Changes In The Eye Fundus In Individuals With High Cardiovascular Risk

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Abstract: Background. The retinal microvasculature reflects systemic vascular health and may serve as a non-invasive marker of cardiovascular risk. This study explores the diagnostic significance of retinal vascular signs in assessing cardiovascular risk in military personnel compared to civilian controls. Objective. To evaluate the prevalence and diagnostic relevance of retinal fundus abnormalities in individuals with varying levels of cardiovascular risk, particularly among active-duty and recently discharged military personnel. Methods. A total of 391 individuals were examined, including 287 military-affiliated subjects and 104 civilian controls. Participants underwent comprehensive clinical and ophthalmological evaluation. Retinal images were obtained using non-mydriatic fundus cameras and analyzed for five key vascular signs: venular dilation, arteriolar narrowing, reduced arterio-venous ratio (AVR < 0,66), vascular tortuosity, and vessel caliber asymmetry. Statistical analysis included group comparisons and frequency analysis across clinical subgroups. Results. Retinal abnormalities were significantly more frequent in military participants with hypertension, ischemic heart disease, or carotid atherosclerosis. AVR < 0,66 and increased vascular tortuosity were the most common signs in these groups. Even in individuals with risk factors but no diagnosed pathology, military personnel exhibited a higher prevalence of microvascular changes compared to civilians. Conclusion. Fundus-based vascular signs, especially reduced AVR and tortuosity, are valuable for early identification of cardiovascular risk. Retinal imaging may enhance non-invasive screening strategies, particularly in high-stress populations such as military personnel.

Keywords: Retinal microvasculature; Cardiovascular risk; Military health; Fundus photography; Arterio-venous ratio.

Introduction: The retinal vasculature offers a unique and non-invasive window into systemic microvascular health. Changes observed in the fundus, such as arteriolar narrowing, venular dilation, vascular tortuosity, and asymmetry in vessel caliber, reflect a variety of pathophysiological processes occurring throughout the body. These ophthalmic signs are increasingly recognized as early biomarkers of systemic vascular dysfunction, particularly in the context of chronic cardiovascular diseases (CVD). In recent years, growing attention has been paid to the use of retinal imaging in cardiovascular risk stratification, as the microcirculation of the retina mirrors the state of cerebral, renal, and coronary microvasculature. Among populations exposed to prolonged physical and psychological stress—such as active-duty military personnel and veterans—the assessment of retinal vascular changes may provide crucial insight into the early stages of cardiovascular pathology.

Military personnel often face a unique set of cardiovascular stressors, including intense physical exertion, disrupted circadian rhythms, chronic stress, and exposure to extreme environmental conditions. These factors may accelerate vascular aging and contribute to the development of hypertensive or atherosclerotic disease, even in the absence of overt

clinical symptoms. Therefore, identifying early, non-invasive indicators of cardiovascular risk in this high-exposure population is of great preventive value.

This study investigates specific retinal vascular signs in a military cohort, including individuals currently serving, recently discharged, and conditionally healthy subjects. Through comparative analysis with civilian controls, both with and without cardiovascular risk factors, the study aims to evaluate the diagnostic and prognostic utility of retinal markers - especially the arterio-venous ratio (AVR), vascular tortuosity, and caliber asymmetry-in stratifying cardiovascular risk and identifying subclinical vascular dysfunction.

METHODS

A total of 391 individuals were examined, of whom 287 (73,4%) comprised the main group-active-duty military personnel and individuals discharged from military service within the past five years at the time of enrollment. An additional civilian comparison group was formed (n=104; 26,6%), including individuals with no military affiliation. The sample was representative in terms of sex and age. All participants provided written informed consent prior to inclusion in the study.

Inclusion criteria for the main group were: age over 30 years; current military service or documented discharge from the armed forces; informed consent; and the ability to undergo a full ophthalmological and clinical examination. Participants were included if they had at least one of the following conditions:

Hypertension, diagnosed according to the criteria of the European Society of Cardiology (ESC) and the European Society of Hypertension (ESH, 2021): persistent elevation of systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg, or ongoing antihypertensive therapy.

Coronary heart disease (CHD), confirmed by clinical and instrumental findings including ECG, echocardiography, history of exertional angina or myocardial infarction, documented coronary angiography results, or post-infarction cardiosclerosis. This subgroup also included patients with both IHD and hypertension.

