Article

Not peer-reviewed version

The Impact of Objective Visual Quality and Retinal Structure on Dynamic Visual Acuity

Ruoyu Li , Zesong Wang , Yuexin Wang *

Posted Date: 28 April 2025

doi: 10.20944/preprints202504.2271.v1

Keywords: dynamic visual acuity (DVA); optical coherence tomography angiography (OCTA); modulation transfer function (MTF); higher-order aberration (HOA); athletic performance

doi:10.20944/preprints202504.2271.v1

Article

The Impact of Objective Visual Quality and Retinal Structure on Dynamic Visual Acuity

Ruoyu Li [1,2], Zesong Wang [1,2] and Yuexin Wang [1,*]

[1] Department of Ophthalmology, Peking University Third Hospital, Beijing, China
[2] Peking University Health Science Center, Beijing, China
* Correspondence: wyx19920330@126.com

Abstract: The study aims to explore the impact of objective visual quality and retinal structure on dynamic visual acuity (DVA) in 30 healthy young adults with a mean age of 23.0 ± 3.7 years. Binocular DVA was assessed at 20, 40, 60, and 80 degrees per second (dps) with habitual spectacles. Modulation transfer function (MTF), higher-order aberrations (HOA) and retinal structure, including retinal thickness and capillary density in the optic disc and macula, were measured. DVA differed significantly across velocities ($P < 0.001$). DVA at 20 dps ($r = -0.537$, $P = 0.002$) and 60 dps ($r = -0.430$, $P = 0.018$) were negatively correlated with the binocular mean sphere. DVA at 20 and 60 dps was significantly associated with MTF value from 5 to 30 cycle/degree (c/d), and 80 dps DVA was associated with MTF value at intermediate spatial frequencies (10 to 20 c/d) ($P < 0.05$, respectively). Limited associations were observed between DVA and retinal thickness or capillary density in the optic disc and macula. In conclusion, better objective visual quality, as measured by MTF, was associated with better DVA at both low and high speeds in healthy adults, whereas retinal structural parameters had a limited association with DVA.

Keywords: dynamic visual acuity (DVA); optical coherence tomography angiography (OCTA); modulation transfer function (MTF); higher-order aberration (HOA); athletic performance

---

1. Introduction

Dynamic visual acuity (DVA) refers to the capacity to discern subtle spatial details within a visual target during relative motion between the observer and the target [1]. Our daily activities frequently require the perception and interaction with moving objects, and dynamic visual functions significantly affect performance in various tasks, such as reading, sports, driving, and walking [2–6]. There are various DVA tests, including the dynamic-object DVA test, where participants identify or assess moving targets with their head stabilized, and the static-object DVA test, where participants view stationary targets while their head or body is in motion [1,7,8]. Dynamic-object DVA (abbreviated as DVA in the following text) test has been applied to assess dynamic visual function in clinical ophthalmology, including cataract, dry eye, myopia and refractive surgery [9–12].

The visual signal transduction pathway of dynamic vision is different from static vision [13]. The difference in transduction pathway determines different influential factors between dynamic and static vision, including ocular functional and structural parameters. Investigating the factors influencing DVA could enhance its clinical applicability and improve the interpretability of test results. Previous research demonstrated that myopia severity affects DVA when corrected to normal static vision with spectacles [11]. In addition to refractive error, higher-order aberration (HOA) and modulation transfer function (MTF) were also quantified to evaluate static visual quality [14–17]. However, the impact of HOA and MTF on DVA has not been investigated. Apart from the P ganglion cell, the M ganglion cell-related pathway is critical in transmitting visual signals with high temporal and low spatial frequency, which is related to dynamic vision [18]. Thus, the retinal structural

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 28 April 2025 doi:10.20944/preprints202504.2271.v1

parameters, including retinal thickness and vascularity, could potentially impact DVA, which remains to be fully explored.

Thus, the present study included healthy young adults to test DVA at different velocities and assessed total eye MTF and HOA as objective measures of visual quality with an aberrometer, as well as measured macular and optic disc retinal thickness and capillary density using optical coherence tomography (OCT) and OCT angiography (OCTA). This study aimed to investigate the influence of objective visual quality and retinal structural parameters on DVA across different velocities. Our findings identify potential factors affecting DVA and provide a foundation for utilizing DVA testing as a tool for assessing visual function.

2. Materials and Methods

2.1. Participants

We recruited healthy young adults aged 18 to 35 years for the study, with the following exclusion criteria: (1) monocular best-corrected visual acuity worse than 0 LogMAR (subjective refraction); (2) monocular corrected distance visual acuity worse than 0.4 LogMAR (habitual spectacles); (3) high myopia (subjective refraction ≤ -6.00D), high hyperopia (subjective refraction ≥ 4.00D) or high astigmatism (subjective refraction ≤ -3.00D); (3) history of severe ocular diseases, including glaucoma, corneal diseases, retinal disorders, or macular degeneration; (4) Systemic conditions that could potentially affect visual acuity; (5) vestibular or cognitive impairments that may interfere with the accuracy of the test; (6) inability to properly track dynamic visual stimuli or follow instructions provided by the examiner. The study was conducted in accordance with the Declaration of Helsinki, received approval from the Institutional Review Board, and all participants provided written informed consent before the study.

