International Journal of Medical Sciences And Clinical Research

VOLUME Vol.05 Issue11 2025
PAGE NO. 224-228
DOI 10.37547/ijmscr/Volume05Issue11-42

AI-Based Retinal Image Analysis For Cardiovascular Risk Screening In Former Military And Civilian Populations: A Comparative Diagnostic Study

Maksudova Z.R.

PhD, Military Medical Academy of the Armed Forces of the Republic of Uzbekistan, Innovative Clinic of Dr. Maksudova – DMC, Uzbekistan

Bakhritdinova F.A.

Department of Ophthalmology, Tashkent State Medical University, Uzbekistan

Received: 30 September 2025; **Accepted:** 26 October 2025; **Published:** 30 November 2025

Abstract: Background. Cardiovascular diseases (CVDs) remain the leading cause of premature death globally. Military personnel, including veterans, represent a high-risk group due to chronic stress and an increased burden of vascular risk factors. Retinal microvascular changes are known to reflect systemic vascular health and may serve as noninvasive biomarkers for early cardiovascular risk assessment. Objective. To evaluate the diagnostic performance of artificial intelligence (AI) -based fundus image analysis compared to traditional ophthalmoscopy in detecting retinal microvascular abnormalities associated with cardiovascular risk. Methods. The study included 391 participants, of whom 287 were active or recently discharged military personnel, and 104 were civilian controls. Retinal images were acquired using high-resolution, non-mydriatic fundus cameras and analyzed via the Retina-based Microvascular Health Assessment System (RMHAS), an AI-powered, validated platform. Features assessed included venular widening, arteriolar narrowing, arteriovenous ratio (AVR), vessel tortuosity, and caliber asymmetry. Diagnostic sensitivity, specificity, and area under the ROC curve (AUC) were calculated for various screening models. Results. AI demonstrated significantly higher detection rates of all key retinal signs compared to ophthalmoscopy (e.g., venular dilation: 43,0% vs. 17,0%). A combined model integrating AI analysis with blood pressure and BMI achieved the highest diagnostic performance (sensitivity: 83,3%; specificity: 80,2%; AUC: 0.84). AI alone outperformed traditional risk assessment based on clinical metrics. Conclusion. AI-based retinal analysis enables more sensitive, standardized, and early detection of microvascular changes indicative of cardiovascular risk.

Keywords: Retinal imaging; Artificial intelligence; Cardiovascular risk; Military personnel.

Introduction: Cardiovascular diseases (CVDs) remain the leading cause of premature mortality and reduced quality of life worldwide. Among high-risk populations, particular attention is drawn to active and former military personnel, who are exposed to significant somatic and psycho-emotional stress, extreme environmental factors, and a higher prevalence of arterial hypertension, dyslipidemia, and other cardiovascular risk factors [1,2,3]. Despite advances in diagnostic tools, early detection of subclinical vascular abnormalities in this cohort remains challenging, especially at the level of outpatient monitoring and primary screening. This underscores the need for accessible, sensitive, and standardized methods for assessing vascular health, capable of identifying early pathological changes before the onset of overt clinical symptoms [4,5,6].

The retinal vasculature is currently regarded as a unique “window” into the body's microvascular system. Retinal vascular changes - such as arteriolar narrowing, venular widening, altered arteriovenous ratio (AVR), increased vessel tortuosity, and greater fractal complexity - have been shown to correlate with elevated blood pressure, impaired glucose metabolism, and overall cardiovascular risk [4,7,8]. However, traditional ophthalmoscopy is largely subjective and depends heavily on the examiner's experience. In this context, automated analysis of fundus photographs using artificial intelligence (AI) technologies is gaining prominence, offering reproducibility and high sensitivity in large-scale screening programs.

The aim of this study was to evaluate the diagnostic effectiveness of artificial intelligence–based analysis of retinal fundus images in detecting microvascular changes associated with cardiovascular risk, compared to traditional ophthalmoscopic methods, with a particular focus on active and former military personnel.

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.

Ischemic heart disease (IHD), 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.

Fundus image analysis was performed using the Retina-based Microvascular Health Assessment System (RMHAS) - an open-access online platform designed for the quantitative evaluation of retinal vascular biomarkers. The system is based on deep learning algorithms and has been validated in international studies.

