

# Correlation Between Retinal Vascular Oxygen Saturation, Red Blood Cell Parameters and Hemorheology Parameters in Healthy Adults

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**Purpose:** Investigate the correlation between retinal vascular oxygen saturation and red blood cell parameters, hemorheology parameters in healthy adults.

**Methods:** The study recruited 120 healthy volunteers, and their elbow venous blood was drawn for examination of RBC parameters and hemorheology. The retinal oximeter measured the retinal vascular oxygen saturation, including retinal arteriolar oxygen saturation (SaO<sub>2</sub>), venous oxygen saturation (SvO<sub>2</sub>) and arteriovenous oxygen saturation Difference (AVD). The *Pearson Correlation* and *Spearman's Correlation* methods were used to analyze the correlation between the SaO<sub>2</sub>, SvO<sub>2</sub>, AVD and the red blood cell parameters, hemorheology parameters.

**Results:** The analysis yielded a statistically significant correlation between SaO<sub>2</sub> and BMI ( $r=0.184$ ,  $P=0.044$ ). SvO<sub>2</sub> was associated with Gender ( $r=-0.227$ ,  $P=0.013$ ), HGB ( $r=-0.190$ ,  $P=0.038$ ), HCT ( $r=-0.236$ ,  $P=0.009$ ), RDW-CV ( $r=0.228$ ,  $P=0.012$ ), WBRH ( $r=0.019$ ,  $P=0.037$ ), WBVL 1/s ( $r=-0.194$ ,  $P=0.034$ ), WBVM 50/s ( $r=-0.206$ ,  $P=0.024$ ), WBVH 150/s ( $r=-0.211$ ,  $P=0.021$ ) and WBVH 200/s ( $r=-0.222$ ,  $P=0.015$ ). AVD was associated with Gender ( $r=-0.318$ ,  $P=0.000$ ), BMI ( $r=0.269$ ,  $P=0.003$ ), RBC ( $r=0.282$ ,  $P=0.002$ ), HGB ( $r=0.263$ ,  $P=0.004$ ), RBCSI ( $r=0.187$ ,  $P=0.041$ ), WBRH ( $r=0.289$ ,  $P=0.001$ ), WBRVH ( $r=0.247$ ,  $P=0.006$ ), WBVL 1/s ( $r=0.220$ ,  $P=0.016$ ), WBVL 10/s ( $r=0.289$ ,  $P=0.001$ ), WBVM 50/s ( $r=0.323$ ,  $P=0.000$ ), WBVH 150/s ( $r=0.320$ ,  $P=0.000$ ) and WBVH 200/s ( $r=0.320$ ,  $P=0.000$ ). Gender ( $\beta=-0.297$ ,  $P=0.005$ ), BMI ( $\beta=0.208$ ,  $P=0.023$ ), PV ( $\beta=-0.304$ ,  $P=0.000$ ) were independent predictors of AVD.

**Conclusion:** Retinal vascular oxygen saturation is correlated with many RBC parameters and hemorheology parameters, indicating that RBC and rheological characteristics of peripheral blood may affect the transport and metabolism of retinal oxygen and are closely related to retinal microcirculation.

**Translational Relevance:** The relationship between retinal blood oxygen saturation and red blood cell and hemorheology parameters confirmed the close correlation between ocular microcirculation and systemic blood circulation, which provided a prospective diagnosis and treatment strategy for microcirculatory-related eye diseases.

**Keywords:** retinal vascular oxygen saturation, retinal oximetry, retinal microcirculation, RBC parameters, hemorheology

## Introduction

Retinal oxygen saturation, a key indicator for assessing microcirculatory status, quantifies the oxygen-binding capacity of hemoglobin in retinal blood vessels. Its measurement is based on the differential light absorption rates of oxygenated and deoxygenated hemoglobin at specific wavelengths, utilizing noninvasive retinal oximetry.<sup>1</sup> In recent years, this technology has been widely applied in disease research, revealing characteristic alterations in retinal oxygen saturation among patients with systemic conditions such as diabetic retinopathy,<sup>2</sup> glaucoma,<sup>3</sup> and chronic kidney disease,<sup>4</sup> suggesting potential associations with underlying pathological mechanisms.

Beyond pathological contexts, physiological factors influencing retinal oxygen saturation have garnered attention, yet existing findings remain contradictory. For instance, age exhibits both positive<sup>5</sup> and negative<sup>6</sup> correlations with arteriolar oxygen saturation (SaO<sub>2</sub>) and venular oxygen saturation (SvO<sub>2</sub>) across studies. Similarly, the effects of refractive status,<sup>7–9</sup> vascular diameter,<sup>10,11</sup> and ambient light intensity<sup>12</sup> lack consensus. Notably, while hemodynamic parameters (eg, retinal capillary flow) and serum biomarkers (eg, HbA1c, lipid profiles) have been implicated in retinal metabolic disorders,<sup>13,14</sup> their relationships with retinal oxygen saturation in healthy individuals remain underexplored.