2.2. Ocular Assessment

The ocular assessment was performed in the following order: corrected distance visual acuity assessed with habitual spectacles (LogMAR visual chart), automatic refraction (Topcon, KR-800, Japan), subjective refraction, slit lamp biomicroscopy, OCTA (Zeiss, Germany) and iTrace (Tracey Technologies, United States).

Subjective refraction was performed monocularly with the following steps: first maximum plus to maximum visual acuity (MPMVA) was achieved after fogging, followed by refinement of the cylinder axis and power with Jackson cross cylinder device, and a second MPMVA to tune the spherical diopter. OCTA was utilized to quantify retinal thickness and capillary density, with a 3*3 mm scan performed for the macula and a 4.5*4.5 mm scan for the optic disc. For the retinal thickness, the peripapillary retinal nerve fiber layer (RNFL), fovea (1.0*1.0 mm), parafovea (1.0mm to 3.0mm) thickness and macular avascular zone size were quantified. For the vascularity, the inside disc (1.5*1.5 mm) and peripapillary capillary density, superficial and deep fovea (1.0*1.0 mm) and parafovea (1.0mm to 3.0mm) capillary density were quantified.

Itrace was conducted to evaluate ocular aberration and the MTF curve. The total eye higher-order aberration at a pupil size of 4.00 mm was quantified for the analysis, including C6 (trefoil), C7 (coma), C8 (coma), C9 (trefoil) and C12 (spherical). The total eye MTF value at a pupil size of 4.00 mm was collected for the analysis, including the spatial frequency of 5, 10, 15, 20, 25 and 30 cycles per degree (c/d).

2.3. Dynamic Visual Acuity Test

Four DVA tests were performed sequentially, with horizontal motion velocities set at 20, 40, 60, and 80 degrees per second (dps). The velocities were selected according to our previous research, considering the variety of eye movement strategies [11]. Binocular DVA was examined with habitual spectacles at 1 meter. The test optotypes were presented on a 24-inch 120 Hz in-plane switching screen. Custom software, created with MATLAB 2017b (MathWorks, United States), was employed

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 28 April 2025 doi:10.20944/preprints202504.2271.v1

to generate moving optotype letter E at predefined speeds and sizes. The configuration and size of the optotype letter E were designed based on the standard logarithmic visual chart, and the moving velocity was quantified as the viewing angle changed per second. During the test, the letter E moved across the screen, starting from the midpoint of the left edge and proceeding to the right. Participants were required to identify the opening direction of the letter E in a four alternative forced choice regime.

The DVA test began with the optotype size, three steps larger than the subjects' static visual acuity. Following a preliminary round of five randomly selected optotypes for familiarization, the formal testing phase commenced. During the formal test, eight optotypes of the same size were presented individually at two-second intervals, featuring a randomly oriented opening. Upon correctly identifying five out of eight optotypes, the size was decremented by one step. We documented the minimum size (A, logMAR) at which participants could reliably identify at least five optotypes and the count (b) of one size smaller that were accurately recognized. The outcomes of the test were determined by applying the subsequent formula

$$DVA = A - \frac{0.1}{8} * b$$

2.4. Statistical Analysis

Statistical analysis was performed with IBM SPSS Statistics (version 23.0, IBM Corp., United States). Continuous variables were expressed as mean and standard deviation (SD), and categorical variables were expressed as numbers and percentages. Shapiro-Wilk test was performed to determine the normality of the distribution.

Pearson correlation analysis was performed to examine the associations between DVA at various velocities and refraction results for normal distributed data. Otherwise, Spearman correlation was performed. Considering the data distribution, generalized linear models were applied to analyze the impact of MTF value, higher-order aberration, retinal thickness, and capillary density on DVA at various velocities while adjusting for the impact of refraction on DVA. Subgroup analysis was further conducted by eye with the generalized linear model. Bonferroni correction was performed for post-hoc analysis. $P < 0.05$ was determined to be significant.

3. Results

3.1. Baseline Characters

A total of 30 participants were enrolled, with a mean age of 23.0 ± 3.7 years, and 40.0% of participants were male. The descriptive results for refraction, MTF value, aberration, retinal thickness and capillary density are summarized in Table 1. The mean sphere power was -4.52 ± 2.23 diopters (D), and the average cylinder power was -1.01 ± 0.59 D. The mean corrected distance visual acuity with habitual spectacles was 0.03 ± 0.11 (LogMAR). A significant difference was observed among DVA results at different velocities ($P < 0.001$). DVA at 20 dps was significantly better than at 40 dps ($P < 0.001$), 60 dps ($P < 0.001$), and 80 dps ($P < 0.001$).

Table 1. The descriptive results (n = 30).

	Mean	**SD**	**Max**	**Min**
Age, years	23.0	3.7	33	20
Refraction and visual acuity				
Sphere (diopter)	-4.52	2.23	-0.38	-8.25
Cylinder (diopter)	-1.01	0.59	-0.13	-2.38
Corrected distance visual acuity (LogMAR)	0.03	0.11	0.35	-0.13