The following vascular features were visualized and analyzed:

– Retinal arteriolar narrowing (blue lines) and venular widening (green lines), which are strongly associated with hypertension and impaired glucose metabolism;

– Central Retinal Arteriolar Equivalent (CRAE) and Central Retinal Venular Equivalent (CRVE), used to calculate the Arteriovenous Ratio (AVR) - a key integrative indicator of retinal microvascular health;

– Increased vessel tortuosity, reflecting reduced vascular wall elasticity;

– Arteriovenous crossing signs, with venular deflection at the crossing point, associated with chronic hypertension;

– Measurement zones - concentric ring-shaped regions around the optic disc, where automated analysis was performed.

This visualization framework forms the basis for quantitative assessment of retinal microcirculation, which can reflect systemic vascular and metabolic processes. The use of such a standardized approach, combined with AI algorithms like RMHAS, enables early detection of elevated cardiovascular risk in a reproducible manner.

All images underwent manual verification by a ophthalmologist. In cases of uncertainty - e.g., vessel intersections where AI may misclassify - marked regions were flagged, reanalyzed, or excluded from the dataset.

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. Diagnostic performance was assessed using sensitivity, specificity, and area under the ROC curve (AUC). Differences were considered statistically significant at $p<0{,}05$.

RESULTS

The comparative analysis of two methods - AI and traditional ophthalmoscopy-for detecting retinal vascular changes demonstrated a clear advantage of the automated approach. Across all evaluated features, including venular widening, arteriolar narrowing, reduced AVR<0,66, vessel tortuosity, and vascular caliber asymmetry, the AI-based analysis showed a substantially higher detection rate.

The most pronounced difference was observed in the identification of venular dilation: AI detected this feature in 43,0% of cases, compared to 17,0% with ophthalmoscopy. A similar pattern was noted for arteriolar narrowing, which was detected in 39,0% of cases using AI versus 22,0% via traditional assessment. These findings underscore the high sensitivity of AI technologies, particularly in light of the inherent subjectivity and limitations of visual diagnostic methods. Detection rates were especially higher for subtle features such as vessel tortuosity (31,0% / 11,0%) and caliber asymmetry (27,0% / 9,0%). These parameters are often difficult to assess reliably through visual inspection alone, especially in the absence of digital tools for quantitative analysis.

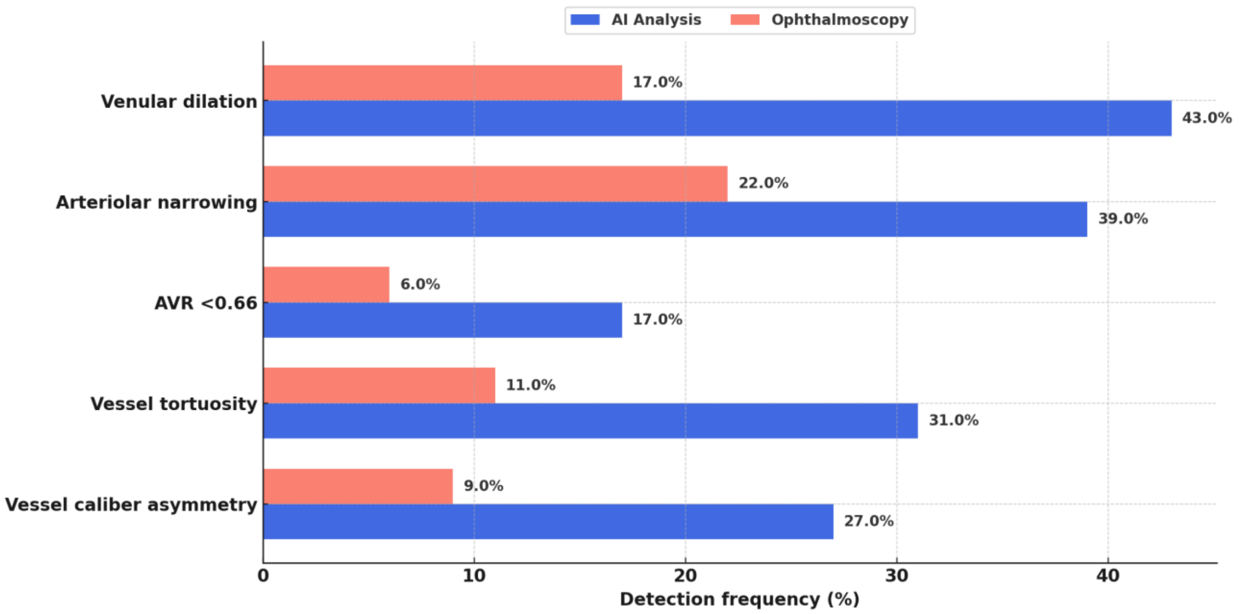

Figure 4.5. Comparison of the detection rates of retinal vascular changes using AI versus traditional ophthalmoscopy.

