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Artificial Intelligence in Cardiovascular Disease Prevention: Current Applications and Future Perspectives

ABSTRACT

Cardiovascular diseases (CVDs) remain the leading cause of morbidity and mortality worldwide, emphasizing the ongoing need for effective and scalable primary and secondary prevention strategies. In this evolving landscape, artificial intelligence (AI) has emerged as a transformative force in preventive cardiology, with the potential to reshape risk assessment, early disease detection, and personalized preventive care. Artificial intelligence—driven models consistently outperform traditional risk scores by integrating large-scale, multidimensional, and longitudinal data derived from various platforms. These capabilities enable dynamic and time-adaptive cardiovascular risk prediction that more accurately reflects the evolving nature of individual risk profiles. Advances in machine learning and deep learning have facilitated the earlier identification of subclinical CVD often preceding clinical manifestation by several years. In parallel, AI-powered wearable devices and digital health (DH) solutions support continuous physiological monitoring, real-time feedback, and personalized lifestyle and behavioral interventions, thereby extending preventive care beyond traditional clinic-based settings. Such approaches appear particularly beneficial for high-risk populations by promoting sustained engagement, early intervention, and improved clinical outcomes. Looking ahead, emerging innovations such as multimodal AI systems, digital twin technologies, and AI-guided clinical guidelines signal a paradigm shift toward predictive, participatory, precision-based, and continuously learning prevention strategies. Nevertheless, the successful translation of AI into routine clinical practice will depend on increasing DH literacy, rigorous prospective validation, ethical and regulatory oversight, data transparency, and seamless integration into clinical workflows. When thoughtfully implemented, AI holds the promise to fundamentally advance preventive cardiology, enabling more patient-centered, participatory, and equitable cardiovascular care while reducing the global burden of CVD.

Keywords: Artifical intelligence, cardiovascular disease, prevention

REVIEW

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INTRODUCTION

In spite of all efforts, cardiovascular disease (CVD) still remains the leading cause of morbidity and mortality worldwide, representing a major public health challenge despite significant advances in diagnosis and treatment.[1]

In this context, prevention strategies, particularly primary and secondary prevention, are fundamental to reducing the overall burden of CVD. Preventive cardiology focuses on the early identification and modification of cardiovascular (CV) risk factors before disease onset (primary prevention) as well as on reducing recurrent events and slowing disease progression in individuals with established CVD (secondary prevention) in line with contemporary evidence and recent advances in CV prevention strategies.[2]

Artificial intelligence (AI) refers to the development of computational systems capable of performing tasks that typically require human intelligence, including pattern recognition, learning, and decision-making. In recent years, AI-based models have demonstrated substantial potential in the detection, screening, and risk stratification of various CVDs. By enabling the identification of novel phenotypes and complex risk patterns beyond traditional clinical approaches, AI has the potential to augment personalized CV prevention and management strategies.[3,4]

Building on its supportive role in preventive care, AI has become particularly influential in CV risk prediction. AI-based systems integrate multidimensional data derived from lifestyle behaviors, clinical parameters, wearable devices, and digital health (DH) platforms to enable continuous risk assessment and personalized preventive strategies.[5]

By simultaneously addressing key determinants of CV care including nutrition, physical activity, weight management, sleep patterns, blood pressure, lipid profiles, smoking, substance use, and mental health, AI has the potential to prioritize individual risk factors, identify early deviations from optimal CV health, and support informed decision-making for both clinicians and patients.

This review provides an overview of current applications of AI in CV prevention, examines their potential clinical impact, and discusses the limitations and challenges associated with their implementation in both primary and secondary prevention of CVD.

ARTIFICIAL INTELLIGENCE–BASED CARDIOVASCULAR RISK PREDICTION

Artifical intelligence–based CV risk prediction models have consistently demonstrated superior predictive accuracy compared with traditional risk scores derived from linear or regression-based approaches representing a major advancement in both primary and secondary prevention of CVD.[6] Conventional risk models typically rely on a limited number of static variables measured at a single time point, which may inadequately capture the complex, dynamic, and evolving nature of CV risk.[5] In contrast, AI-driven models are capable of integrating large-scale, multidimensional, and longitudinal data including clinical characteristics, laboratory parameters, imaging findings, and sociodemographic factors.

