generalized to the general population. Population-based studies and standard random sampling methods are required for accurate estimation of the prevalence of a disorder in a population.[22] As for the target population, all previous studies focused on children and young adults; therefore, there is no information on the prevalence of FVD in older age groups, especially in the presbyopia age range. In this study, the prevalence of this anomaly was investigated in a wide age range, which is very important, considering the relationship between age and FVD found in this study. Moreover, there are differences in measurement methods and diagnostic criteria among studies (in terms of the cut-off points of tests and number of criteria), which is the other possible reason for differences in FVD prevalence between different studies. We used clinical standards to measure binocular and accommodative indices to increase the reliability of the data. For example, we evaluated both the amplitude and dynamics of the vergence system even though its dynamics have been overlooked in many previous studies. A person suffering from symptomatic FVD may have normal amplitudes of fusional vergence but impaired facility or dynamics,[23,24] resulting in underestimation of the prevalence

Table 2: Comparison of near and far phoria, fusional vergence amplitudes, monocular and binocular accommodative facility (monocular accommodative facility and binocular accommodative facility), and spherical equivalent refraction in cases with and without fusional vergence dysfunction

Index	FVD, mean±SD (range)		*P*
	Yes	No	
Distance phoria (PD)	0.05±0.29 XP (orthophoria-3.00 XP)	0.05±0.37 XP (1.00 EP-3.00 XP)	0.99
Near phoria (PD)	1.82±2.10 XP (2.00 XP-6.00 XP)	1.81±2.17 XP (orthophoria-6.00 XP)	0.96
Distance NFV (break) (PD)	1.76±0.43 (1.00-4.00)	8.17±3.65 (6.00-10.00)	<0.001
Distance PFV (break) (PD)	2.76±1.75 (2.00-8.00)	13.55±6.71 (10.00-22.00)	<0.001
Near NFV (break (PD)	5.06±2.03 (4.00-10.00)	15.91±4.38 (12.00-20.00)	<0.001
Near PFV (break) (PD)	6.53±3.66 (4.00-12.00)	18.34±7.84 (15.00-25.00)	<0.001
MAF (cpm)	10.05±4.80 (8.00-14.00)	10.55±5.20 (8.00-16.00)	0.77
BAF (cpm)	3.18±3.02 (0.00-7.00)	9.22±4.40 (8.00-15.00)	<0.001
AA (D)	7.51±3.75 (3.03-16.67)	11.18±6.53 (1.25-50.00)	<0.001
SE (D)	0.27±1.00 (−3.75-2.00)	0.13±1.14 (−8.5-6.75)	0.35

FVD: Fusional vergence dysfunction, SD: Standard deviation, PD: Prism diopter, NFV: Negative fusional vergence, PFV: Positive fusional vergence, MAF: Monocular accommodative facility, cpm: Cycles per minute, BAF: Binocular accommodative facility, AA: Accommodative amplitude, SE: Spherical equivalent, XP: Exophoria, EP: Esophoria

Table 3: Multiple linear regression models for fusional vergence amplitudes, monocular and binocular accommodative facility in the presence of age and sex

	Coefficient (*P*)	
	Sex	**Age (year)**
Distance NFV break (PD)	0.395 (0.059)	−0.011 (0.190)
Distance PFV blur (PD)	0.159 (0.226)	−0.004 (0.448)
Distance PFV break (PD)	0.156 (0.711)	0.010 (0.489)
Near NFV blur (PD)	0.394 (0.016)*	0.011 (0.085)
Near NFV break (PD)	0.566 (0.019)*	−0.012 (0.209)
Near PFV blur (PD)	0.103 (0.803)	−0.024 (0.139)
Near PFV break (PD)	0.156 (0.711)	−0.041 (0.015)*
BAF (cpm)	0.014 (0.680)	−0.152 (<0.001)*
MAF (cpm)	0.018 (0.425)	−0.108 (0.020)*

*$P<0.05$. NFV: Negative fusional vergence, PD: Prism diopter, PFV: Positive fusional vergence, BAF: Binocular accommodative facility, cpm: Cycles per minute, MAF: Monocular accommodative facility

Table 4: The reported prevalence of fusional vergence dysfunction in the literature

First author	Prevalence %	Target population	Study setting
Scheiman[13]	0.4	Children	Clinical
García-Muñoz[19]	0.57	Young adults	University
Darko-Takyi[15]	0.8	Children	School
Hussaindeen[16]	Rural: 0.8 Urban: 1.3	Children	Population-based
Porcar[14]	1.5	Young adults	Clinical
Present study	3.2	All age groups	Population-based
Wajuihian[18]	3.3	Children	School
Paniccia[17]	4.7	Children	Clinical

of FVD. Moreover, we used the criteria recommended by Wick and Scheiman[3] for the definition of FVD, which are accepted as a valid guideline in binocular vision studies.