DVA (20 dps, LogMAR)	0.1400	0.1013	0.0125	0.3000
DVA (40 dps, LogMAR)	0.2604	0.0949	0.0750	0.5625
DVA (60 dps, LogMAR)	0.3104	0.0836	0.1625	0.4500
DVA (80 dps, LogMAR)	0.2975	0.1080	0.0750	0.5500
Total eye modulation transfer function value (4.0 mm)				
5 c/d (%)	0.748	0.114	0.921	0.530
10 c/d (%)	0.476	0.159	0.792	0.200
15 c/d (%)	0.308	0.143	0.652	0.094
20 c/d (%)	0.220	0.109	0.524	0.086
25 c/d (%)	0.167	0.085	0.417	0.063
30 c/d (%)	0.135	0.069	0.334	0.052
Total eye higher-order aberration (4.0 mm)				
Trefoil aberration (C6, μm)	0.072	0.057	0.237	0.006
Coma aberration (C7, μm)	0.082	0.048	0.183	0.016
Coma aberration (C8, μm)	0.053	0.024	0.116	0.017
Trefoil aberration (C9, μm)	0.064	0.045	0.250	0.005
Spherical aberration (C12, μm)	0.047	0.030	0.123	0.005
Optic disc and macula thickness and capillary density				
Peripapillary RNFL thickness (μm)	119	12	146	101
Fovea thickness (μm)	250	22	306	209
Parafovea thickness (μm)	323	11	344	304
Avascular zone (mm^2)	0.291	0.109	0.559	0.090
Inside optic disc capillary density (%)	54.3	3.9	61.5	46.1
Peripapillary capillary density (%)	52.2	3.0	60.1	45.6
Superficial fovea capillary density (%)	19.6	6.2	32.8	4.9
Superficial parafovea capillary density (%)	49.7	3.2	56.9	43.9
Deep fovea capillary density (%)	35.2	6.9	48.7	18.1
Deep parafovea capillary density (%)	52.5	3.7	61.0	45.1

Abbreviation: dps, degrees per second; DVA, dynamic visual acuity; RNFL, retinal nerve fiber layer; SD, standard deviation.

3.2. The Correlation Between Refraction and DVA

The outcome of the correlation analysis between mean refraction and DVA is demonstrated in Table 2. DVA at 20 dps (r = -0.537, P = 0.002) and 60 dps (r = -0.430, P = 0.018) were significantly negatively correlated with the mean sphere. DVA at 80 dps was positively correlated with mean visual acuity (r = 0.469, P = 0.009). The results of subgroup analysis by eye are summarized in Table

 doi:10.20944/preprints202504.2271.v1

A1. The DVA at 20 dps (P = 0.003), 40 dps (P = 0.036), 60 dps (P = 0.023) and 80 dps (P = 0.046) were negatively associated with the right eye sphere, but a significant correlation between left eye sphere and DVA was observed only at 20 dps (P = 0.001) and 60 dps (P = 0.018). A significant correlation was observed between DVA at 80 dps and visual acuity in the right eye (P = 0.025) but not in the left (P = 0.059).

Table 2. The correlation between mean refraction result and DVA.

		Mean sphere	Mean SE	Mean visual acuity
DVA (20 dps)	*r*	-0.537	-0.598	0.068
	P	0.002	<0.001	0.719
DVA (40 dps)	*r*	-0.337	-0.350	0.259
	P	0.069	0.058	0.167
DVA (60 dps)	*r*	-0.430	-0.403	0.309
	P	0.018	0.027	0.096
DVA (80 dps)	*r*	-0.335	-0.313	0.469
	P	0.070	0.092	0.009

Abbreviation: dps, degrees per second; DVA, dynamic visual acuity; SE, spherical equivelant.

3.3. The Impact of Objective Visual Quality on DVA

The impact of the total eye MTF value of different spatial frequencies on DVA is demonstrated in Table 3. Higher MTF values at the temporal frequencies of 5 to 30 c/d were significantly associated with better DVA at 20 dps, with regression coefficients (β) ranging from -0.338 (5 c/d, P = 0.013) to -0.511 (30 c/d, P = 0.021). Similarly, at 60 dps, significant negative associations were found at higher spatial frequencies (15 to 30 c/d), with β values ranging from -0.239 (15 c/d, P = 0.009) to -0.488 (30 c/d, P = 0.010). For DVA at 80 dps, significant negative associations were observed at intermediate spatial frequencies (10 to 20 c/d), with β values ranging from -0.250 (10 c/d, P = 0.021) to -0.312 (20 c/d, P = 0.050). No significant associations were observed between MTF values at all temporal frequencies and DVA at 40 dps (P > 0.05, respectively). The results of subgroup analysis by eye are summarized in Table A2. For the right eye, significant negative associations between MTF values and DVA at 60 and 80 dps were observed at spatial frequencies ranging from 10 to 25 c/d (P < 0.05, respectively). In the left eye, a significant negative association was observed between DVA at 20 and 60 dps and MTF values (P < 0.05, respectively).

Table 3. The impact of total eye MTF value of different spatial frequency* on DVA.

		5 c/d	10 c/d	15 c/d	20 c/d	25 c/d	30 c/d
DVA (20 dps)	Beta	-0.338	-0.253	-0.302	-0.384	-0.457	-0.511
	P	0.013	0.008	0.003	0.005	0.010	0.021

DVA (40 dps)	Beta	-0.027	-0.066	-0.101	-0.112	-0.119	-0.116
	P	0.862	0.549	0.402	0.478	0.558	0.643
DVA (60 dps)	Beta	-0.140	-0.158	-0.239	-0.340	-0.427	-0.488
	P	0.278	0.073	0.009	0.004	0.005	0.010
DVA (80 dps)	Beta	-0.291	-0.250	-0.278	-0.312	-0.352	-0.391
	P	0.065	0.021	0.019	0.050	0.091	0.129

* The MTF parameter was measured at the pupil size of 4.0 mm. Abbreviation: c/d, cycles per degree; dps, degrees per second; DVA, dynamic visual acuity; MTF, modulation transfer function.

