Original Article

Ocular dominance and refractive error: a cross-sectional study of 400 individuals at a tertiary eye hospital in eastern Nepal

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ABSTRACT

Background: Ocular dominance is the consistent preference of using one eye over the other during visual processing, a phenomenon analogous to hand dominance. Ocular dominance often aligns with the eye delivering clearer vision, but does not always correspond to superior visual acuity or refractive status. Mechanisms underlying ocular dominance remain unclear, particularly in individuals whose refractive errors have remained uncorrected since childhood. In this study, we investigated ocular dominance patterns and their association with refractive error and handedness in individuals without early optical correction.

Methods: In this cross-sectional study, we recruited individuals aged 16–40 years with refractive errors, who had no history of spectacle use since childhood, from Biratnagar Eye Hospital, Nepal. Participants underwent anterior and posterior segment examinations using slit-lamp, followed by non-cycloplegic retinoscopy and subjective refraction. Ocular dominance was assessed using the Hole-in-the-Card (Dolman's) and Miles tests. Hand dominance was determined through standardized questioning and observation during tasks. Spherical equivalents (SEQ) were calculated, and anisometropia was defined as an interocular refractive difference ≥ 1.00 D.

Results: Four hundred participants (mean [standard deviation, SD] age 26.1 [6.0] years; 61.3% males) were assessed for ocular and hand dominance. Refractive error SEQ ranged from +9.25 D to –13.50 D (mean [SD] –1.75 [2.46] D). Myopia was most common among students (n = 93, 23.3%) and least common among tailors (n = 14, 3.5%). The most frequent dominance pattern was right-hand combined with right-eye dominance (n = 328, 82%). A strong, statistically significant association was found between ocular and hand dominance ($P < 0.01$; Cramer's V = 0.73). Moderate but statistically significant associations were observed between refractive error type and both ocular ($P < 0.01$; V = 0.25) and hand dominance ($P < 0.01$; V = 0.21). The dominant eye was not always the eye with better visual acuity. Among the 103 individuals with anisometropia (25.8%), ocular dominance was not consistently accompanied by either the higher refractive error or better visual acuity.

Conclusions: In this study, we demonstrated a strong and statistically significant association between ocular and hand dominance, suggesting existence of a significant lateralization pattern among individuals with refractive error who had no history of spectacle use since childhood. While a right-hand/right-eye dominance pattern was predominant, variations such as cross-dominance and absence of ocular dominance were also observed. A moderate but significant association was found between the type of refractive error and both ocular and hand dominance, indicating that visual and motor lateralization may influence refractive development. The dominant eye did not consistently accompany by better visual acuity or greater refractive error in individuals with anisometropia, underscoring the complexity of ocular dominance and its clinical implications. These findings may aid in understanding visual behavior and inform clinical decisions related to refractive surgeries, amblyopia management, and binocular vision assessments. Further research is needed to explore the underlying neurophysiological mechanisms.

KEYWORDS
refractive error, dominant, hands, preference, eyes, vision, Nepal

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INTRODUCTION

Like other paired organs, such as the limbs and cerebral hemispheres, the eyes exhibit functional lateralization [1-5]. Ocular dominance reflects a preferential reliance on visual input from one eye over the other, even when both eyes have comparable visual acuity. The dominant eye is not always the one with superior visual clarity in cases with unequal vision [1-5]. This phenomenon was first described as early as 1593 [2].

Understanding ocular dominance has become particularly relevant in clinical settings, particularly prior to cataract surgery, in which it can help to predict patient satisfaction with monovision strategies [1, 6]. Traditionally, the dominant eye is corrected for distance vision, and the non-dominant eye for near tasks. This approach is based on the premise that the dominant eye tends to suppress the comparatively blurred images obtained via the fellow, non-dominant eye [1, 7].

While most individuals have a dominant eye, this dominance is not necessarily aligned with the eye that has better visual acuity [1, 8]. Some studies have suggested that the right eye more frequently tends to be the dominant eye, and in individuals with myopia, the dominant eye may present a lower spherical equivalent (SEQ) [9]. In contrast, other studies have associated ocular dominance with greater myopia or with less hyperopia in individuals with anisometropia [10].

However, not all individuals exhibit clear ocular dominance. Several categories of ocular dominance variability have been reported, including absent dominance [2, 11], uncertain dominance [12-14], and alternating dominance [15]. Nevertheless, the mechanisms underlying these variations remain poorly understood.

Ocular dominance has practical significance in presbyopic vision correction techniques, such as monovision, refractive surgeries, and multifocal contact lens fitting [1, 7]. It also plays an essential role in visually demanding activities, such as photography, archery, and shooting [16]. In the management of intermittent exotropia, ocular dominance status guides occlusion therapy by influencing the frequency and laterality of eye patching [17].

