Association of Ocular Dominance and Anisometropic Myopia

Ching-Yu Cheng,1,2,3,4 May-Yung Yen,1,2 Hsin-Yi Lin,2 Wet-Wei Hsia,2 and Wen-Ming Hsu1,2

PURPOSE. To determine the association between ocular dominance and degree of myopia in patients with anisometropia.

METHODS. Fifty-five subjects with anisometropic myopia were recruited. None of them had amblyopia. Refractive error and axial length were measured in each subject. Ocular dominance was determined using the hole-in-the-card test and convergence near-point test.

RESULTS. There was a threshold level of anisometropia (1.75 D) beyond which the dominant eye was always more myopic than the nondominant eye. Of the 35 subjects with anisometropia of ≤1.75 D, the dominant eye was more myopic in 17 (51.5%) subjects. Dominant eyes, determined by the hole-in-the-card test, had a significantly greater myopic spherical equivalent (−5.27 ± 2.45 D) than nondominant eyes (−3.94 ± 3.10 D; P < 0.001). Dominant eyes also had a longer axial length than nondominant eyes (25.15 ± 0.96 mm vs. 24.69 ± 1.17 mm, respectively; P < 0.001). The difference was more evident in those subjects with higher anisometropia (>1.75 D), but was not significant in those with lower anisometropia (≤1.75 D). Similar results were obtained using the convergence near-point test.

CONCLUSIONS. The present study shows that the dominant eye has a greater degree of myopia than the nondominant eye in subjects with anisometropic myopia. Taking ocular dominance into account in the design of randomized clinical trials to assess the efficacy of myopia interventions may provide useful information. (Invest Ophthalmol Vis Sci. 2004;45:2856–2860) DOI:10.1167/iovs.03-0878

Functional lateralization occurs in the paired organs of the body, such as hands, legs, and cerebral hemispheres. Ocular dominance, first described in 1593, is the tendency to prefer visual input from one eye over the other,1-3 and may be defined as the faculty whereby one of the eyes commonly dominates or leads the other eye, both in fixation and attention or in perceptive function.4 Ocular dominance is related to some ocular mechanism or function, such as eye movement.5

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or amblyopia,6 and is thought to be important in the control of reading. A recent report suggests that ocular dominance is an important determinant of the visual handicap suffered by patients with unilateral macular hole.9 The recent success of monovision for presbyopic correction by refractive surgery or contact lenses9,10 further demonstrates the impact of ocular dominance on visual outcomes. Beyond these examples, however, the association between ocular dominance and other eye conditions or diseases is poorly understood.

The prevalence of myopia has increased dramatically in recent years in many parts of the world.11 Nevertheless, the etiology of myopia remains unclear, although both genetic and environmental components are thought to be involved. The “use–abuse theory” states that sustained near work or prolonged reading leads to the development of myopia.12 A more recent theory suggests that if the accuracy of accommodation during near work is not maintained, the defocused retinal image leads to the development of myopia.13-15 The dominant eye plays a primary role in accommodation during binocular viewing, with an increased static tonus of its ciliary muscle compared with that of the nondominant eye.16 The increased static tonus of the ciliary muscle may interfere with normal accommodative responses. Because ocular dominance represents the tendency to prefer visual input from the dominant eye, the preferential use of the dominant eye for viewing might render the dominant eye more myopic than the nondominant eye.

Anisometropia, a relative difference in the refractive state of the two eyes, is not uncommon in myopic patients.1,2 If ocular dominance has a role in the mechanism of myopia, this effect would be most manifest in those with anisometropic myopia. Dominant eyes may be more myopic than nondominant eyes in patients with anisometropic myopia. Studies of the association between ocular dominance and myopic refractive error might help to elucidate the mechanisms underlying myopia.