The impact of total eye higher-order aberration on DVA is presented in Table 4. Specifically, the C9 aberration showed a significant positive association with DVA at 20 dps (β = 0.685, P = 0.047), and the C7 aberration showed a significant positive association with DVA at 80 dps (β = 0.799, P = 0.030). No significant associations were detected between other types of higher-order aberration and DVA at 40 and 60 dps (P > 0.05, respectively). The results of subgroup analysis by eye are summarized in Table A3. For the left eye, a significant positive association was found between the C9 aberration and DVA at 20 dps (β = 0.548, P = 0.027). No significant associations were observed between higher-order aberration in the right eye and DVA across all velocities (P > 0.05, respectively).

Table 4. The impact of total eye higher-order ocular aberration* on DVA.

		C6	**C7**	**C8**	**C9**	**C12**
DVA (20 dps)	Beta	0.436	0.353	0.044	0.685	0.985
	P	0.112	0.285	0.947	0.047	0.052
DVA (40 dps)	Beta	0.106	<0.001	-0.177	0.414	-0.105
	P	0.720	0.999	0.800	0.269	0.851
DVA (60 dps)s	Beta	0.264	0.298	0.256	0.300	-0.340
	P	0.284	0.303	0.662	0.342	0.466
DVA (80 dps)	Beta	0.487	0.799	1.008	0.358	0.048
	P	0.135	0.030	0.191	0.404	0.940

*The total eye higher-order ocular aberration was measured at the pupil size of 4.0 mm.
Abbreviation: dps, degrees per second; DVA, dynamic visual acuity.

3.4. The Impact of Retinal Structure on DVA

The impact of the optic disc and macular structure on DVA is demonstrated in Table 5. No significant associations were observed between peripapillary RNFL thickness, foveal thickness,

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 28 April 2025 doi:10.20944/preprints202504.2271.v1

parafoveal thickness, avascular zone area and DVA across all velocities (P > 0.05, respectively). The results of subgroup analysis by eye are summarized in Table A4. A statistically significant positive association was observed between peripapillary RNFL thickness of the right eye and DVA at 60 dps (β = 0.002, P = 0.013). For the left eye, a significant positive association was found between the avascular zone area and DVA at 80 dps (β = 0.391, P = 0.022).

Table 5. The impact of optic disc* and macular# structure on DVA.

		Peripapillary RNFL thickness	**Fovea thickness**	**Parafovea thickness**	**Avascular zone**
DVA (20 dps)	Beta	0.002	-0.001	-0.001	0.179
	P	0.115	0.138	0.162	0.221
DVA (40 dps)	Beta	<0.001	<0.001	-0.001	0.116
	P	0.812	0.572	0.707	0.451
DVA (60 dps)	Beta	0.002	-0.001	-0.001	0.152
	P	0.085	0.279	0.288	0.238
DVA (80 dps)	Beta	0.001	-0.001	<0.001	0.319
	P	0.424	0.140	0.850	0.057

*The optic disc retinal nerve fiber layer thickness was measured at the size of 4.5*4.5mm. #The fovea thickness was measured at the size of 1*1mm, and the parafovea thickness was measured at the range between 1 to 3mm. Abbreviation: dps, degrees per second; DVA, dynamic visual acuity; RNFL, retinal nerve fiber layer.

The impact of optic disc and macular capillary density on DVA is presented in Table 6. A significant negative association was observed between peripapillary capillary density and DVA at 80 dps (β = -0.013, P = 0.019). No other significant associations were detected between capillary density in the optic disc (inside disc), superficial macula (fovea and parafovea), or deep macula (fovea and parafovea) and DVA across all velocities (P > 0.05, respectively). The results of the subgroup analysis by eye are summarized in Table A5. For the right eye, significant negative associations were observed between peripapillary capillary density and DVA at 80 dps (β = -0.014, P = 0.007) and between parafoveal deep macular capillary density and DVA at 80 dps (β = -0.007, P = 0.047). A significant negative association was found between the foveal deep macular capillary density of the left eye and DVA at 80 dps (β = -0.005, P = 0.027).

Table 6. The impact of optic disc* and macular# capillary density on DVA.

		Optic Disc		**Superficial macula**		**Deep macula**	
		Inside disc	Peripapillary	Fovea	Parafovea	Fovea	Parafovea
DVA (20dps)	Beta	-0.002	-0.003	-0.002	0.002	-0.003	-0.004
	P	0.726	0.511	0.412	0.624	0.166	0.378
DVA (40dps)	Beta	-0.004	-0.004	-0.002	0.004	-0.002	0.002
	P	0.471	0.493	0.534	0.382	0.523	0.711

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 28 April 2025 doi:10.20944/preprints202504.2271.v1

DVA (60dps)	Beta	-0.001	-0.006	-0.001	0.001	-0.002	-0.001
	P	0.888	0.174	0.539	0.800	0.428	0.809
DVA (80dps)	Beta	0.004	-0.013	0.003	-0.003	-0.004	0.002
	P	0.522	0.019	0.588	0.252	0.174	0.654

*The inside disc capillary density was measured at the size of 1.5*1.5mm and the peripapillary capillary density was measured at the range between 1.5 to 4.5 mm. #The fovea capillary density was measured at the size of 1*1mm and the parafovea capillary density was measured at the range between 1 to 3mm. Abbreviation: dps, degrees per second; DVA, dynamic visual acuity.