Based on these gaps, we propose the central hypothesis: retinal vascular oxygen saturation in healthy adults is significantly associated with red blood cell parameters, hemorheological indices and systemic circulatory characteristics, and these associations reflect an interaction between ocular microcirculation and systemic blood circulation. By integrating retinal oxygen saturation data with hematological profiling, this study aims to identify key determinants of retinal oxygen metabolism, providing a theoretical foundation for early detection of microcirculatory dysfunction.

## Methods

This study was an observational cross-sectional study of healthy adults. It was conducted following the tenets of the Declaration of Helsinki and was approved by the Medical Ethics Committee of Ineye Hospital of Chengdu University of Traditional Chinese Medicine (Approval Number: 2021yh-021). A total of 120 healthy volunteers were enrolled in this study, who all had full knowledge of the study and voluntarily signed the informed consent form before participation.

## Inclusion and Exclusion Criteria

The Inclusion criteria of this study were best-corrected visual acuity more than 1.0, refractive errors lower or equal  $-6.00/+3.00$  dioptres, age between 18 and 75 years old, Body Mass Index (BMI) between 18.5 and 23.9. The exclusion criteria of this study were pregnant or lactating women, a history of diabetes, hypertension, cardiovascular and respiratory diseases and other severe diseases and mental illness, a history of eye trauma, eye surgery and glaucoma, retinitis pigmentosa, age-related macular degeneration, retinal artery or vein occlusion and other eye diseases, long-term history of cigarette, alcohol and other unhealthy habits.

## Inspection

120 healthy adults were enrolled in this study. Each participant underwent the same examination: Height, Weight, Routine Blood Examination, Hemorheology Examination, Visual Acuity (logMAR), IOP (TopconCT-80A, Topcon Inc., Tokyo, Japan), Slit-Lamp Examination (Keeler SL4, Keeler Co. Ltd, Berkshire, UK), Ophthalmoscope Examination (YZ6F, 66 Vision-Tech Co. Ltd, Suzhou, China), Retinal Oximetry (Oxymap T1, Oxymap ehf., Reykjavik, Iceland).

Each participant arrived at the hospital on an empty stomach and rested for 30 minutes before examination. The researchers first performed Visual Acuity, IOP, Slit-Lamp Examination, Ophthalmoscope Examination to exclude eye diseases. Then the elbow vein blood of participants was drawn for Routine Blood Examination and Hemorheology Examination.

The subjects did not take any drugs affecting blood rheology and microcirculation within 2 weeks before the blood draw, and had blood test on an empty stomach in the morning of the same day. The reagents and quality control products used for blood drawing were provided by the manufacturer, and the specific inspection procedures were conducted in strict accordance with the laboratory instrument operation manual. RBC-related parameters were analyzed using the automatic five-classification blood cell analyzer (DH76, Dymind Biotechnology Co. Ltd., Shenzhen, China) and the parameters for their analysis included Red Blood Cell (RBC), Hemoglobin (HGB), Hematocrit (HCT), Mean Corpuscular Volume (MCV), Mean Corpuscular Hemoglobin (MCH), Mean Corpuscular Hemoglobin Concentration (MCHC), Red Blood Cell Distribution Width-Standard Deviation (RDW-SD), Red Blood Cell Distribution Width-Coefficient of Variation (RDW-CV). Hemorheological parameters were analyzed using the automatic blood viscosity analyzer (South990-ACC2000, Nanfang Numerical Control Equipment Co., Ltd, Chongqing, China), the parameters for their analysis included Plasma Viscosity (PV), Red Blood Cell Stiffness Index (RBCSI), Red Blood Cell Aggregation Index (RBCAI), Red Blood Cell Deformation Index (RBCDI), Whole Blood Relative Index Low-cut (WBRIL), Whole Blood Relative Index High-cut (WBRIH), Whole Blood Reduced Viscosity Low-cut (WBRVL), Whole Blood Reduced