Interestingly, ocular dominance may be altered after cataract surgery and intraocular lens implantation. The improved and asymmetric visual experience can lead to a shift in ocular dominance, demonstrating the plasticity of the visual system [18]. Furthermore, binocular pattern deprivation from birth can permanently disrupt functional ocular dominance [19].

We hypothesized that individuals whose binocular refractive errors have remained uncorrected from early childhood may experience visual deprivation that potentially influences the development and physiology of ocular dominance. Therefore, we investigated whether individuals with refractive errors without a history of spectacle use since childhood consistently exhibited a dominant eye, and evaluated the reliability of uncertain or alternating ocular dominance patterns.

METHODS

In this cross-sectional study, we recruited consecutive individuals with refractive error, whose eyes were otherwise healthy, without a history of spectacle use since childhood, who attended Biratnagar Eye Hospital (BEH), Nepal, between January and May 2023. The Institutional Review Committee of BEH approved the study (Ref. BEH-IRC-55/A), which adhered to the ethical mandates outlined in the Declaration of Helsinki. All participants received a study information sheet with a participation consent form, which they were asked to read and sign voluntarily. Participants who signed the consent form were then provided with additional details regarding the various assessments involved in the study.

Assuming a 50% prevalence of refractive error among all individuals visiting the hospital and considering an average daily outpatient volume of 750 individuals over the previous 3 months, we calculated that a sample size of 379 patients was needed to achieve a 95% confidence interval with a 5% margin of error. To account for an estimated 5% non-consent rate, the final target sample size was set at 400 individuals. Consecutive eligible patients were enrolled by the examiner (S.K.S.).

Patients aged 16–40 years with a refractive error, who presented to the Refraction Department of BEH, were enrolled on a first-come, first-served basis. Inclusion criteria were a best-corrected distance visual acuity (BCDVA) of 6/9 or better for distance and N6 or better for near vision in each eye. Participants with an unclear or unknown history of spectacle use since childhood were excluded from analyses involving the influence of early optical correction on ocular dominance. Furthermore, patients presenting with amblyopia, strabismus, ptosis, keratoconus, glaucoma, a history of ocular surgery, retinal disease, or any other condition potentially affecting BCDVA were excluded.

All examinations were conducted by a single examiner (S.K.S.) to minimize inter-observer variability. A brief socio-demographic profile was obtained from each participant. A comprehensive anterior segment examination was performed using a slit-lamp biomicroscope (SL 800; Carl Zeiss Meditec, Dublin, CA, USA). The posterior segment was evaluated with a 90-diopter (D) non-contact lens (Volk Optical, Inc., Mentor, OH, USA) using a slit-lamp.

All participants underwent objective retinoscopy (Heine Beta-200 Streak Retinoscope; Heine Optotechnik, Herrsching, Germany), followed by non-cycloplegic subjective refraction. The refractive error in each eye was defined as the SEQ of the measured refractive error (either myopia or hypermetropia), and absolute values greater than ± 0.50 D were considered clinically significant [20]. Cylindrical powers exceeding ± 3.00 D cylinder (DC) were excluded from the study. For astigmatism up to ± 3.00 DC, the refractive error was converted to SEQ to allow uniform analysis. An interocular SEQ difference of ≥ 1.00 D was defined as anisometropia [21].

Each participant was asked several questions to determine hand dominance, including: “Which statement best describes you: I am right-handed, I am left-handed, or I use both hands equally?” and “Which hand they primarily used for tasks, such as buttoning a shirt, eating, writing, or playing?” This subjective response was then verified objectively by asking the patient to hold the book in one hand for 5 s. The hand that the individual first used to respond to this instruction was classified as the dominant hand [22-24]. For participants who initially did not understand the questions, the examiner provided explanations in the local language. All inquiries and hand dominance assessments were conducted by the same examiner (S.K.S.) who performed the ocular dominance tests.

Two well-established tests were performed consecutively to assess ocular dominance: the Hole-in-the-Card (Dolman's) test [24, 25] and the Eye Preference (Miles) test [26].