4. Discussion

Dynamic visual acuity (DVA) is crucial for tasks involving moving objects and serves as a promising metric for assessing visual function [19]. However, the factors influencing DVA have not been fully investigated. This study aimed to explore the impact of objective visual quality, including higher-order aberrations and MTF, and retinal structural parameters on DVA across different velocities in healthy young adults. The goal was to identify key influential factors and enhance the clinical utility of the DVA test.

Velocity is a significant influential factor for DVA. The present research demonstrated that DVA at 20 dps was significantly better than at higher speeds, and no significant differences were observed between DVA at 40 dps and 80 dps, or between 60 dps and 80 dps. These results are consistent with our previous research on horizontal motion DVA [20]. As velocity increases, the ability to track moving targets diminishes, significantly impacting DVA outcomes [21,22].

Refractive errors significantly influence DVA, including uncorrected and corrected refractive errors [11,23]. For uncorrected refractive errors, previous studies have shown that minor retinal defocus may not significantly affect athletic performance. However, higher refractive errors are likely to impair DVA [24]. Additionally, Jorge et al. identified a significant correlation between DVA and astigmatism [19]. In the present research, all participants had their static visual acuity (SVA) corrected with habitual spectacles during the DVA test. The binocular mean sphere and SE had significant correlations with DVA at 20 and 60 dps, while the monocular sphere and SE in the right eye were significantly correlated with DVA at all tested velocities. These results suggest that the further the refractive state deviates from emmetropia, the worse the DVA, even after correction. This finding aligns with our previous research [11]. There are several potential reasons. First, for participants with more severe myopia, the prism effect of the spectacles became more pronounced. The prism effect might cause spatial disorientation, which impairs the ability to track moving targets and leads to worse DVA performance. Second, the defocus effect in the peripheral regions of spectacles reduces visual clarity outside the central visual field, essential for tracking objects moving across a wide range of visual angles [25]. The subgroup analysis revealed that the right eye's refractive error had significant correlations with DVA at 40 and 80 dps, while the left did not. In our study, the right eye was more frequently the dominant eye among participants. Previous studies have found that, compared to the nondominant eye, the dominant eye is more sensitive and performs better in visual target detection [26]. The visual sensitivity difference between the dominant and nondominant eye might explain the greater influence of the right eye's refractive error on DVA.

The MTF value is a widely recognized metric for evaluating objective visual quality. It quantifies the resolution of an optical system at different spatial frequencies [16,17]. The present research found negative associations between MTF values and DVA at 20, 60 and 80 dps, suggesting that superior visual quality contributes to better DVA performance. Significant associations between DVA at 20 and 60 dps and MTF values were observed across low to high spatial frequencies. In contrast, DVA at 80 dps was associated with MTF values at intermediate spatial frequencies (10 to 20 c/d) but not at high spatial frequencies. The results might be attributed to the difference between static and dynamic

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 28 April 2025 doi:10.20944/preprints202504.2271.v1

visual signal transduction, which becomes more pronounced at higher velocities. The M ganglion cell-related pathway mainly transmits visual signals with low spatial and high temporal frequencies, which is associated with dynamic vision [18]. At 40 dps, no significant association was observed between MTF values and DVA, possibly due to perceptual learning effects in the DVA test [20]. When performing DVA tests at 60 and 80 dps, participants might benefit from transfer learning acquired during the DVA test at 40 dps. However, the learning effect might be less significant at 40 dps since the speed doubled from 20 to 40 dps, making adaptation more challenging.

The retinal structure, including retinal thickness and vascularity, might influence visual signal transduction. In the present research, higher capillary density in the peripapillary area was associated with better DVA at 80 dps. However, no significant relationship was observed between DVA and macular thickness or vascularity. These findings suggest that increased vascular density in the optic nerve head, rather than in the macular region, may enhance visual perception during rapid motion. Previous studies have demonstrated that M ganglion cells, which are primarily linked to rod cells, are related to the transduction of dynamic visual signals [18]. The mid-peripheral retina, rather than the macular region, contains the highest density of rod cells, which might explain the lack of association between macular structure and DVA. Further research is required to investigate the potential impact of peripheral retinal structure and rod cell density on DVA. In contrast to high-speed DVA, low-speed DVA was not associated with retinal structure in this study. These results indicate that higher-speed DVA might serve as a more promising indicator of subtle retinal structural damage than lower-speed DVA.

This study has several limitations. First, DVA was evaluated using habitual spectacles. Although static vision and refractive error were adjusted using the generalized linear model, their influence could not be completely ruled out. Second, only horizontally moving DVA was assessed in this study. Other motion patterns, such as vertical and diagonal motion, may be influenced by different factors, which require further investigation. Third, the sample size of this study was limited, highlighting the need for larger-scale studies in the future to validate these findings.

5. Conclusions

This study investigates the relationship between DVA and objective visual quality and retinal structure in healthy young adults. Our findings suggest that a higher modulation transfer function (MTF) value was associated with better DVA at both low and high velocities. However, only weak or nonsignificant associations were observed between DVA and retinal thickness or capillary density in the optic disc and macula.