SUBJECTS AND METHODS

Between February 2001 and October 2002, 55 subjects with anisotropic myopia were recruited from patients who attended clinics for refractive errors and itchy eye. All subjects included in this study underwent a complete ophthalmic examination and ascertainment of ocular and hand dominance. In this study, a diagnosis of anisometropic myopia was made if an individual had a spherical equivalent of less than −0.5 diopters (D) in one eye and no more than 0 D in the other eye, and a difference in spherical equivalent of at least 0.5 D between the two eyes. The following inclusion criteria were required: orthophoria determined by the cover test, and an optimum distance correction giving an equal vision of better than 20/22 (6/6.7) in the two eyes (i.e., the absence of amblyopia). Because anisometropia is associated with amblyopia,17 only nonamblyopic subjects were included in the study to avoid any effect of amblyopia on ocular dominance.18 Subjects were not eligible and were excluded from the study for any one of the following: history of ocular surgery including cataract or refractive surgery; history of strabismus or ptosis; any clinically significant retinal pathology, glaucoma, optic neuropathy, optic disc anomalies or other diseases that might affect visual acuity after correction; and the presence of marked facial asymmetry. The

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study protocol was conducted according to the tenets of the Declaration of Helsinki of the World Medical Association regarding scientific research on human subjects. Informed consent was obtained from the subjects after explanation of the nature and possible consequences of the study.

Clinical Measures

Ocular dominance was determined using the hole-in-the-card test (Dolman method) and convergence near-point test. In the hole-in-the-card test, the subject was given a piece of cardboard in which there was a central circular hole 3 cm in diameter. The patient was asked to hold the cardboard with both hands and to view a target 6 m away through the hole, with both eyes open. Each eye was then occluded in turn. When the dominant eye was covered, the target could not be seen through the hole. Alternatively, when the nondominant eye was covered, the dominant eye continued to fix the target through the aperture. This test is a “forced choice” test of dominance, which allows only a right or left eye result.

For the convergence near-point test, ocular dominance was confirmed by having the subject fixate on an object that was moved toward the nose until divergence occurred in one eye, which was taken to be the nondominant eye. The divergence in one eye was judged by an ophthalmologist, who was masked with respect to which eye was more myopic. The convergence near-point test has the advantage of being largely objective. It might be difficult, however, to decide which eye deviates first in some subjects, whose ocular dominance would be classified as “undetermined”.

Each of the two ocular dominance tests was repeated at least three times to confirm dominance. For both ocular dominance tests, subjects with different results on the repeated measures were not included in this study (e.g., right ocular dominance on the first measurement, but left ocular dominance on the repeated measurement). If the result of the hole-in-the-card test was contrary to that of the convergence near-point test in an individual (e.g., right ocular dominance by hole-in-the-card test but left ocular dominance by convergence near-point test, and vice versa), the condition was identified as “disagreement” between the two tests.

Hand dominance was ascertained by interview. Each subject was asked his/her handedness, especially for near-work activity such as writing, using a hammer or a screwdriver, and using chopsticks when eating.

Autorefration (RK-8100; Topcon, Tokyo, Japan) was used to obtain at least five consecutive refraction measures. After instillation of 0.5% proparacaine, three drops of 1% cyclopentolate were instilled 10 minutes apart to induce cycloplegia in each eye. Autorefration was measured at least 50 minutes after the last drop of cyclopentolate was instilled. Refraction data were converted to spherical equivalents. The spherical equivalent is derived by adding the spherical component of a refraction to half the cylindrical component. The axial lengths of the eyes, considered to be the principal cause of myopic anisometropia, were measured in each subject using A-scan ultrasonography (AL-1000; Tomey Corporation, Nagoya, Japan) at a probe frequency of 10 MHz. Before ultrasound biometry measurements were made, one drop of 0.5% proparacaine was instilled into the lower cul de sac. The subject was asked to sit up straight and fixate on an eye-level target on the wall. Care was taken to ensure that the ultrasound probe did not compress the cornea. An average of ten axial length measurements were taken, which were accepted only if the SD of these ten readings was <0.12 mm.