Hole-in-the-Card (Dolman's) Test [25]: A white, square card (20 cm × 20 cm) with a central circular hole (3-cm diameter) was handed to the participant. They were instructed to bring the card close to their face and count the raised finger of the examiner, who was positioned 1 m away. The eye toward which the card was shifted to allow visualization of the finger was recorded as the dominant eye. Subsequently, the participant held the card at arm's length with both hands, looking through the central hole at a visual target located 6 m away. With both eyes open, the participant was asked to fixate on the target, located 3 meters away, through the hole (either 6/9 or 6/12, depending on the participant's BCDVA). The participant was then instructed to close each eye with one hand, alternately. The eye that continued to visualize the target with a minimal shift was identified as the dominant eye, whereas the eye demonstrating noticeable deviation from the binocular view was noted as the non-dominant eye.

Eye Preference (Mile's) Test [26]: This confirmatory test required participants to extend both arms forward and form a small triangular aperture by overlapping the thumbs and index fingers. They were then instructed to look at a 6/6 or 6/9 optotype, located 3 m away, through the triangle, with both eyes open. The examiner then had the patient alternately close each eye. The eye that continued to align with the target within the triangular frame (without any shift) was considered to be the dominant eye.

Both tests [24-26] were repeated twice. To minimize order bias, half of the participants performed the Hole-in-the-Card (Dolman's) test first, followed by the Miles test, while the remaining half were tested in the reverse sequence.

All data were initially entered into a Microsoft Excel spreadsheet (Microsoft Corp., Redmond, WA, USA) and were subsequently analyzed using STATA version 16.0 (StataCorp, College Station, TX, USA). Descriptive statistics were used to characterize the sample, with categorical variables reported as frequencies and percentages, and continuous variables summarized as means with standard deviations (SD). The chi-square test of independence was used to evaluate the statistical significance of association between categorical variables. Fisher's exact test was used to determine the association between ocular dominance and better visual acuity. The strength of association between categorical variables was assessed using Cramer's V coefficient, with higher values indicating stronger associations. A P-value < 0.05 was considered statistically significant.

RESULTS

Four hundred individuals, of which 245 (61.3%) were male and 155 (38.8%) were female, were assessed for ocular and hand dominance. Table 1 summarizes the demographic and refractive characteristics of the study participants. The mean (SD) age of the participants was 26.1 (6.0) years. The SEQ of refractive errors ranged from +9.25 D to –13.50 D. The mean (SD) SEQ was –1.75 D (2.46 D). Myopia was most prevalent among students, at 93 cases (23.3%), followed by individuals engaged in business (n = 62; 15.5%), and was least common among those working in tailoring (n = 14; 3.5%) (Table 1).

In the study population overall, the most common dominance pattern was right-hand dominance combined with right-eye dominance, which was observed in 328 participants (82%), accounting for approximately three-fourths of the cohort. In contrast, right-handed individuals with left-eye dominance were relatively few, comprising only 22 participants (5.5%) (Table 2). A small subset of right-handed individuals (n = 14; 3.5%) did not exhibit any detectable ocular dominance, whereas no such cases were found among left-handed participants. A negligible proportion of patients (n = 2; 0.5%) were left-handed but exhibited right-eye dominance. Thirty-four patients (8.5%) demonstrated both left-hand and left-eye dominance. The association between ocular dominance and handedness was statistically significant (P < 0.05). These findings are summarized in Table 2.

Statistical analysis revealed a moderate but statistically significant association between the type of refractive error (myopia or hypermetropia) and ocular dominance (P < 0.01, Cramer's V = 0.25). Similarly, a moderate but significant association was observed between the type of refractive error and hand dominance (P < 0.01, Cramer's V = 0.21). A strong, statistically significant association was found between ocular dominance and hand dominance (P < 0.01, Cramer's V = 0.73). Fisher's exact test demonstrated a significant association between eye dominance and the visual acuity category (P < 0.01). Detailed examination of the data showed that the dominant eye was not always the eye with better visual acuity.

Overall, 103 individuals (25.8%) were identified as having anisometropia. Among them, 84 (81.6%) had myopic anisometropia, while 19 (18.4%) had hypermetropic anisometropia. Within the myopic anisometropia group, 39 participants (46.4%) exhibited a higher myopic SEQ in their dominant eye, whereas 45 (53.6%) demonstrated less myopia in the dominant eye. In the hypermetropic group, 12 individuals (63.2%) had a higher hypermetropic SEQ in their dominant eye, while 7 (36.8%) had less hypermetropia in the dominant eye. Among the 103 individuals with anisometropia, ocular dominance was not consistently accompanied by either the higher refractive error or better visual acuity.