Author Contributions: Conceptualization: Y. W., R. L.; Methodology: Y. W., R. L., Z. W. ; Investigation: R. L., Z. W.; Data curation: Z. W.; Formal analysis: Y. W., R. L.; Writing-original draft preparation: R. L., Z. W.; Writing-review and editing: Y. W.; Supervision: Y. W.. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Natural Science Foundation of China, grant number 82201243.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee of Peking University Third Hospital.

Informed Consent Statement: The consent of participants was waived due to the retrospective design of the research by the Peking University Third Hospital Ethics Committee.

Data Availability Statement: The datasets generated during the current study are available from the corresponding author upon reasonable request.

Acknowledgments: None.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

DVA	Dynamic visual acuity
MTF	Modulation transfer function
HOA	Higher-order aberration
OCT	Optical coherence tomography
OCTA	Optical coherence tomography angiography
RNFL	Retinal nerve fiber layer

Appendix A

Table A1. The correlation between DVA and refraction by eyes.

		Sphere		SE		Visual acuity	
		Right	Left	Right	Left	Right	Left
DVA (20 dps)	*r*	-0.519	-0.572	-0.546	-0.618	0.130	0.002
	P	0.003	0.001	0.002	<0.001	0.492	0.990
DVA (40 dps)	*r*	-0.384	-0.279	-0.378	-0.311	0.237	0.193
	P	0.036	0.136	0.040	0.094	0.208	0.307
DVA (60 dps)s	*r*	-0.414	-0.431	-0.369	-0.421	0.237	0.248
	P	0.023	0.018	0.044	0.020	0.208	0.186
DVA (80 dps)	*r*	-0.367	-0.292	-0.337	-0.279	0.408	0.349
	P	0.046	0.117	0.069	0.136	0.025	0.059

Abbreviation: dps, degrees per second; DVA, dynamic visual acuity; SE, spherical equivelant.

Table A2. The impact of total eye MTF value of different spatial frequency* on DVA.

		5 c/d	10 c/d	15 c/d	20 c/d	25 c/d	30 c/d
Right eye							
DVA (20 dps)	Beta	-0.115	-0.130	-0.181	-0.208	-0.208	-0.204
	P	0.421	0.166	0.068	0.113	0.204	0.300
DVA (40 dps)	Beta	-0.121	-0.139	-0.177	-0.188	-0.187	-0.175
	P	0.398	0.133	0.074	0.153	0.255	0.374
DVA (60 dps)	Beta	-0.190	-0.170	-0.226	-0.283	-0.290	-0.287
	P	0.113	0.027	0.005	0.007	0.032	0.081
DVA (80 dps)	Beta	-0.282	-0.228	-0.266	-0.277	-0.276	-0.269
	P	0.059	0.020	0.011	0.050	0.118	0.206

 doi:10.20944/preprints202504.2271.v1

Left eye							
DVA (20 dps)	Beta	-0.248	-0.212	-0.256	-0.353	-0.459	-0.561
	P	0.007	0.005	0.003	0.002	0.002	0.003
DVA (40 dps)	Beta	0.038	0.033	0.030	0.026	0.027	0.029
	P	0.726	0.717	0.780	0.854	0.884	0.899
DVA (60 dps)s	Beta	-0.019	-0.054	-0.121	-0.216	-0.321	-0.420
	P	0.831	0.470	0.154	0.046	0.021	0.015
DVA (80 dps)	Beta	-0.097	-0.103	-0.117	-0.128	-0.127	-0.175
	P	0.432	0.307	0.324	0.411	0.536	0.496

*The MTF parameter was measured at the pupil size of 4.0 mm. Abbreviation: c/d, cycles per degree; dps, degrees per second; DVA, dynamic visual acuity; MTF, modulation transfer function.

Table A3. The impact of total eye higher-order ocular aberration* on DVA by eye.

		C6	C7	C8	C9	C12
Right eye						
DVA (20 dps)	Beta	0.238	-0.026	0.314	0.312	0.866
	P	0.365	0.912	0.549	0.379	0.105
DVA (40 dps)	Beta	0.159	0.076	0.409	0.166	0.275
	P	0.546	0.743	0.432	0.642	0.619
DVA (60 dps)s	Beta	0.130	0.267	0.410	-0.059	-0.043
	P	0.570	0.169	0.360	0.850	0.928
DVA (80 dps)	Beta	0.437	0.420	1.086	0.190	0.607
	P	0.134	0.097	0.055	0.641	0.331
Left eye						
DVA (20 dps)	Beta	0.262	0.389	-0.246	0.548	0.527
	P	0.168	0.111	0.567	0.027	0.140
DVA (40 dps)	Beta	0.005	-0.103	-0.436	0.328	-0.241
	P	0.982	0.705	0.339	0.242	0.541
DVA (60 dps)s	Beta	0.172	-0.069	-0.052	0.382	-0.384
	P	0.315	0.758	0.892	0.092	0.231
DVA (80 dps)	Beta	0.216	0.355	0.149	0.282	-0.305

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 28 April 2025 doi:10.20944/preprints202504.2271.v1

P	0.359	0.239	0.776	0.380	0.495

*The total eye higher-order ocular aberration was measured at the pupil size of 4.0 mm.
Abbreviation: dps, degrees per second; DVA, dynamic visual acuity.

Table A4. The impact of optic disc* and macular# structure on DVA by eye.