The analysis of the presented data clearly demonstrates the advantages of using AI methods for assessing retinal vascular changes within the framework of cardiovascular risk screening. In particular, the combined approach-which integrated AI-based image analysis, traditional questionnaires, and measurements of blood pressure and BMI - achieved the highest sensitivity and specificity among all evaluated strategies. The area under the ROC curve (AUC) reached 0,84, indicating a high level of diagnostic accuracy. Importantly, this approach had the lowest proportion of missed cases, which is especially critical in the context of preventing cardiovascular complications in former military personnel, a group characterized by elevated health risks.

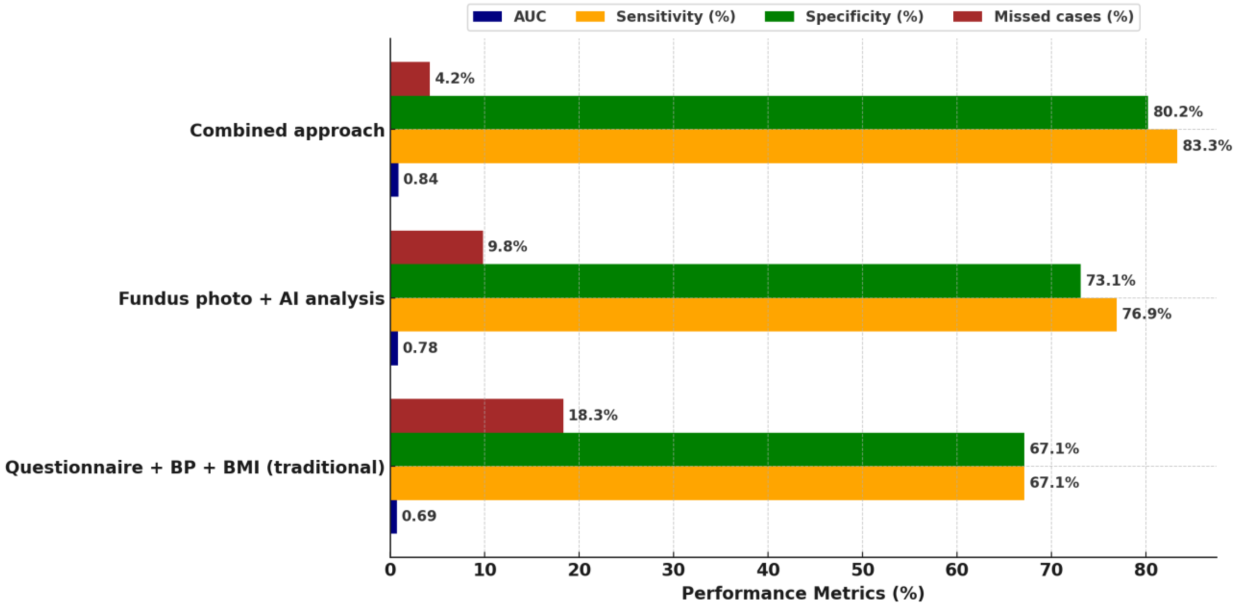

Figure 4.6. Effectiveness of AI-based fundus analysis as a screening tool in former military personnel, compared to traditional cardiovascular risk assessment methods.

For comparison, the use of AI-based fundus image analysis alone, without additional clinical data, also demonstrated favorable results: sensitivity reached 76,9%, specificity was 73,1%, and the AUC was 0,78. Although the proportion of missed cases increased to 9,8%, this approach still significantly outperformed the traditional risk assessment model, which relied solely on survey data, blood pressure, and BMI. The latter method showed the lowest sensitivity and AUC, indicating limited effectiveness in identifying individuals with high cardiovascular risk at early stages. Furthermore, the missed case rate for the traditional approach was 18,3%, raising concerns about potential underestimation of risk in a substantial portion of the examined population.

DISCUSSION

The integration of AI-based tools into diagnostic workflows helps objectify the assessment process and ensures more consistent reproducibility of results, regardless of the examiner's experience. Moreover, the availability of standardized algorithms and automated metrics enhances both accuracy and reliability, which is particularly important for large-scale screening or longitudinal monitoring. The findings of this study support the clinical potential of AI in detecting retinal microvascular changes, which are especially relevant for cardiovascular risk stratification. The greater sensitivity of AI compared to traditional ophthalmoscopy opens the door for earlier detection of subclinical pathologies and enables precise quantitative assessment. This, in turn, may serve as a powerful tool in developing personalized prevention strategies and long-term follow-up for patients at elevated cardiovascular risk.