Table 1. Demographic and refractive characteristics of the study participants

Variable	Value
Age (y), Mean ± SD (Range)	26.1 ± 6.0 (16 to 40)
Sex (Male / Female), n (%)	245 (61.3) / 155 (38.8)
SEQ (D), Mean ± SD (Range)	- 1.75 ± 2.46 (+ 9.25 to - 13.50)
Refractive error (Myopia/ Hyperopia/ Antimetropia), n (%)	341 (85.2) / 56 (14.0) / 3 (0.8)
Occupation (Myopia/ Hyperopia/ Antimetropia), n (%)	
Accountant	20 (5.0) / 0 (0.0) / 1 (0.3)
Engaged in business	62 (15.5) / 10 (2.5) / 0 (0.0)
Farmer	29 (7.3) / 6 (1.5) / 0 (0.0)
Housewife	61 (15.3) / 17 (4.3) / 0 (0.0)
IT officer	18 (4.5) /4 (1.0) / 0 (0.0)
Paramedical officer	22 (5.5) / 4 (1.0) / 0 (0.0)
Student	93 (23.3) / 12 (3.0) / 1 (0.3)
Working in tailoring	14 (3.5) / 0 (0.0) / 0 (0.0)
Teacher	22 (5.5) / 3 (0.8) / 1 (0.3)

Abbreviations: y, years; SD, standard deviation; n, numbers; %, percentage; SEQ, spherical equivalent; D, diopters; IT officer, information technology officer. Note: SEQ was computed by adding the spherical component of the refractive error to half of the cylindrical component.

Table 2. Association of ocular dominance and handedness

	Right eye dominance, n (%)	Left eye dominance, n (%)	*P*-value
Right-handed	328 (82)	22 (5.5)	**< 0.001**
Left-handed	2 (0.5)	34 (8.5)	
Total	330 (82.5)	56 (14)	

Abbreviations: n, numbers; %, percentage. Note: *P* < 0.05 is shown in bold.

DISSCUSSION

This study assessed ocular dominance and its association with refractive error and handedness in 400 individuals with otherwise healthy eyes. The majority of participants demonstrated right-eye dominance and right-handedness, and a strong, statistically significant association was noted between these two dominance types. A moderate but statistically significant association was also identified between refractive error and both ocular and hand dominance. Ocular dominance did not consistently correspond to superior visual acuity. Among individuals with anisometropia, the dominant eye showed variable associations with higher or lower refractive error, suggesting that ocular dominance does not necessarily align with refractive power asymmetry.

Globally, myopia is the most prevalent type of refractive error [27]. This trend was also mirrored in our study population, where it accounted for 85.2% (n = 341) of participants. The relationship between ocular dominance and the refractive error type remains debated in the literature [2, 9, 10, 12]. Our findings revealed a moderate, statistically significant association between refractive error and both ocular and hand dominance. Previous studies have noted that in cases of anisometropia, the dominant eye may exhibit either a higher degree of myopia or a lower degree of hypermetropia than that of the non-dominant eye [2, 10]. Cheng et al. [2] reported that in anisometropic myopia, the dominant eye tends to be significantly more myopic than the non-dominant eye [2]. Linke et al. [12] reported that in hyperopic individuals, the non-dominant eye exhibited a higher degree of hyperopia and astigmatism, and the likelihood thereof increased with the anisometropia severity [12]. In a separate study involving candidates for myopic refractive surgery, Linke et al. [28] observed that when the anisometropia SEQ exceeded 2.5 D, the non-dominant eye was typically more myopic, and when the cylindrical anisometropia was >0.5 D, the non-dominant eye exhibited greater astigmatism [28].

In our study, most patients (n = 297; 74.2%) showed small interocular differences in refractive error (< 1.0 D). Approximately 85% of the study population exhibited myopia ranging from –0.50 D to –13.50 D. We observed a significant association between eye dominance and refractive error type. Furthermore, we observed that ocular dominance was not consistently associated with better visual acuity. Zhou et al. [29] reported that the uncorrected distance visual acuity was significantly better in the dominant than in the non-dominant eye, particularly in individuals with pronounced interocular acuity differences [29]. Our findings suggested that this relationship may not be universally applicable.

Ocular dominance has been the subject of extensive research over the past century. Various theories have addressed the development of ocular dominance and its relationship to laterality across body systems. Structurally, afferents in the lateral geniculate nucleus that represent the two eyes overlap early in development and subsequently segregate into eye-specific zones [13–15]. The emergence of ocular dominance columns is thought to result from neuronal activity-dependent mechanisms that guide the sorting of geniculocortical axons into distinct cortical domains. These columns are now known to appear earlier than previously thought, during a distinct stage of cortical maturation [30–32]. In addition, their development is influenced by visual experience and eye opening [33, 34]. The dominant eye column begins to develop before birth during visual cortex formation [14, 35]. At the retinal level, structural asymmetries have been found between dominant and non-dominant eyes. The dominant eye exhibits significantly thicker average, temporal, and nasal retinal nerve fiber layers (RNFLs), while the non-dominant eye often shows a thicker superior RNFL [36]. These findings provide insight into the inherent structural basis of ocular dominance.