Statistical Analysis

Data analyses were performed using the commercial statistical software package, Stata (Stata Corporation, College Station, TX). The assumption of normality of the data was assessed using the Shapiro-Wilk test. A two-tailed P-value of <0.05 was considered to be significant. The Kappa statistic was used to assess the agreement between the two ocular dominance tests. The pattern of hand–ocular dominance was classified as “uncrossed” dominance (i.e., both right eye and hand or both left eye and hand dominance) or “crossed” dominance (i.e., left eye and right hand or right eye and left hand). The association between hand dominance and ocular dominance was assessed using Fisher’s exact test. The difference in spherical equivalent or axial length between the two eyes (the dominant vs. nondominant eyes, or the right vs. left eyes) was compared with a paired Student’s t test. With a sample size of 55, the study had sufficient power (80%) to detect a difference of 0.70 D in spherical equivalent and 0.31 mm in axial length between the nondominant and dominant eyes. To determine the relationship between ocular dominance and the degree of anisometropic myopia, a graph was plotted with the average amount of myopia in the left and right eyes on the x-axis versus the amount of anisometropia on the y-axis. The likelihood that the dominant eye was more myopic as a function of the amount of anisometropia was assessed using multivariate logistic regression analysis, controlling for the potential effects of hand–ocular dominance pattern on the degree of myopia.

RESULTS

A total of 55 eligible subjects were enrolled. The mean age was 30.3 ± 9.5 years; 27 (49%) subjects were female. The average spherical equivalent of the right and left eyes was −4.60 ± 2.66 D, and there was no significant difference in spherical equivalent between the right eye (−4.72 ± 2.78 D) and the left eye (−4.49 ± 2.96 D; P = 0.453). The average axial length of the two eyes was 24.89 ± 1.03 mm, and the axial length of the right eye (25.00 ± 1.19 mm) did not differ significantly from that of the left eye (24.78 ± 1.05 mm; P = 0.067).

Table 1 shows the results of the ocular dominance tests. When ocular dominance was determined using the hole-in-the-card test, right ocular dominance was present in 55 (63.6%) of the 55 subjects and left ocular dominance in 20 (36.4%) subjects. The convergence near-point test indicated right ocular dominance in 24 (43.6%) subjects and left ocular dominance in 18 (32.7%); the other 13 (23.6%) subjects were classified as “undetermined”. Disagreement between the results of the two ocular dominance tests occurred in five (9.1%) subjects. The agreement of measurements was moderate (Kappa = 0.46, P < 0.001) between the two tests for all subjects. For subjects whose ocular dominance could be determined by both tests (n = 42), the agreement of measurements was good (Kappa = 0.76, P < 0.001).

<table>
<thead>
<tr>
<th>Table 1. Dominant Eyes by Ocular Dominance Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hole-in-the-Card Test</strong></td>
</tr>
<tr>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td><strong>Right eye</strong></td>
</tr>
<tr>
<td><strong>Left eye</strong></td>
</tr>
<tr>
<td><strong>Total (%)</strong></td>
</tr>
</tbody>
</table>

Data are number of subjects.
Hand dominance was right-sided in 51 (92.7%) subjects, and left-sided in four (7.3%) subjects (Table 2). Using the hole-in-the-card test, 33 (60%) subjects showed uncrossed hand-ocular dominance and 22 (40%) subjects showed crossed dominance. Of the 42 subjects whose ocular dominance could be clearly determined by the convergence near-point test, 21 (50%) had crossed dominance. No significant association was found between hand dominance and ocular dominance by either the hole-in-the-card test or the convergence near-point test (both \( P > 0.05 \) by Fisher’s exact test; Table 2).

Table 2. Ocular Dominance by Hand Dominance

<table>
<thead>
<tr>
<th>Dominant Hand</th>
<th>Right Hand</th>
<th>Left Hand</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>By hole-in-the-card test ((n = 55))</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right eye</td>
<td>32 (91.4%)</td>
<td>3 (8.6%)</td>
<td>35</td>
</tr>
<tr>
<td>Left eye</td>
<td>19 (95.0%)</td>
<td>1 (5.0%)</td>
<td>20</td>
</tr>
<tr>
<td>By convergence near-point test ((n = 42)^*)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right eye</td>
<td>21 (87.5%)</td>
<td>3 (12.5%)</td>
<td>24</td>
</tr>
<tr>
<td>Left eye</td>
<td>18 (100.0%)</td>
<td>0 (0%)</td>
<td>18</td>
</tr>
</tbody>
</table>

* Subjects whose ocular dominance was undetermined by the convergence near-point test were not included.