We believe that the high prevalence of FVD in the present study, apart from its epidemiological aspect, is clinically important. As mentioned earlier, this anomaly has been less investigated compared to other binocular vision disorders.[3,10] It is not included in Duane's classification of binocular dysfunctions and is not defined in the majority of the binocular vision analysis systems.[2,3,11] As a result, it may be easily missed or dismissed by clinicians. For example, a patient may present with asthenopic symptoms, without significant refractive errors, normal eye health, intact accommodative function, normal AC/A, and clinically unremarkable distance and near heterophorias. In this situation, many clinicians may not assess fusional vergences due to normal heterophoria at all distances; therefore, FVD will not be diagnosed in this case. Considering the high prevalence of FVD in the present study, we recommend that the amplitude of both PFV and NFV and facility of accommodation should be measured in all symptomatic subjects as a routine to avoid missing this disorder.

We evaluated the relationship between age and FVD. According to our findings, the prevalence of FVD increased linearly with age from 2.3% in the age group 10–19 years to 5.4% in the age group of 40–49 years. Therefore, there was a significant relationship between age and FVD. The age-related increase in the prevalence of FVD may be explained by a decrease in the amplitude of fusional vergences, accommodative vergence, and vergence facility with aging. We used multiple regression models to identify the possible cause of age-related increase in the prevalence of FVD. The results showed no marked changes in blur values of fusional reserves with aging. Since blur values indicate pure fusional vergence,[3,11] the findings of the present study suggest that fusional vergence is not affected by age. On the other hand, the break values of fusional vergences, except for distance base-out break, decreased with aging although this decrease was only statistically significant for near base-out break.[25] Since break values indicate the sum of fusional and accommodative vergences,[3,11] considering the lack of change in fusional vergence with age, this decrease may be attributed to an age-related decrease in accommodative vergence. In the present study, BAF also decreased markedly with age. The age-related decrease in BAF may result from reduced accommodative effort along with reduction in AA[25] or a decrease in fusional vergence dynamics/facility since BAF testing evaluates vergence facility indirectly as well.[26] Similar findings were observed in the study by Yekta *et al*. regarding the age-related changes in fusional vergences and BAF.[25] We believe that the age-related increase in the prevalence of FVD mostly results from a decrease in the accommodative effort (leading to vulnerability of the vergence system through decreasing the effect of accommodative vergence and increasing the demand on fusional vergence) or a decrease in vergence facility due to decreased plasticity of the vergence system.

The relationship between FVD and gender was assessed in the present study. Although the prevalence of FVD was higher in men than in women (4.0% vs. 2.9%), this difference was not statistically significant. Therefore, the findings of this study do not suggest a statistically significant association between sex and FVD. We also evaluated the relationship between FVD and refractive errors but found no significant association. It should be mentioned that no certain trend has been reported relative to refractive errors in FVD, according to the literature.[3] Scheiman and Wick also reported that in their clinical experience, FVD patients lack clinically significant refractive errors.[3] We proved this point in an evidence-based manner in our study; therefore, refractive errors are not considered a risk factor for FVD.

One of the strengths of this study was its robust design. It was one of the very few population-based studies in the field of binocular vision. Moreover, a large sample size, meticulous exclusion and exclusion criteria, and the use of standard diagnostic criteria were other strong points of this study. Considering the possibility of a relationship between ethnicity and binocular vision disorders,[10] further studies are required in different ethnic groups. One limitation of the present study is the subjective nature of the most reported accommodative and binocular data.

In conclusion, the prevalence of FVD was 3.2% in this study, which was higher than most previous reports. The prevalence of this disorder increased significantly with age. FVD had no significant association with gender and refractive errors.

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Conflicts of interest

There are no conflicts of interest.

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