Carotid artery atherosclerosis, diagnosed by duplex ultrasound scanning (DUS): intima-media thickness (IMT) ≥0.9 mm and/or presence of atherosclerotic plaques causing ≥50% stenosis of the vessel lumen, considered hemodynamically significant (based on ESC, AHA, and ultrasound guidelines).

In addition, the sample included military personnel with significant cardiovascular risk factors but no clinically established pathology. These factors included: high-normal blood pressure (130–139/85–89 mmHg), dyslipidemia (LDL >3,0 mmol/L, low HDL,

hypertriglyceridemia), impaired glucose tolerance, overweight (BMI >25 kg/m²), smoking, a family history of early cardiovascular events, and high levels of chronic stress. These individuals were classified as having moderate to high cardiovascular risk.

A separate subgroup consisted of conditionally healthy military personnel-individuals without diagnosed chronic somatic diseases, with normal blood pressure, glycemia, lipid profile, and no retinal abnormalities on ophthalmological examination. For inter-population comparisons, two civilian subgroups were also included: individuals with cardiovascular risk factors, and conditionally healthy civilians who met control criteria.

The civilian comparison sample was formed for intergroup analysis purposes. It included individuals over the age of 30 with no military background who were able to undergo outpatient examination. Based on similar clinical and laboratory criteria, two subgroups were identified: civilians with cardiovascular risk factors (e.g., borderline blood pressure, elevated BMI, lipid abnormalities, or chronic stress without diagnosed pathology) and healthy civilian controls-individuals without risk factors and with no fundus abnormalities.

Acquisition and Processing of Fundus Images. Retinal fundus images were obtained using a non-mydriatic digital fundus camera with a field of view ranging from 45° to 60°. The camera provided high-resolution images (at least 2048×1536 pixels) and supported image formats such as JPEG, PNG, or DICOM.

Imaging procedure: Pupil dilation was performed when necessary or upon participant request using 0,5% tropicamide solution. Participants were positioned in front of the fundus camera. At least one macula-centered image and one optic disc image were captured per eye; when possible, panoramic or mosaic images were also acquired.

Image quality criteria included sharpness, absence of artifacts (e.g., glare or shadowing), and clear visualization of the vascular network-down to the peripheral arterioles and venules. Brightness, contrast, and focus had to meet standards suitable for automated image analysis.

Statistical analysis was performed using SPSS version 25.0. Standard descriptive statistics were applied. Group comparisons used the Chi-square test, Student's t-test, or the Mann–Whitney U test, depending on data type and distribution. Differences were considered statistically significant at p<0,05.

RESULTS

A total of 391 participants were included in the study,

comprising 287 military-affiliated individuals and 104 civilian controls. The primary outcome measures were specific ophthalmoscopic signs of retinal microvascular change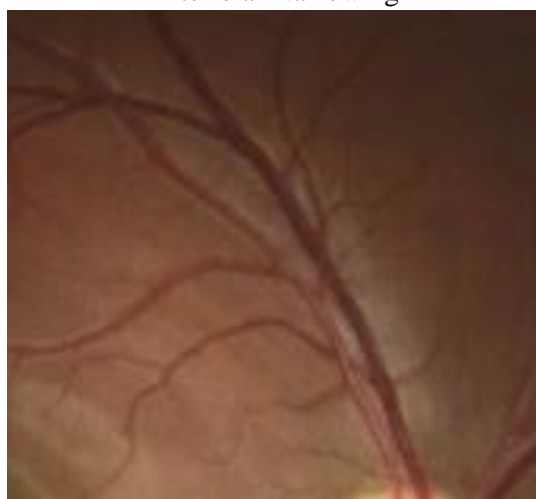s, assessed to evaluate cardiovascular risk stratification. Key retinal markers analyzed included venular dilation, arteriolar narrowing, reduced arteriovenous ratio, increased vascular tortuosity, and asymmetry of vessel caliber (Fig. 1).
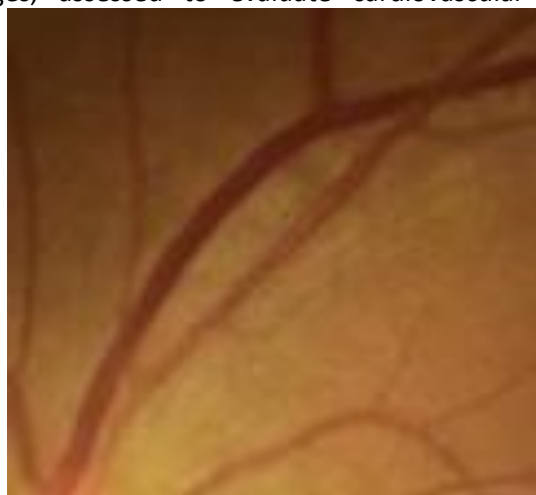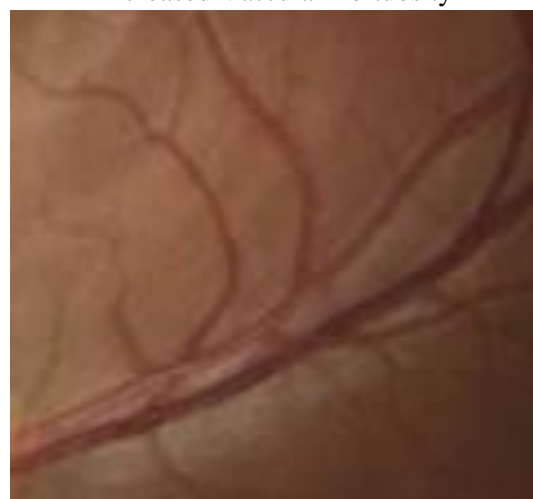