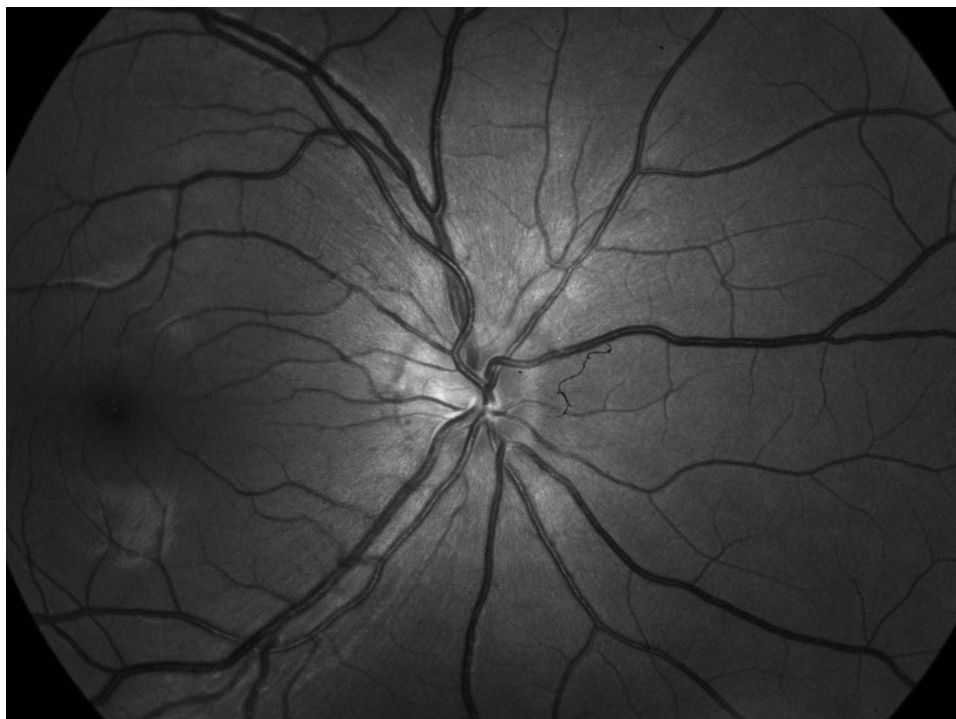
Viscosity High-cut (WBRVH), Whole Blood Viscosity Low-cut 1/s (WBVL 1/s), Whole Blood Viscosity Low-cut 10/s (WBVL 10/s), Whole Blood Viscosity Mid-cut 50/s (WBVM 50/s), Whole Blood Viscosity High-cut 150/s (WBVH 150/s), Whole Blood Viscosity High-cut 200/s (WBVH 200/s).

The pupil were dilated to a diameter of 6–8 mm by using Compound Tropicamide Eye Drops before retinal oximetry. The fundus images acquisition were performed under darkroom conditions. The fundus images were taken in a 50° field centred at the optic disc and the light flash was set at 50 Ws. The right eye of each subject was selected for the study. The fundus images were analysed by Oxymap Analyzer software (Oxymap T1, Version 1.2, the interface is shown in Figures 1 and 2). The measurement zone was a concentric circle area centered on the optic disc, which inner circle diameter was 1.5 times the optic disc and the outer circle was 3 times the optic disc. Small retinal vessels with width more than 8 pixels and length more than 100 pixels within the region were selected for analysis. If there were branching blood vessels, the parent branch vessel was selected. If the length of the parent branch was less than 100 pixels, the sub-branch was selected. At the intersections of vessels, the distal segment was selected unless the length of it was less than 100 pixels. The mean retinal vessel oxygen saturation level was calculated as shown in the following formula:  $S = (S1 * D14 + S2 * D24 + S3 * D34 + \dots + Sn * Dn4) / (D14 + D24 + D34 + \dots + Dn4)$ , where  $S$  represented Mean oxygen saturation,  $Sn$  represented saturation of  $n$  vessel segment,  $Dn$  represented diameter of  $n$  vessel segment. The Arteriovenous Oxygen Saturation Difference (AVD) is calculated as the difference between  $SaO_2$  and  $SvO_2$ , expressed as:  $AVD = SaO_2 - SvO_2$ .