		Peripapillary RNFL thickness	**Fovea thickness**	**Parafovea thickness**	**Avascular zone**
Right eye					
DVA (20 dps)	Beta	0.002	-0.001	-0.001	0.136
	P	0.104	0.164	0.558	0.329
DVA (40 dps)	Beta	<0.001	<0.001	-0.001	0.076
	P	0.821	0.555	0.521	0.588
DVA (60 dps)	Beta	0.002	-0.001	-0.001	0.100
	P	0.013	0.355	0.301	0.406
DVA (80 dps)	Beta	0.001	-0.001	<0.001	0.226
	P	0.296	0.206	0.897	0.147
Left eye					
DVA (20 dps)	Beta	0.001	-0.001	<0.001	0.214
	P	0.296	0.140	0.859	0.145
DVA (40 dps)	Beta	-0.001	<0.001	<0.001	0.150
	P	0.530	0.602	0.923	0.352
DVA (60 dps)s	Beta	0.001	-0.001	-0.001	0.199
	P	0.566	0.237	0.301	0.127
DVA (80 dps)	Beta	0.001	-0.001	<0.001	0.391
	P	0.702	0.103	0.808	0.022

*The optic disc retinal nerve fiber layer thickness was measured at the size of 4.5*4.5mm.
#The fovea thickness was measured at the size of 1*1mm and the parafovea thickness was measured at the range between 1 to 3mm.
Abbreviation: dps, degrees per second; DVA, dynamic visual acuity.

Table A5. The impact of optic disc* and macular# capillary density on DVA by eye.

		Optic Disc		**Superficial macula**		**Deep macula**	
		Inside disc	Peripapillary	Fovea	Parafovea	Fovea	Parafovea

 doi:10.20944/preprints202504.2271.v1

Right eye							
DVA-20dps	Beta	-0.001	-0.005	-0.001	0.001	-0.002	-0.001
	P	0.801	0.341	0.693	0.872	0.382	0.847
DVA-40dps	Beta	-0.005	-0.003	-0.001	0.002	-0.001	0.003
	P	0.227	0.609	0.621	0.609	0.804	0.327
DVA-60dps	Beta	-0.006	-0.007	-0.001	0.001	-0.001	-0.001
	P	0.105	0.118	0.756	0.776	0.542	0.811
DVA-80dps	Beta	<0.001	-0.014	-0.001	-0.001	-0.001	0.007
	P	0.941	0.007	0.588	0.778	0.657	0.047
Left eye							
DVA-20dps	Beta	-0.002	-0.001	-0.003	0.003	-0.004	-0.007
	P	0.613	0.768	0.231	0.435	0.065	0.080
DVA-40dps	Beta	<0.001	-0.003	-0.002	0.005	-0.002	-0.003
	P	0.897	0.559	0.513	0.265	0.333	0.459
DVA-60dps	Beta	0.003	-0.003	-0.002	0.001	-0.002	-0.001
	P	0.328	0.381	0.387	0.807	0.350	0.697
DVA-80dps	Beta	0.003	-0.007	-0.005	0.006	-0.005	-0.009
	P	0.413	0.150	0.095	0.184	0.027	0.066

*The inside disc capillary density was measured at the size of 1.5*1.5mm and the peripapillary capillary density was measured at the range between 1.5 to 4.5 mm. #The fovea capillary density was measured at the size of 1*1mm and the parafovea capillary density was measured at the range between 1 to 3mm. Abbreviation: dps, degrees per second; DVA, dynamic visual acuity.

References

1. Palidis, D.J.; Wyder-Hodge, P.A.; Fooken, J.; Spering, M. Distinct Eye Movement Patterns Enhance Dynamic Visual Acuity. *PLoS ONE* **2017**, *12*, e0172061, doi:10.1371/journal.pone.0172061.
2. Land, M.F. Eye Movements and the Control of Actions in Everyday Life. *Progress in Retinal and Eye Research* **2006**, *25*, 296–324, doi:10.1016/j.preteyeres.2006.01.002.
3. Ao, M.; Li, X.; Huang, C.; Hou, Z.; Qiu, W.; Wang, W. Significant Improvement in Dynamic Visual Acuity after Cataract Surgery: A Promising Potential Parameter for Functional Vision. *PLoS One* **2014**, *9*, e115812, doi:10.1371/journal.pone.0115812.
4. Ishigaki, H.; Miyao, M. Differences in Dynamic Visual Acuity between Athletes and Nonathletes. *Percept Mot Skills* **1993**, *77*, 835–839, doi:10.2466/pms.1993.77.3.835.
5. Shinar, D.; Schieber, F. Visual Requirements for Safety and Mobility of Older Drivers. *Hum Factors* **1991**, *33*, 507–519, doi:10.1177/001872089103300503.
6. Sharma*, N.; Thakur, R. Dynamic & Static Visual Acuity Chart – Past, Present & Future: A Brief Review. *Indian Journal of Clinical and Experimental Ophthalmology 10*, 213–217, doi:10.18231/j.ijceo.2024.039.