Arteriolar Narrowing
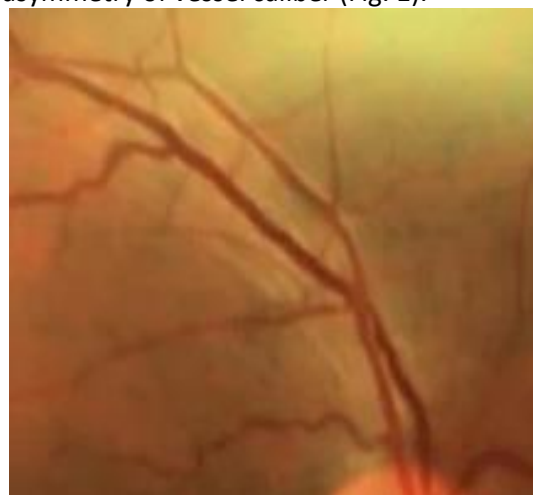
Increased Vascular Tortuosity

Vessel Caliber Asymmetry

AVR < 0,66

Figure 1. Key ophthalmoscopic signs considered for cardiovascular risk identification and stratification.

The most frequently observed retinal abnormality across all military subgroups with established cardiovascular pathology was venular dilation. This sign was present in 84,6% of hypertensive service members, 84,9% of those with CHD or combined CHD and hypertension, and in 58,5% of those diagnosed with carotid artery atherosclerosis. Among those with only cardiovascular risk factors (but no established pathology), venular dilation was observed in 46,2%. By contrast, conditionally healthy military personnel and civilians showed significantly lower frequencies-22,0% and 15,4%, respectively (Tab. 1).

Arteriolar narrowing was similarly prevalent in participants with hypertension (82,1%) and combined CHD or CHD plus hypertension (79,2%). It was present in 48,8% of those with carotid atherosclerosis and 41,5% of those with cardiovascular risk factors alone. This finding was comparatively rare among healthy military personnel (20,0%) and civilians (11,5%),

supporting its role as a marker of chronic vascular remodeling under hemodynamic stress. The reduction of the arteriovenous ratio emerged as a particularly sensitive marker in identifying individuals with clinically confirmed cardiovascular pathology. It was present in 56,6% of participants with CHD and 55,1% of those with isolated hypertension. The marker was less frequent in participants with atherosclerosis (26,8%) and those with risk factors alone (15,4%). Among conditionally healthy military individuals, the prevalence dropped to 10,0%, and was even lower among healthy civilians (5,8%) and civilian individuals with risk factors (11,5%).