When ocular dominance was determined using the hole-in-the-card test, the dominant eyes were more myopic \((-5.27 \pm 2.45 \text{ D})\) than the nondominant eyes \((-3.94 \pm 3.10 \text{ D}; P < 0.001)\), and the mean axial length of the dominant eyes \((25.15 \pm 0.96 \text{ mm})\) was significantly longer than that of the nondominant eyes \((24.69 \pm 1.17 \text{ mm}; P < 0.001)\). When ocular dominance was determined using the convergence near-point test, the results were similar. The dominant eyes were again more myopic \((-5.29 \pm 2.36 \text{ D})\) than the nondominant eyes \((-3.89 \pm 3.05 \text{ D}; P < 0.001)\), and had longer axial lengths \((25.15 \pm 0.96 \text{ mm} vs. 24.69 \pm 1.16 \text{ mm}, respectively; P = 0.002)\).

![Figure 1](http://iovs.arvojournals.org/pdfaccess.ashx?url=/data/journals/iovs/932928/)
groups. In the high anisometropia group, the dominant eyes had significantly higher myopic spherical equivalent values and longer axial lengths than the nondominant eyes (both \( P < 0.001 \)), whereas in the low anisometropia group, there were no significant differences in these parameters.

**DISCUSSION**

Ocular dominance was thought to be independent of refraction.\(^1\) The present study indicates that this is not the case in patients with anisometropic myopia. The dominant eye had a higher degree of myopic refractive error and longer axial length than the nondominant eye, especially in patients with high amounts of anisometropia.

To the best of our knowledge, the only available data regarding the association between ocular dominance and refraction was described in a review article by Fink.\(^1\) In an analysis of 32 subjects with myopia, the dominant eye corresponded to the eye with the greater degree of myopia in 19 subjects, whereas in the remaining subjects, the dominant eye was the less myopic one. However, the study described by Fink did not use the same analysis as the present study; that is, neither the difference in the degree of myopia between the two eyes nor the threshold level of anisometropia, beyond which the dominant eye is always more myopic, was reported. In the present study, the dominant eye was always the more myopic eye in those with high anisometropia (>1.75 D), whereas the dominant eye was more myopic in only half the subjects with low anisometropia (≤1.75 D). The higher the amount of anisometropia, the greater the likelihood that the dominant eye was more myopic than the nondominant eye. Accommodation is implicated in the mechanisms underlying myopia.\(^2\) Could a difference in accommodation response between the two eyes explain why the degree of myopia is higher in dominant eyes? In binocular viewing of targets, the accommodative demand on the two eyes is not usually identical, yet the innervation for accommodation in the two eyes is derived from a common source,\(^2\) and the accommodation response in the two eyes is thought to be equal. However, there is some evidence supporting the existence of an anisometric accommodative response.\(^10\) A study comparing the accommodative responses of the two eyes in binocular viewing of real targets showed that myopia shifts were observed in dominant eyes, both in the near position after far-to-near accommodation and in the far position after near-to-far accommodation, and that the near-to-far response was suppressed in the dominant eyes compared with the nondominant eyes.\(^16\) This suggests that under normal conditions, the dominant eye may be in a tonic state and may play the primary role in accommodation in binocular viewing.

Retinal defocus (or the "blur hypothesis") is a more recent hypothesis proposed to explain the development of myopia.\(^14,15\) For those with a reduced capacity for accommodation, near work may result in retinal defocus and blur, and it is this chronic blur that leads to myopia.\(^15\) We speculate that during or immediately after sustained near work, the tonic state of the ciliary smooth muscle in the dominant eye might result in less accommodative accuracy or a greater lag of accommodation compared with that of the nondominant eye, leading to greater defocus. This might explain, in part, why the dominant eye is more myopic.