7. Wu, T.-Y.; Wang, Y.-X.; Li, X.-M. Applications of Dynamic Visual Acuity Test in Clinical Ophthalmology. *Int J Ophthalmol* **2021**, *14*, 1771–1778, doi:10.18240/ijo.2021.11.18.
8. Chen, G.; Zhang, J.; Qiao, Q.; Zhou, L.; Li, Y.; Yang, J.; Wu, J.; Huangfu, H. Advances in Dynamic Visual Acuity Test Research. *Front. Neurol.* **2023**, *13*, doi:10.3389/fneur.2022.1047876.
9. Ren, X.; Wang, Y.; Wu, T.; Jing, D.; Li, X. Binocular Dynamic Visual Acuity in Dry Eye Disease Patients. *Front Neurosci* **2023**, *17*, 1108549, doi:10.3389/fnins.2023.1108549.
10. Wang, Y.; Guo, Y.; Li, Y.; Zhang, Y.; Yuan, Y.; Wu, T.; Chen, Y.; Li, X. The Impact of Different Corneal Refractive Surgeries on Binocular Dynamic Visual Acuity. *Front Neurosci* **2023**, *17*, 1142339, doi:10.3389/fnins.2023.1142339.
11. Wang, Y.; Guo, Y.; Wei, S.; Yuan, Y.; Wu, T.; Zhang, Y.; Chen, Y.; Li, X. Binocular Dynamic Visual Acuity in Eyeglass-Corrected Myopic Patients. *JoVE* **2022**, 63864, doi:10.3791/63864.
12. Ren, X.; Wang, Y.; Wang, D.; Wu, B.; Wu, L.; Xu, Y.; Yang, J.; Chen, Z.; Li, X. A Novel Standardized Test System to Evaluate Dynamic Visual Acuity Post Trifocal or Monofocal Intraocular Lens Implantation: A Multicenter Study. *Eye* **2020**, *34*, 2235–2241, doi:10.1038/s41433-020-0780-9.
13. Rokszin, A.; Márkus, Z.; Braunitzer, G.; Berényi, A.; Benedek, G.; Nagy, A. Visual Pathways Serving Motion Detection in the Mammalian Brain. *Sensors (Basel)* **2010**, *10*, 3218–3242, doi:10.3390/s100403218.
14. Oliveira, C.M.; Ferreira, A.; Franco, S. Wavefront Analysis and Zernike Polynomial Decomposition for Evaluation of Corneal Optical Quality. *J Cataract Refract Surg* **2012**, *38*, 343–356, doi:10.1016/j.jcrs.2011.11.016.
15. Hartwig, A.; Atchison, D.A. Analysis of Higher-Order Aberrations in a Large Clinical Population. *Investigative Ophthalmology & Visual Science* **2012**, *53*, 7862–7870, doi:10.1167/iovs.12-10610.
16. Ruiz-Alcocer, J.; Madrid-Costa, D.; García-Lázaro, S.; Ferrer-Blasco, T.; Montés-Micó, R. Optical Performance of Two New Trifocal Intraocular Lenses: Through-Focus Modulation Transfer Function and Influence of Pupil Size. *Clin Exp Ophthalmol* **2014**, *42*, 271–276, doi:10.1111/ceo.12181.
17. Sinha, A. iTrace – A Ray Tracing Aberrometer. *DJO* **2019**, *30*, doi:10.7869/djo.489.
18. Skottun, B.C. A Few Words on Differentiating Magno- and Parvocellular Contributions to Vision on the Basis of Temporal Frequency. *Neurosci Biobehav Rev* **2016**, *71*, 756–760, doi:10.1016/j.neubiorev.2016.10.016.
19. Jorge, J.; Jorge, J.P. Relationship between Dynamic Visual Acuity and Static Visual Acuity, Refractive Error, and Binocular Vision in Elite Soccer Players. *Clinical and Experimental Optometry* **2024**, *107*, 820–825, doi:10.1080/08164622.2024.2301981.
20. Wang, X.; Yan, M.; Li, J.; Wang, Y. The Short- and Long-Term Perceptual Learning of Clinical Dynamic Visual Acuity Test. *Invest Ophthalmol Vis Sci* **2024**, *65*, 43, doi:10.1167/iovs.65.12.43.
21. Geer, I.; Robertson, K.M. Measurement of Central and Peripheral Dynamic Visual Acuity Thresholds during Ocular Pursuit of a Moving Target. *Optom Vis Sci* **1993**, *70*, 552–560, doi:10.1097/00006324-199307000-00006.
22. Hirano, M.; Hutchings, N.; Simpson, T.; Dalton, K. Validity and Repeatability of a Novel Dynamic Visual Acuity System. *Optom Vis Sci* **2017**, *94*, 616–625, doi:10.1097/OPX.0000000000001065.
23. Jorge, J.; Fernandes, P. Static and Dynamic Visual Acuity and Refractive Errors in Elite Football Players. *Clin Exp Optom* **2019**, *102*, 51–56, doi:10.1111/cxo.12812.
24. Bulson, R.C.; Ciuffreda, K.J.; Hayes, J.; Ludlam, D.P. Effect of Retinal Defocus on Basketball Free Throw Shooting Performance. *Clin Exp Optom* **2015**, *98*, 330–334, doi:10.1111/cxo.12267.
25. Erdinest, N.; London, N.; Lavy, I.; Berkow, D.; Landau, D.; Levinger, N.; Morad, Y. Peripheral Defocus as It Relates to Myopia Progression: A Mini-Review. *Taiwan J Ophthalmol* **2023**, *13*, 285–292, doi:10.4103/tjo.TJO-D-22-00100.
26. Shneor, E.; Hochstein, S. Effects of Eye Dominance in Visual Perception. *International Congress Series* **2005**, *1282*, 719–723, doi:10.1016/j.ics.2005.05.006.