Increased vascular tortuosity, another marker of microvascular dysfunction and chronic hemodynamic overload, was found in 67,9% of military participants with CHD or CHD plus hypertension and in 66,7% of those with hypertension alone. This sign was observed in 41,5% of those with carotid artery disease and 29,2% of those with cardiovascular risk factors. By contrast, it

was much less frequent among healthy military (14,0%) and civilian individuals (11,5%), with only 19,2% prevalence among civilians with risk factors. The presence of asymmetry in vascular caliber was most notable among military individuals with CHD or combined pathology (60,4%) and those with hypertension (56,4%). It was also observed in 36,6% of the carotid atherosclerosis group and in 26,2% of those with cardiovascular risk factors. In contrast, this sign was less frequent in healthy military individuals (12,0%), civilians with risk factors (17,3%), and was rare in healthy civilians (7,7%).

Table 1

Frequency of Retinal Fundus Vascular Signs in the Study Groups (n, %).

Retinal Sign Venular Dilation	Military with HD (n=78)	Military with CHD or CHD+HD (n=53)	Military with Carotid Atherosclerosis (n=41)	Military with Cardiovascular Risk Factors (n=65)	Conditionally Healthy Military (n=50)	Civilians with Cardiovascular Risk Factors (n=52)	Conditionally Healthy Civilians (n=52)
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Arteriolar Narrowing	66 (84,6%)	45 (84,9%)	24 (58,5%)	30 (46,2%)	11 (22,0%)	16 (30,8%)	8 (15,4%)
AVR<0,66	64 (82,1%)	42 (79,2%)	20 (48,8%)	27 (41,5%)	10 (20,0%)	14 (26,9%)	6 (11,5%)
Increased Vascular Tortuosity	43 (55,1%)	30 (56,6%)	11 (26,8%)	10 (15,4%)	5 (10,0%)	6 (11,5%)	3 (5,8%)
Vessel Caliber Asymmetry	52 (66,7%)	36 (67,9%)	17 (41,5%)	19 (29,2%)	7 (14,0%)	10 (19,2%)	6 (11,5%)

DISCUSSION

The results of this study highlight the diagnostic relevance of retinal microvascular markers in assessing cardiovascular risk, particularly in a high-exposure population such as military personnel. Among the signs analyzed, a reduced arteriovenous ratio (AVR < 0,66) and increased vascular tortuosity emerged as the most consistent indicators of systemic cardiovascular pathology. These findings support the notion that non-invasive retinal imaging can serve as a valuable tool for early identification of microvascular dysfunction and subclinical cardiovascular disease.

The significantly higher frequency of abnormal retinal findings in military individuals-especially those with ischemic heart disease, hypertension, or carotid artery atherosclerosis-suggests a strong association between systemic hemodynamic stress and retinal vascular remodeling. The elevated prevalence of these signs even among military personnel with no formally diagnosed cardiovascular conditions but known risk factors points to a preclinical stage of vascular involvement, which may remain undetected through conventional clinical assessments. These results are consistent with previous studies that have shown a strong link between hypertensive retinopathy signs and increased cardiovascular morbidity and mortality (Wong et al., 2004; Cheung et al., 2012).

One of the most noteworthy findings is the diagnostic value of AVR < 0,66 as an early indicator of systemic vascular imbalance. This ratio reflects a disproportion between arteriolar narrowing and venular dilation, often associated with elevated peripheral resistance, chronic endothelial dysfunction, and early vascular aging. The presence of this marker in over half of the military participants with hypertension or CHD, compared to only 5,8% in healthy civilians, illustrates its sensitivity and potential specificity in identifying individuals at heightened cardiovascular risk. These observations align with the microvascular hypothesis of end-organ damage, which posits that structural changes in small vessels precede clinical manifestations

of disease.

Vascular tortuosity and asymmetry of vessel caliber, while less frequently studied, also demonstrated clinical relevance in this cohort. Increased tortuosity may result from chronic mechanical stress on the vessel wall, leading to elongation and curvature, often observed in long-standing hypertension or metabolic dysregulation. Asymmetric vessel caliber may reflect localized autoregulatory failure or early atherosclerotic changes affecting one side of the retinal vasculature more prominently. The disproportionately higher occurrence of these signs in military participants compared to civilians further supports the role of occupational stress and environmental factors in accelerating vascular dysfunction.

CONCLUSION

In conclusion, this study demonstrates that fundus-based markers-particularly AVR<0,66, vascular tortuosity, and caliber asymmetry-are frequent in military individuals with cardiovascular disease or risk factors. These signs may serve as early, accessible, and non-invasive indicators of systemic vascular health, supporting their use in screening and prevention strategies in both military and civilian populations.

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