The extent of ocular dominance appears to vary among individuals, and those with stronger ocular dominance might eventually develop higher amounts of anisometropia, whereas those with less dominance might not. This speculation is supported by the fact that clear ocular dominance could not be determined using the convergence near-point test in nine (27.3%) of the 33 subjects with low anisometropia, compared with only four (18.2%) of 22 subjects with high anisometropia. An important concern is that hand dominance may affect which eye is held closer to the plane of the near task, especially when writing. In subjects with right-hand dominance, the spherical equivalent in the right eye (−4.72 ± 2.80 D) did not differ significantly from that in the left eye (−4.49 ± 2.97 D; \( P = 0.497 \)). There was also no significant difference in spherical equivalent between the two eyes in left-handed subjects. Therefore, hand dominance may not affect the degree of myopia. The lack of association between handedness and refraction is consistent with a previous report.\(^2\) Nevertheless, there remains a limitation in evaluating the association with hand dominance in the present study insofar as only four subjects were left-handed. Further studies with larger sample sizes of

### TABLE 4. Spherical Equivalent and Axial Length in Dominant and Nondominant Eyes (Convergence Near-Point Tests)

<table>
<thead>
<tr>
<th>Variables</th>
<th>High Anisometropia (&gt;1.75 D, n = 18)</th>
<th>Low Anisometropia (≤1.75 D, n = 24)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dominant Eyes</td>
<td>Nondominant Eyes</td>
</tr>
<tr>
<td>Spherical equivalent (D)</td>
<td>−5.23 ± 2.05</td>
<td>−1.95 ± 2.07</td>
</tr>
<tr>
<td>Axial length (mm)</td>
<td>25.13 ± 0.96</td>
<td>24.11 ± 1.17</td>
</tr>
</tbody>
</table>

Data are mean ± SD.  
* \( P \) values for the comparison of the dominant eyes versus nondominant eyes by paired \( t \)-test.
left-handed subjects are required to validate the relationship between handedness and myopic refractive error.

A feature of interest in anisometropia is the predilection for the right eye to be the more myopic of the two eyes. A survey of 1168 subjects revealed that the right eye was more myopic in 55% of cases, whereas the left eye was more myopic in 45%, and this difference was statistically significant. A recent retrospective study of 1356 subjects indicated that the mean spherical equivalent was significantly less in the right eye (−1.23 D) than in the left eye (−1.11 D). In the present study, the right eye (−4.72 D) was generally more myopic than the left eye (−4.49 D), although the difference was not statistically significant. The difference between the present results and those of earlier studies showing right–left eye differences might be attributable to differences in sample size and in the characteristics of the study subjects. In the present study, however, if the comparison was based on ocular dominance, the difference became greater and was significant (−5.27 D in the dominant eye vs. −3.94 D in the nondominant eye; P < 0.001). Therefore, it may be ocular dominance, not eye laterality, that contributes to the observed difference. Previous studies indicated that approximately 65% of individuals are right-eyed. This is consistent with the present study, in which 63.6% of the study subjects were right-eyed according to the hole-in-the-card test. Ocular dominance thus confounds the relationship between eye laterality and the degree of myopia.

Ocular dominance is not established in many children before the age of three, after which it is commonly found. Ocular dominance is stable and reliable (at least within a given viewing situation or stimulus arrangement), and it cannot actually shift unless the vision of the dominant eye is greatly decreased. Therefore, ocular dominance may be apparent before the onset of myopia in most of our subjects. However, the limitations of this study should be considered. That the cross-sectional nature of this study precludes any definite conclusions on the causality or temporal relationship between ocular dominance and myopia is acknowledged. Because myopia may develop early in childhood, further longitudinal studies assessing ocular dominance in myopic children that are developing anisometropia may help to elucidate the causality.

Moreover, there is a need for further studies that evaluate the progression of myopia in the dominant eye compared with that in the nondominant eye. From a therapeutic point of view, it will be interesting to know whether different interventional strategies, such as eye drops or refraction correction, in the dominant and nondominant eyes can effectively slow the progression of myopia in both eyes, particularly in patients with higher amounts of anisometropia.

In conclusion, the dominant eye had a greater myopic refractive error and longer axial length than the nondominant eye, especially in subjects with higher amounts of anisometropia. In subjects with anisometropia beyond 1.75 D, the dominant eye was always more myopic than the nondominant eye. Taking ocular dominance into account in the design of randomized clinical trials to assess the efficacy of myopia interventions may provide useful information.

References