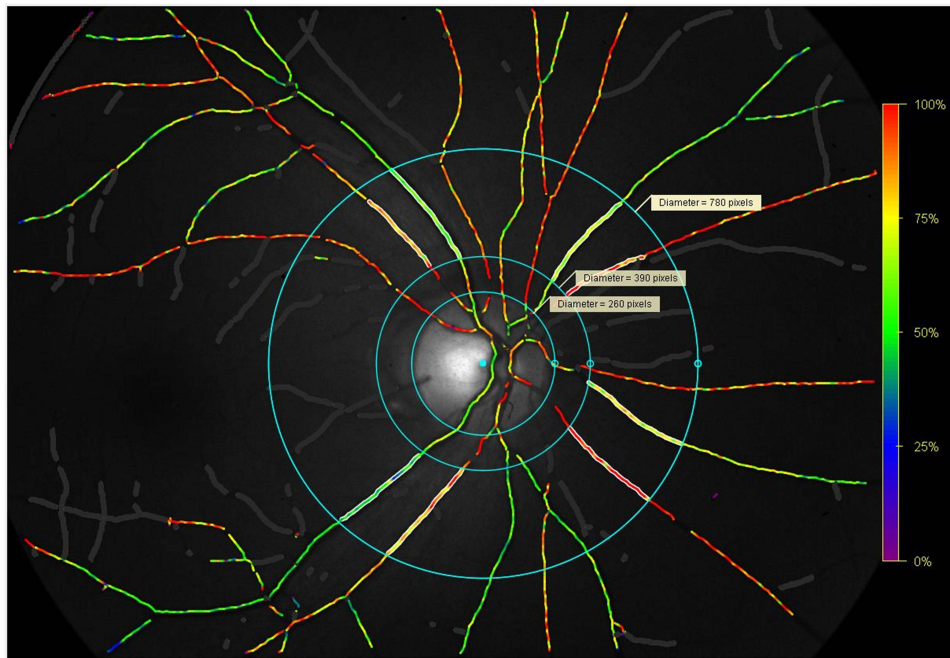
## Statistical Analysis

A priori power analysis was performed using GPower (Version 3.1). Based on an expected medium effect size ( $f^2=0.15$ ,  $f^2=0.15$ ), a significance level of  $\alpha=0.05$ , and a power of 80%, the minimum required sample size was determined to be 85 participants. Our final sample of 120 participants exceeded this requirement, ensuring adequate statistical power.

The statistical analysis was performed using software IBM SPSS Statistics (Version 24.0) and Origin (Version 2024). All the data were performed for the test of normality using the Kolmogorov–Smirnov method. All normally distributed variables were reported as Mean±Standard Deviation (SD), and other variable as Median with Range. Pearson Correlation method was performed for the correlation between data meeting the normal distribution, while Spearman's



**Figure 1** The original image captured using the Oxymap Analyzer software.



**Figure 2** In the Oxymap Analyzer software, blood vessels are automatically identified. The redder the color of the blood vessels, the higher the blood oxygen saturation, while the greener the color, the lower the blood oxygen saturation.

*Correlation* method was performed for the correlation between data not meeting the normal distribution. Furthermore, to account for potential confounding effects and evaluate the independent contributions of variables, *multiple linear regression analyses* were employed. To address multicollinearity, variables with *variance inflation factors (VIF) >10* were excluded based on statistical thresholds and theoretical relevance, and the regression model was refitted to ensure stability and interpretability. All statistical tests were two-tailed, with a corrected significance threshold of  $P<0.05$ .

## Results

A total of 120 eyes were enrolled in this study, 32 (26.67%) males and 88 (73.33%) females. The *mean±standard deviation* of each normally distributed variables can be seen in detail in [Table 1](#) and [Table 2](#).

The analysis yielded a statistically significant correlation between  $SaO_2$  and BMI ( $r=0.184, P=0.044$ ).  $SvO_2$  was associated with Gender ( $r=-0.227, P=0.013$ ), HGB ( $r=-0.190, P=0.038$ ), HCT ( $r=-0.236, P=0.009$ ), RDW-CV

**Table 1** Descriptive Statistical Data for Normally Distributed Variables

Parameter	Mean	SD
SaO <sub>2</sub> [%]	93.85	5.45
SvO <sub>2</sub> [%]	58.25	5.84
AVD[%]	35.60	6.39
BMI[kg/m <sup>2</sup> ]	21.43	2.57
RBCAI	5.06	0.56
WBRIL	13.86	1.95
WBRVL[mPa.s]	42.08	5.57
WBVL 1/s[mPa.s]	19.65	2.63

**Table 2** Descriptive Statistical Data for Other Variables

Parameter	Median	Range
Age[Year]	25.00	57.00
RBC[10 <sup>9</sup> /L]	4.63	4.18
HGB[g/L]	137.00	196.73
HCT[%]	40.65	53.52
MCV[fL]	88.90	43.40
MCH[pɡ]	29.70	17.20
MCHC[g/L]	334.50	64.00
RDW-SD[%]	43.10	25.60
RDW-CV[%]	13.50	7.10
PV[mPa.s]	1.43	11.55
RBCSI	3.94	3.61
RBCDI	0.76	1.03
WBRIH	2.67	2.48
WBRVH[mPa.s]	5.52	4.60
WBVL 10/s[mPa.s]	6.79	5.61
WBVM 50/s[mPa.s]	4.59	4.02
WBVH 150/s[mPa.s]	3.94	3.53
WBVH 200/s[mPa.s]	3.85	3.44