Electronic health (EHR), wearable device data, retinal fundus images, electrocardiograms (ECG), and genetic information have all been utilized to train AI models capable of predicting incident CVD, hypertension, dyslipidemia, and atherosclerotic CVD events.[7-12]

HIGHLIGHTS

- Artifical intelligence (AI) enables dynamic and personalized cardiovascular risk prediction by integrating multimodal and longitudinal data beyond traditional risk models.
- Early identification of subclinical cardiovascular disease is enhanced by AI, supporting timely intervention before overt clinical manifestation.
- Artifical intelligence–powered wearables, digital health tools, and emerging technologies such as digital twins may transform preventive cardiology toward proactive, participatory, precision-based, and continuously learning care.

By integrating these heterogeneous data sources, AI-based clinical decision support systems can analyze large volumes of patient information to support accurate and informed clinical decision-making.[13]

Moreover, the ability of AI-based systems to continuously update risk estimates as new data become available enables dynamic and time-adaptive risk prediction, making them particularly valuable in preventive cardiology, where individual risk profiles evolve over time in response to aging, lifestyle modifications, and therapeutic interventions.

The major domains and key clinical contributions of AI across the spectrum of CV prevention are summarized in Table 1.

EARLY DETECTION OF SUBCLINICAL CARDIOVASCULAR DISEASE

The early detection of subclinical CVD is a cornerstone of effective preventive cardiology, as structural and functional abnormalities frequently precede the onset of clinical symptoms by several years.[14]

In this context, AI-based approaches have demonstrated substantial potential in identifying silent CV abnormalities, such as atrial fibrillation (AF), left ventricular (LV) dysfunction, and early coronary atherosclerosis, before overt disease manifestation.[15] By leveraging advanced pattern recognition capabilities, AI algorithms can detect subtle signals within routinely acquired diagnostic data that may not be readily apparent to human observers, thereby enabling earlier risk stratification and timely intervention.

Machine learning (ML) /Deep Learning (DL) models trained on standard 12-lead ECGs have shown high accuracy in identifying occult AF, asymptomatic LV systolic dysfunction, and other electrophysiological abnormalities, even in patients with normal sinus rhythm at the time of recording.[15] Similarly, AI-assisted echocardiographic analysis enables automated and reproducible assessment of cardiac structure and function, facilitating the early recognition of subclinical LV remodeling, diastolic dysfunction, and valvular abnormalities.[16,17]

Beyond functional assessment, AI has also enhanced the detection of early atherosclerotic disease through advanced imaging modalities such as computed tomography (CT). Artifical intelligence algorithms applied to coronary CT angiography and calcium scoring can identify high-risk plaque characteristics, accurately quantify coronary calcification, and refine CV risk prediction beyond traditional imaging metrics.[18]

WEARABLES AND DIGITAL HEALTH IN CARDIOVASCULAR PREVENTION

Artificial intelligence–powered wearable technologies enhance patient engagement by delivering personalized feedback, real-time alerts, and adaptive behavioral interventions tailored to individual CV risk profiles. Machine learning models can analyze longitudinal data collected from wearable devices to detect deviations from baseline physiological patterns, predict impending clinical

Table 1. Artificial Intelligence Applications Across the Spectrum of Cardiovascular Prevention

Domain	Data Sources	AI Approach	Clinical Contribution	Prevention Level
Cardiovascular risk prediction	Electronic health records, laboratory data, imaging, genomic information, sociodemographic variables, wearable devices	Machine learning/deep learning, multimodal data integration	Dynamic and time-adaptive risk estimation; individualized cardiovascular risk profiling	Primary and Secondary
Detection of subclinical CVD	Standard 12-lead ECG, echocardiography, coronary computed tomography	Deep learning–based signal and image analysis	Early identification of silent atrial fibrillation, subclinical left ventricular dysfunction, and early atherosclerosis	Primary
Wearables and digital health	Smartwatches, mobile sensors, remote monitoring systems	Continuous data analysis, anomaly detection	Real-time physiological monitoring, early warning signals, proactive risk management	Primary and Secondary
Lifestyle and behavioral prevention	Physical activity, sleep metrics, body weight, heart rate variability, patient-reported data	AI-supported digital coaching	Personalized lifestyle interventions and sustained behavioral change	Primary
High-risk populations (HF, DM, HT)	Wearables, mobile applications, longitudinal clinical data	Predictive machine learning models	Early detection of clinical deterioration and reduction of hospitalizations	Secondary

AI, artificial intelligence; CVD, cardiovascular disease; DM, diabetes mellitus; ECG, electrocardiogram; EHR, electronic health record; HF, heart failure; HT, hypertension.