Functional magnetic resonance imaging studies have demonstrated that the dominant eye activates a larger area in the visual cortex than does the non-dominant eye [37, 38]. Ocular dominance is also partially linked to cerebral laterality [37] and hand dominance [39]. In the present study, 9.0% (n = 36) of participants were left-handed, in agreement with previously reported prevalence estimates [40]. Our finding of right-eye dominance in 82.5% (n = 330) of participants was also consistent with prior research [28, 41-43], which estimated that approximately 67% of individuals demonstrate right-eye dominance. Dominant eyes are often more myopic [2] and show less astigmatic power than do non-dominant eyes [28]. Our slightly higher rate of right-eye dominance may be attributable to our inclusion criteria, which did not exclude participants with indeterminate dominance. We also did not assess sensory dominance. This, along with the modest sample size, may explain why left-eye dominance was observed in only 14.0% (n = 56) of cases.

In our cohort, 14 participants (3.5%) did not demonstrate a clear ocular dominance. Yang et al. [44] reported alternating ocular dominance in only 0.8% of cases, whereas Chia et al. [24] found that 12% of participants had no eye preference, which was a higher proportion than that found in our study. Neural plasticity in the visual cortex, which is influenced by visual experience and monocular task training, may contribute to the emergence or modification of ocular dominance patterns [16, 18].

Ocular and hand dominance are not always aligned; when they differ, the phenomenon is referred to as "cross-dominance" [45]. In our study, cross-dominance was observed in 24 individuals (6%), with 22 (5.5%) being right-handed and left-eye dominant, and 2 (0.5%) being left-handed with right-eye dominance. Previous research has suggested that cross-dominance may confer performance advantages in sports and other visuomotor tasks [46, 47]. Interestingly, 14 right-handed individuals (3.5%) in our study did not exhibit any detectable ocular dominance, while no such cases were observed among left-handed participants. This agreed with prior assertions that ocular dominance may be present even when it is not detected by standard tests [11, 13], an observation substantiated by our findings.

This study benefited from a relatively large, well-defined sample and standardized data collection, with all assessments conducted by a single examiner, to minimize interobserver variability. The use of two validated tests to determine ocular dominance increased methodological rigor. However, the absence of examiner masking may have introduced a bias. Non-cycloplegic refraction could have affected accuracy in younger participants. The exclusion of individuals in whom the history of childhood spectacle use was unknown and the absence of emmetropic participants limit the generalizability of our findings. Astigmatism was not analyzed separately, and the small number of cases of anisometropia precluded further statistical analysis of the association between refractive asymmetry and ocular dominance. As data were drawn from a single tertiary eye hospital, the broader generalizability of our findings may be limited. Future large-scale, longitudinal studies, which should include emmetropic controls, varying degrees of anisometropia, and sensory dominance testing, are warranted to provide a more comprehensive understanding of ocular dominance and its clinical implications. Incorporating neurophysiological imaging and binocular visual performance measures may further elucidate the underlying mechanisms of ocular dominance and its plasticity. Additionally, exploring ocular dominance in the context of visual rehabilitation, particularly in patients with anisometropia and presbyopia, could offer valuable clinical insights.

CONCLUSIONS

This study demonstrated that ocular dominance is a prevalent and measurable phenomenon among individuals who have had uncorrected refractive errors since childhood. We found a strong association between ocular and hand dominance, with a moderate relationship identified between refractive error type and both ocular and hand dominance. Ocular dominance did not consistently correspond with the eye demonstrating better visual acuity or lower refractive error, particularly in cases of anisometropia. A small subset of participants lacked clear ocular dominance, highlighting interindividual variability. These findings may support the notion that ocular dominance is influenced by both neurological development and visual experience. Clinically, an understanding of ocular dominance in patients with long-standing uncorrected refractive errors may inform personalized approaches to vision correction, particularly when using monovision strategies. Further research is warranted to explore the neuroplasticity mechanisms and functional implications of ocular dominance.

ETHICAL DECLARATIONS

Ethical approval: The Institutional Review Committee of Biratnagar Eye Hospital approved the study (Ref. BEH-IRC-55/A), which adhered to the ethical mandates outlined in the Declaration of Helsinki. All participants received a study information sheet with a participation consent form, which they were asked to read and sign voluntarily. Participants who signed the consent form were then provided with additional details regarding the various assessments involved in the study.

Conflict of interests: None.

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