( $r=0.228$ ,  $P=0.012$ ), WBRIH ( $r=0.019$ ,  $P=0.037$ ), WBVL 1/s ( $r=-0.194$ ,  $P=0.034$ ), WBVM 50/s ( $r=-0.206$ ,  $P=0.024$ ), WBVH 150/s ( $r=-0.211$ ,  $P=0.021$ ) and WBVH 200/s ( $r=-0.222$ ,  $P=0.015$ ). AVD was associated with Gender ( $r=-0.318$ ,  $P=0.000$ ), BMI ( $r=0.269$ ,  $P=0.003$ ), RBC ( $r=0.282$ ,  $P=0.002$ ), HGB ( $r=0.263$ ,  $P=0.004$ ), RBCSI ( $r=0.187$ ,  $P=0.041$ ), WBRIH ( $r=0.289$ ,  $P=0.001$ ), WBRVH ( $r=0.247$ ,  $P=0.006$ ), WBVL 1/s ( $r=0.220$ ,  $P=0.016$ ), WBVL 10/s ( $r=0.289$ ,  $P=0.001$ ), WBVM 50/s ( $r=0.323$ ,  $P=0.000$ ), WBVH 150/s ( $r=0.320$ ,  $P=0.000$ ) and WBVH 200/s ( $r=0.320$ ,  $P=0.000$ ). These can be seen in detail in [Table 3](#). The correlation heat map is shown in [Figure 3](#).

This study aimed to conduct multiple linear regression analysis on the research data to explore the relationships between variables. However, preliminary analysis revealed that multiple data points exhibited multicollinearity issues ( $VIF > 10$ ). Therefore, the data were first screened, and Gender, Age, BMI, RBC, HGB and PV. These representative and relatively independent indicators were selected for the *multiple linear regression analysis*. *Multiple linear regression analyses* revealed that the model for AVD was statistically significant ( $R^2=0.479$ ,  $F=5.596$ ,  $P=0.000$ ), whereas models for SaO<sub>2</sub> ( $R^2=0.300$ ,  $F=0.869$ ,  $P=0.092$ ) and SvO<sub>2</sub> ( $R^2=0.311$ ,  $F=2.023$ ,  $P=0.068$ ) did not reach significance. Further examination of individual predictors in the AVD model indicated that gender ( $\beta=-0.297$ ,  $P=0.005$ ), BMI ( $\beta=0.208$ ,  $P=0.023$ ), PV ( $\beta=-0.304$ ,  $P=0.000$ ) was independently associated with AVD. These can be seen in detail in [Table 4](#).

## Discussion

This study was the first to reveal the dynamic correlations between retinal vascular oxygen saturation and RBC parameters as well as hemorheological characteristics in healthy adults, systematically elucidating the interactive mechanisms among RBC function, hemorheological properties and retinal oxygen metabolism.