deterioration, and support lifestyle modification strategies related to physical activity, weight management, and sleep hygiene.[19] These DH tools enable scalable, population-level prevention while simultaneously empowering individuals to take an active role in managing their CV health. The integration of AI-enabled wearables with telemedicine and remote monitoring platforms represents a pivotal advancement in preventive cardiology. By facilitating continuous data transmission from patients' homes to healthcare providers, these systems support timely clinical decision-making, early intervention, and proactive CV risk management.[19]

ARTIFICIAL INTELLIGENCE FOR LIFESTYLE MODIFICATION AND BEHAVIORAL PREVENTION

Lifestyle modification remains a cornerstone of CV prevention; however, sustained adherence to healthy behaviors continues to be a major challenge in routine clinical practice. Artificial intelligence–supported digital coaching systems offer a scalable and personalized solution to this problem by tailoring interventions to individual behavioral patterns, preferences, and CV risk profiles. By leveraging ML algorithms, these platforms can analyze real-time data from wearable devices, mobile applications, and self-reported inputs to deliver personalized recommendations aimed at improving physical activity, dietary habits, weight management, and smoking cessation, which facilitates primary and secondary prevention of CVD.[20]

Patients with heart failure (HF) and other high-risk cardiovascular populations also represent groups in whom lifestyle modification has a profound impact on clinical outcomes yet is often difficult to maintain over time.[21] In this context, AI-enabled digital coaching and remote monitoring systems have demonstrated particular promise by supporting individualized physical activity planning, promoting dietary adherence, facilitating symptom tracking, and enabling early detection of clinical decompensation. In patients with HF, ML models integrated into wearable devices and mobile platforms can continuously monitor daily activity levels, heart rate variability, sleep patterns, and weight fluctuations to identify early signs of clinical deterioration and prompt timely lifestyle or therapeutic adjustments.[22] Similarly, in other high-risk populations including older adults and individuals with diabetes, obesity, or hypertension, AI-driven behavioral interventions can dynamically adapt recommendations based on functional capacity, comorbid conditions, and real-world adherence patterns. By delivering tailored, context-aware feedback and reinforcing self-management behaviors, these systems may improve quality of life, reduce hospitalizations, and support sustained engagement in preventive strategies among vulnerable populations.[23]

ETHICAL, REGULATORY, AND PRACTICAL CHALLENGES

Despite the growing promise of AI in CV prevention, several ethical challenges must be addressed to ensure its responsible implementation. Data privacy and security remain central concerns, as AI systems depend on large volumes of sensitive personal and health-related information derived from EHRs, wearable devices, and digital platforms. Inadequate data governance frameworks or data breaches may undermine patient trust and compromise confidentiality. Moreover, algorithmic bias resulting from imbalanced or non-representative training datasets can lead to differential performance across sex, age, ethnicity, or socioeconomic groups, potentially exacerbating existing CV health disparities.

Regulatory and legal considerations represent additional barriers to the widespread adoption of AI-based preventive tools. Many AI algorithms function as adaptive systems that continuously evolve as new data become available, posing significant challenges for traditional regulatory frameworks that were designed for static medical devices.[24] Ensuring transparency, explainability, and reproducibility is therefore essential for both regulatory approval and clinical acceptance. Clear and standardized requirements for model validation, performance reporting, and post-market surveillance are necessary to define accountability and liability when AI-driven recommendations influence preventive care decisions.[24]

From a practical standpoint, the successful integration of AI across the spectrum of CVD, interventional cardiology, and CV prevention relies on effective clinician oversight, seamless integration into existing clinical workflows, and robust prospective and external validation in representative cohorts.[25]

However, limited interoperability with current health information systems, insufficient DH literacy and clinician training, and the risk of alert fatigue may hinder real-world implementation.[26]

Therefore, future efforts should prioritize prospective trials, real-world effectiveness studies, and clinician-centered design to ensure that AI technologies function as safe, interpretable, and well-aligned decision support tools that complement rather than replace clinical judgment.[27,28]

FUTURE PERSPECTIVES

The future of preventive cardiology is poised to be fundamentally transformed by advanced multimodal AI systems capable of integrating and interpreting vast, heterogeneous data streams to generate clinically actionable insights. By combining longitudinal clinical records, advanced imaging data, wearable-derived physiological signals, genomic information, and social determinants of health, next-generation AI models may enable continuous, individualized CV risk profiling. This paradigm has the potential to shift preventive cardiology from a reactive model—focused on established risk—to a proactive, participatory, and precision-based approach that predicts disease trajectories before clinical manifestation.