Incorporating AI-driven retinal analysis into the structure of screening diagnostics can significantly enhance the identification of individuals with high cardiovascular risk. A combined strategy - integrating both ophthalmic imaging and clinical-laboratory parameters - appears particularly promising. This is especially relevant for former military personnel, who typically face higher somatic and psycho-emotional stress levels, necessitating more sensitive and accurate assessment tools to monitor their health status.

Furthermore, the integration of AI-based retinal screening into routine clinical practice holds promise not only for individual risk assessment but also for broader public health applications. In resource-limited settings or primary care environments where access to advanced cardiovascular diagnostics is restricted, fundus imaging combined with automated analysis could serve as a low-cost, scalable solution for population-level screening. This is particularly relevant for military healthcare systems, which often require standardized, reproducible, and rapid methods for evaluating the health status of large cohorts. The noninvasive nature of retinal imaging, coupled with AI's ability to quantify subtle microvascular changes, may facilitate early intervention strategies and reduce long-term cardiovascular morbidity.

CONCLUSION

The study confirms the diagnostic value of artificial intelligence–based analysis of retinal fundus images as a sensitive and objective tool for detecting microvascular changes associated with cardiovascular risk. Compared to traditional ophthalmoscopy, AI demonstrated superior performance across all key retinal biomarkers, particularly in identifying subtle abnormalities such as venular dilation, arteriolar narrowing, and vessel tortuosity. The highest diagnostic accuracy was achieved through a combined screening model integrating AI image analysis with basic clinical parameters, including blood pressure and BMI. These findings highlight the potential of AI-assisted retinal screening to enhance early cardiovascular risk stratification, especially in high-risk populations such as active and former military personnel.

REFERENCES

1. Wong DYL, Lam MC, Ran A, Cheung CY. Artificial intelligence in retinal imaging for cardiovascular disease prediction: current trends and future directions. Curr Opin Ophthalmol. 2022 Sep 1;33(5):440-446. doi: 10.1097/ICU.0000000000000886
2. Zhang W, Guo X, Jiang X, Liu J, Han X, Guo C. RETINAL MICROVASCULAR CHANGES AND RISK OF CORONARY HEART DISEASE: A Systematic Review and Meta-Analysis. Retina. 2024 Feb 1;44(2):333-344. doi: 10.1097/IAE.0000000000003959
3. Colcombe J, Mundae R, Kaiser A, Bijon J, Modi Y. Retinal Findings and Cardiovascular Risk: Prognostic Conditions, Novel Biomarkers, and Emerging Image Analysis Techniques. J Pers Med. 2023 Oct 31;13(11):1564. doi: 10.3390/jpm13111564
4. Arnould L, Meriaudeau F, Guenancia C, Germanese C, Delcourt C, Kawasaki R, Cheung CY, Creuzot-Garcher C, Grzybowski A. Using Artificial Intelligence to Analyse the Retinal Vascular Network: The Future of Cardiovascular Risk Assessment Based on Oculomics? A Narrative Review. Ophthalmol Ther. 2023 Apr;12(2):657-674. doi: 10.1007/s40123-022-00641-5
5. Syed MG, Trucco E, Mookiah MRK, Lang CC, McCrimmon RJ, Palmer CNA, Pearson ER, Doney ASF, Mordi IR. Deep-learning prediction of cardiovascular outcomes from routine retinal images in individuals with type 2 diabetes. Cardiovasc Diabetol. 2025 Jan 2;24(1):3. doi: 10.1186/s12933-024-02564-w
6. Iorga RE, Costin D, Munteanu-Dănulescu RS, Rezuș E, Moraru AD. Non-Invasive Retinal Vessel Analysis as a Predictor for Cardiovascular Disease. J Pers Med. 2024 May 9;14(5):501. doi: 10.3390/jpm14050501
7. Danielescu C, Dabija MG, Nedelcu AH, Lupu VV, Lupu A, Ioniuc I, Gîlcă-Blanariu GE, Donica VC, Anton ML, Musat O. Automated Retinal Vessel Analysis Based on Fundus Photographs as a Predictor for Non-Ophthalmic Diseases-Evolution and Perspectives. J Pers Med. 2023 Dec 29;14(1):45. doi: 10.3390/jpm14010045
8. Chikumba S, Hu Y, Luo J. Deep learning-based fundus image analysis for cardiovascular disease: a review. Ther Adv Chronic Dis. 2023 Nov 18;14:20406223231209895. doi: 10.1177/20406223231209895