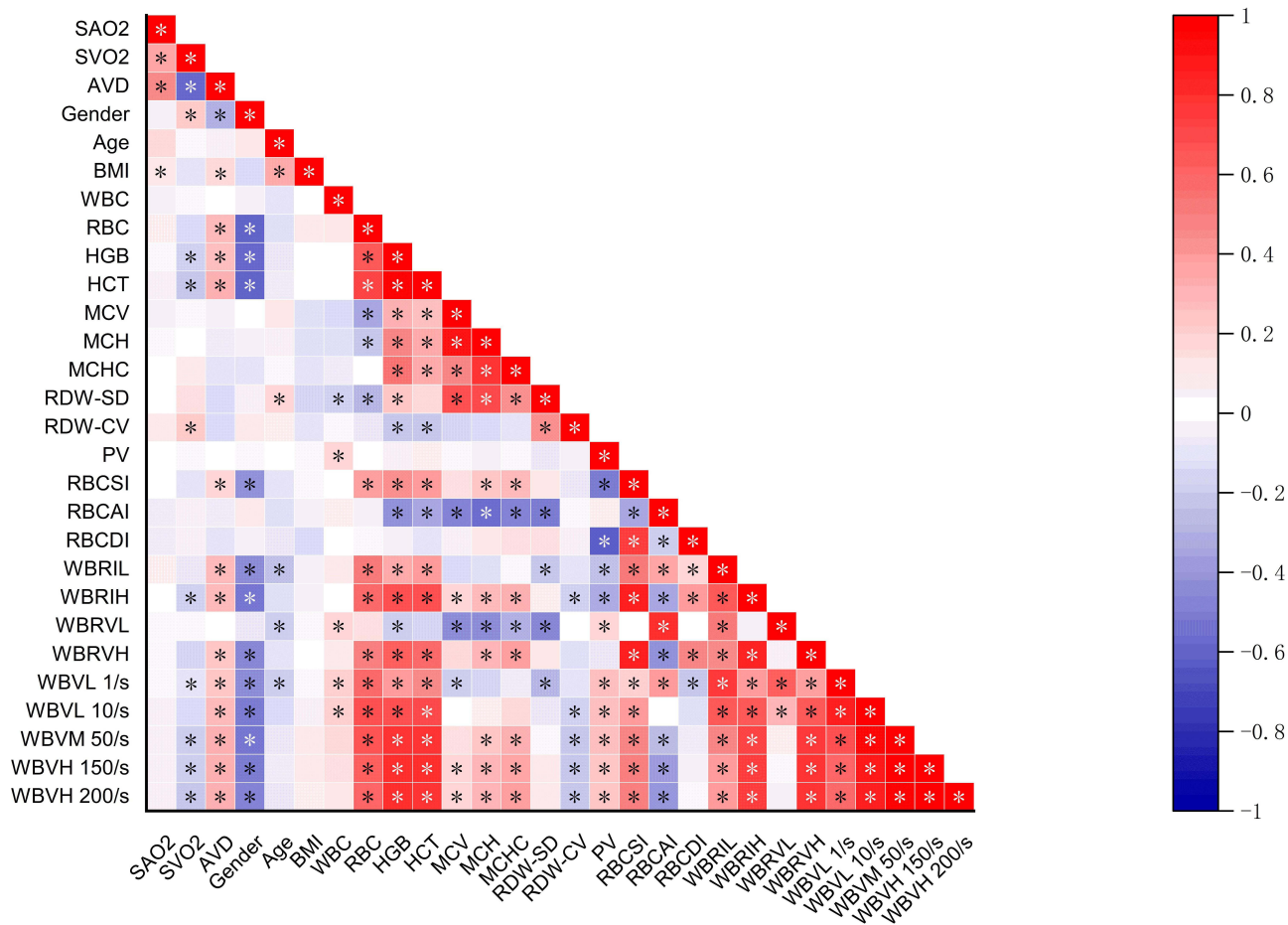
**Table 3** Correlation Between SaO<sub>2</sub>, SvO<sub>2</sub>, AVD and Red Blood Cell Parameters, Hemorheology Parameters

Parameter	SaO <sub>2</sub>		SvO <sub>2</sub>		AVD	
	r	P	r	P	r	P
Gender <sup>S</sup>	-0.059	0.524	0.227	0.013*	-0.318	0.000*
BMI <sup>P</sup>	0.184	0.044*	-0.123	0.180	0.269	0.003*
Age <sup>S</sup>	0.171	0.062	0.052	0.572	0.063	0.497
RBC <sup>S</sup>	0.084	0.362	0.083	-0.159	0.282	0.002*
HGB <sup>S</sup>	0.046	0.617	-0.190	0.038*	0.263	0.004*
HCT <sup>S</sup>	0.064	0.485	-0.236	0.009*	0.327	0.000*
MCV <sup>S</sup>	-0.050	0.590	-0.022	0.815	-0.055	0.553
MCH <sup>S</sup>	-0.028	0.762	0.034	0.711	-0.072	0.433
MCHC <sup>S</sup>	-0.010	0.914	0.110	0.232	-0.101	0.272
RDW-SD <sup>S</sup>	0.030	0.748	0.154	0.094	-0.143	0.118
RDW-CV <sup>S</sup>	0.105	0.252	0.228	0.012*	-0.149	0.104
PV <sup>S</sup>	-0.009	0.918	-0.039	0.676	0.030	0.747
RBCSI <sup>S</sup>	0.035	0.708	-0.101	0.274	0.187	0.041*
RBCAI <sup>P</sup>	-0.104	0.258	0.089	0.336	-0.170	0.064
RBCDI <sup>S</sup>	-0.076	0.412	0.068	0.464	-0.106	0.249
WBRIL <sup>P</sup>	0.055	0.551	-0.142	0.122	0.177	0.054
WBRIH <sup>S</sup>	0.034	0.711	0.190	0.037*	0.289	0.001*
WBRVL <sup>P</sup>	-0.051	0.107	0.019	0.834	-0.061	0.509
WBRVH <sup>S</sup>	0.042	0.648	-0.167	0.069	0.247	0.006*
WBVL 1/s <sup>P</sup>	0.050	0.588	-0.194	0.034*	0.220	0.016*
WBVL 10/s <sup>S</sup>	0.061	0.509	-0.152	0.097	0.289	0.001*
WBVM 50/s <sup>S</sup>	0.072	0.434	-0.206	0.024*	0.323	0.000*
WBVH 150/s <sup>S</sup>	0.075	0.418	-0.211	0.021*	0.320	0.000*
WBVH 200/s <sup>S</sup>	0.070	0.447	-0.222	0.015*	0.320	0.000*