Among the most transformative innovations in this evolving landscape is the emergence of digital twin technology. Digital twins are dynamic, virtual representations of individual patients that evolve in parallel with real-world clinical, physiological, and behavioral data.[29] In CV prevention, digital twins could enable the simulation of lifestyle interventions, pharmacological therapies, and risk factor modification strategies before their implementation in real life.[30] Such simulations may facilitate scenario-based decision-making, optimize preventive strategies for high-risk individuals, and enhance shared decision-making by allowing clinicians and patients to visualize potential future risk pathways and outcomes.

Looking forward, the integration of validated AI tools into clinical guidelines may redefine the practice of preventive cardiology. Artificial intelligence–guided guidelines can complement traditional evidence-based recommendations by incorporating real-time patient data and continuously updating individualized risk estimates, thereby enabling adaptive and context-aware prevention strategies.[31]

Realizing this vision will require close collaboration among clinicians, professional societies, regulators, and data scientists to ensure transparency, clinical validity, interpretability, and ethical oversight. Furthermore, increasing DH literacy among the population carries utmost importance as it constitutes a prerequisite for meaningful patient engagement, informed decision-making, and effective adoption of AI-driven DH Technologies.[32,33]

If successfully implemented, AI-driven and digital twin–informed frameworks may mark a paradigm shift from static, population-level prevention toward continuously learning, patient-centered, and participatory CV care empowering patients to actively engage in and comanage their own disease trajectories.

DISCUSSION

This review highlights the rapidly expanding role of AI across the full spectrum of CV prevention, ranging from individual-level risk prediction to population-based public health strategies. Artificial intelligence–driven approaches offer clear advantages over traditional methods by enabling the integration of multimodal data, dynamic risk assessment, and the early detection of subclinical CVD.[34] In particular, advances in ML and DL have enhanced CV risk prediction, facilitated earlier identification of silent pathologies such as AF and LV dysfunction, and supported the development of personalized preventive strategies that extend beyond conventional clinic-based care.[35]

The preventive potential of AI has been further amplified by the growing use of wearable technologies, DH platforms, and telemedicine, which enable continuous monitoring and real-time feedback in real-world settings.[36] These tools play a critical role in lifestyle modification and behavioral prevention, areas in which long-term adherence remains a major challenge.[37] Artifical intelligence–supported digital coaching systems and remote monitoring frameworks appear especially valuable for high-risk populations, including patients with HF, older adults, and individuals with multiple cardiometabolic comorbidities, by facilitating sustained engagement in preventive care and enabling early intervention.[38]

Looking ahead, emerging concepts such as multimodal AI models, digital twin technologies, and AI-guided clinical guidelines represent a potential paradigm shift in preventive cardiology. These innovations may enable more proactive and precision-based prevention by simulating disease trajectories and tailoring interventions to individual risk profiles. Nevertheless, their successful translation into clinical practice will depend on robust prospective validation, interdisciplinary collaboration, and thoughtful integration into existing healthcare systems. Importantly, AI should be viewed as a complement to, rather than a replacement for, clinical expertise, supporting shared decision-making and reinforcing evidence-based CV prevention.

CONCLUSION

Artificial intelligence represents a transformative opportunity for the prevention of CVD by enabling earlier detection of risk, personalized risk stratification, and scalable preventive interventions. Across multiple domains—including CV risk prediction, early identification of subclinical disease, and lifestyle modification—AI-driven approaches have demonstrated substantial potential to enhance preventive cardiology beyond the limitations of traditional models.

Despite these promising advances, widespread clinical implementation requires robust prospective validation, careful integration into healthcare systems, and sustained clinician engagement. Ethical governance, regulatory clarity, data transparency, and mitigation of algorithmic bias are essential to ensure equitable and responsible use of AI in CV prevention. Importantly, AI should function as a decision support tool that augments clinical expertise rather than replacing it.

Future developments in multimodal AI, digital twin technologies, and AI-guided clinical guidelines may further shift preventive cardiology toward a proactive, precision-based, and continuously learning paradigm. If thoughtfully developed and rigorously validated, AI has the potential to fundamentally reshape CV prevention, advancing patient-centered care while reducing the global burden of CVD.

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