**Notes:** <sup>P</sup>represents Pearson Correlation, <sup>S</sup>represents Spearman's Correlation. \*represents statistically significant differences.

## Correlation Between Gender, Age and BMI with Retinal Oximetry Measures

The results of this study confirmed that gender was an independent negative predictor of AVD, suggesting that the retinal oxygen uptake and utilization may be different in women and men. In previous studies, the influence of gender on retinal vascular oxygen saturation has been inconsistent. Some investigations demonstrated no significant association between retinal vascular oxygen saturation and gender,<sup>15,16</sup> while others identified gender-related differences.<sup>17</sup> This discrepancy might be explained by the observation that venous oxygen saturation decreases with age at a faster rate in males compared to females, a phenomenon potentially attributable to sex-specific patterns of vascular aging and hemodynamic regulation.<sup>17</sup>



**Figure 3** The correlation heat map of all the parameters. \* represents statistically significant differences. Blue represents the negative correlation between parameters, red represents the positive correlation between parameters. The deeper the color, the stronger correlation.

The results also suggested that SaO<sub>2</sub>, SvO<sub>2</sub> and AVD were not related with age. Several previous studies had explored the relationship between age and retinal vascular oxygen saturation. Geirsdottir et al<sup>17</sup> found that SaO<sub>2</sub> was not correlated with age in healthy people, while SvO<sub>2</sub> was negatively correlated with age, and AVD was negatively correlated with age. However, Man et al<sup>5</sup> found a positive relationship between SaO<sub>2</sub>, SvO<sub>2</sub> and age, while Jani et al<sup>6</sup> found a negative relationship between SaO<sub>2</sub>, SvO<sub>2</sub> and age. The differences in these results may be related to the ethnic differences,<sup>16</sup> the age range of the sample population, the opacity of the dioptric media, and the confounding factors such as having other diseases.

**Table 4** Multiple Linear Regression Analysis of AVD and Red Blood Cell Parameters, Hemorheology Parameters

Variables	$\beta$	t	P	VFI	95% CI
Constant	–	3.947	0.000	–	(17.733, 53.471)
Gender	–0.297	–2.840	0.005*	1.606	(–7.261, –1.293)
Age	–0.043	–0.477	0.635	1.199	(–0.096, 0.059)
BMI	0.208	2.300	0.023*	1.195	(0.072, 0.961)
RBC	–0.047	–0.330	0.742	2.980	(–3.833, 2.739)
HGB	0.058	0.441	0.660	2.543	(–0.061, 0.096)
PV	–0.304	–3.585	0.000*	1.054	(–2.938, –0.846)

**Notes:** \*represents statistically significant differences.  $\beta$  represents Standardized Coefficients, CI represents Confidence Interval.

BMI is a widely used parameter of reflecting human obesity and nutritional degree. The results suggested that SaO<sub>2</sub> and AVD were related with BMI, and BMI existed as an independent factor of AVD, which was consistent with the findings of Liu et al.<sup>18</sup> Related studies had shown that there was a positive correlation between human BMI and blood hemoglobin content, which can directly affect the measurement value of retinal vascular oxygen saturation. In addition, women had a significantly lower basal metabolic rate than men.<sup>19</sup> From this, we can speculate that the retinal vascular oxygen saturation can reflect the systemic nutritional metabolic state of the human body to a certain extent. In some eye diseases with retinal microcirculation disorders, controlling a certain BMI can be used as an important means of adjuvant treatment.

## Correlation Between RBC Parameters with Retinal Oximetry Measures

The results of this study showed that the correlation of retinal vascular oxygen saturation and RBC parameters were mainly focused on RBC, HGB, HCT and RDW-CV. RBC is the carrier of the body for transporting oxygen, while HGB is the oxygen transport protein. HCT refers to packed RBC relative to whole blood, which indirectly reflects the amount of RBC and HGB and determines the oxygen-carrying capacity of blood.<sup>20</sup> RDW-CV reflects the difference in RBC volume, and its elevation represents the dysregulation of RBC homeostasis, including impaired erythropoiesis and abnormal RBC survival,<sup>21</sup> which is associated with various diseases of hypoxemia.<sup>22</sup> The results of this study suggested a positive correlation between SvO<sub>2</sub> and RDW-CV, indicating that high RDW-CV may reduce the absorption and utilization of oxygen in retinal tissue. In the process of retinal microcirculation, oxygen is freely diffused from HGB to various retinal tissues for its physiological function,<sup>23</sup> and the level of retinal oxygen saturation can reflect the function of oxygenation and metabolism.<sup>24</sup> The more mature RBC, the more HGB that can transport oxygen. Thus, due to the different oxygen partial pressure, more oxygen is distributed to various retinal tissues, so the lower the SvO<sub>2</sub>, the higher the AVD.

Based on the existing technology, we are unable to measure RBC and HGB in retinal blood vessels, but the correlation between peripheral RBC parameters and retinal vascular oxygen saturation explored in this study can initially reflect the relationship between systemic blood circulation and retinal microcirculation. We can speculate that individuals with high RBC and high HGB have higher oxygen demand and utilization in their retina and more active retinal microcirculation.

## Correlation Between Hemorheology with Retinal Oximetry Measures

The results of this study showed that the correlation between retinal vascular oxygen saturation and hemorheology were mainly focused on RBCSI, WBRH, WBRVH, WBVL 1/s, WBVL 10/s, WBVM 50/s, WBVH 150/s and WBVH 200/s. Hemorheology is the parameter of the physical properties of blood cells, the properties of blood flow and the interaction state with the vascular wall. It is closely related to the deformation, aggregation, surface charge, changes in plasma composition, shear force of blood and other factors of RBC. The main determinants of whole blood viscosity are HCT, PV, fibrinogen level and the properties of RBC, including stiffness, aggregation and deformation.<sup>25</sup> Under pathological conditions, RBC deforms, aggregates, stiffness decreases, while blood viscosity increases and other circulating cells and endothelial cells are activated, leading to vascular occlusion and slow blood flow, which affecting hemorheology parameters.<sup>26</sup> Abnormal hemorheological parameters can directly affect the blood perfusion of tissues, thus leading to tissue metabolic disorders and hypoxia, while hypoxia can also cause the change of hemorheological parameters. Kang et al<sup>27</sup> found that hypoxia can increase whole blood viscosity, so as to impair the function of RBC and promote the platelet aggregation, leading to various hypoxic diseases. In addition, Esteva et al<sup>28</sup> found that hypoxia can cause a significant reduction in PV. As one of the most vigorous tissues of systemic oxygen metabolism, the retina needs abundant oxygen for its physiological function, and oxygen is closely related to hemorheology parameters. Plasma viscosity emerges as a critical determinant of intraretinal oxygen gradients, exerting significant modulation over oxygen availability within the retinal ganglion cell microenvironment through its impact on capillary perfusion dynamics.<sup>29</sup> Cross-sectional evidence have linked PV to critical ocular disease markers, including retinal vascular occlusions, glaucoma, diabetic retinopathy,<sup>30–32</sup> suggesting PV's role as a shared hemodynamic risk modulator across diverse retinal pathologies. The results of this study showed the correlation between multiple hemorheology parameters and retinal

vascular oxygen saturation, and PV was an independent factor affecting ADV after excluding various confounding factors.

Consequently, we can know that retinal vascular oxygen saturation is correlated with many RBC and hemorheological parameters, indicating that RBC and peripheral blood features may affect the transport and metabolism of retinal oxygen, and are closely related to retinal microcirculation.

## Limitations

Our study has several limitations. For instance, we did not control for the gender ratio of participants. In addition, we did not collect systemic oxygen circulation parameters such as blood gas analysis and peripheral oxygen saturation. As a cross-sectional study, it was not possible to observe the longitudinal effects of various factors on retinal oxygen metabolism. We plan to address these aspects in future research to obtain more comprehensive findings.

## Conclusion

This study demonstrated significant associations between retinal vascular oxygen saturation and systemic circulatory parameters, including gender, BMI, erythrocyte characteristics and hemorheological indices, establishing a robust connection between retinal oxygen dynamics and systemic hemodynamics. Gender, BMI and PV were identified as independent determinants of AVD. These observations suggest that systemic circulatory mechanisms, mediated by oxygen transport efficiency and metabolic adaptation, may critically influence retinal function, offering potential pathways to mitigate hypoxia-induced microvascular dysfunction. Future investigations should prioritize causal validation of these systemic–retinal interactions and evaluate their disease-specific manifestations in several conditions.

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## Disclosure

All authors declared no potential conflicts of interest.

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