Health Science Reports

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NARRATIVE REVIEW OPEN ACCESS

Environmental Factors and Cardiovascular Susceptibility: Toward Personalized Prevention Mediated by the Role of Artificial Intelligence–A Narrative Review

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Received: 26 March 2024 | **Revised:** 3 January 2025 | **Accepted:** 16 February 2025

Funding: The authors received no specific funding for this work.

Keywords: artificial intelligence | cardiovascular disease (CVD) | cardiovascular susceptibility | environmental factors | personalized prevention

ABSTRACT

Background and Purpose: Cardiovascular diseases (CVD) represent a significant global health challenge due to high morbidity and mortality rates, that necessitate approaching the intricate relation between cardiovascular susceptibility and environmental factors, highlighting the importance of creating personalized cardiovascular prevention plans. Furthermore, as it is becoming integrated with the various aspects of healthcare, the role of artificial intelligence in cardiovascular and precision medicine is driving innovations towards personalized care. This review dives into the complex connection between cardiovascular susceptibility and environmental risk highlighting the importance of creating personalized cardiovascular preventive strategies in light of the upcoming artificial intelligence.

Methods: An in-depth review was conducted using PubMed and ScienceDirect, to collect data from all articles that handled environmental factors and cardiovascular susceptibility with special emphasis on the up-to-date emerging role of artificial intelligence in preventive strategies.

Results: The review revealed high heritability estimates and highlighted the significance of modifiable risk factors which are pivotal determinants affecting CVD susceptibility. The integration of artificial intelligence is implementing the power of precision preventive medicine that can be directed toward specific environmental factors, shifting the whole healthcare system to superior outcomes.

Conclusion: Recognizing the preventability of CVD through personalized environmental modifications, this review advocates tailored prevention plans that account for individual characteristics. Despite its proven efficacy in managing modifiable risk factors, achieving optimal cardiovascular health remains challenging, necessitating innovative strategies and the integration of artificial intelligence in personalized healthcare.

Abbreviations: AHA, American Heart Association; AI, artificial intelligence; ASCVD, atherosclerotic cardiovascular disease; BMI, body mass index; BPA, bisphenol A; CAD, coronary artery diseases; CHAMP, chronic disease management program; CHD, congenital heart diseases; CHD, congenital heart diseases; CMD, cardiometabolic diseases; CVD, cardiovascular diseases; DASH diet, dietary approaches to stop hypertension diet; DL, deep learning; EDC, endocrine-disrupting chemicals; EMR, electromagnetic radiation; GIS, geographic information system; LANl, light at night; ML, machine learning; MNP, microplastics and nano-plastics; NCD, noncommunicable diseases; OCPs, organochlorine pesticides; PAD, peripheral artery diseases; PCBs, polychlorinated biphenyls; PM2.5, particulate matter; PSTP, personalized statin treatment plan; RCT, randomized controlled trials; RF-EMR, radiofrequency electromagnetic radiation; SCORE, systemic coronary risk evaluation; SDH, social determinants of health; WHO, world health organization.

1 | Introduction

Despite the significant improvement in diagnostic instruments and the notable progress in the management as well as treatment, cardiovascular diseases (CVDs) remain the primary cause of mortality and morbidity and among the most prevalent noncommunicable diseases (NCDs) in the world [1]. In general, NCDs account for 70% of annual deaths globally where CVDs are responsible for the largest portion, and this number is expected to increase by 10% in 2030 [1]. Actually, the World Health Organization (WHO) illustrated that in 2019 every one in four deaths in the United States was caused by cardiovascular disease, which account for 18.6 million deaths worldwide [2]. These diseases are responsible for high death burden globally, years lived with disability as well as socioeconomic burden. For instance, the economic burden is huge and can be estimated at $47 trillion [1]. Furthermore, CVDs were previously thought to be a problem in developed countries, however, the highest proportion of premature death caused by CVDs was seen in low- and middle-income countries [1].

Widely known as the diseases of the heart, cardiovascular diseases comprise a wide array of diseases subdivided into four categories. These include coronary artery diseases (CAD), peripheral artery diseases (PAD), cerebrovascular diseases, and aortic atherosclerosis [3]. Furthermore, CAD, corresponding to more than a third of CVDs, can have various consequences such as myocardial infarction, heart failure, and arrhythmias [3]. Moreover, less common entities, such as infectious and rheumatic heart disease and valvular heart disease, may also bring about many mortalities and morbidities [3]. Besides, some types of CVD have strong heritable predispositions whereas others are strongly determined by other risk factors that are not directly attributed to genetics [4]. Therefore, the recognition of the etiologies and underlying risk factors with the creation of careful prevention plans can help bring down the international burden of such diseases [5]. Indeed, the complicated interaction between both, environmental and genetic risk factors, can be inferred as the cause behind CVDs [4].

To describe the environmental factors that can influence the cardiovascular susceptibility and well-being of an individual, it is essential to identify one's environment and its complexity [6]. The environment of a human, or the human environment, can be classified into three circles; the personal, social, and natural environment [6]. The personal, or the microenvironment, constitutes the direct environment of a human and contains physical activity, nutrition, and smoking [6]. These microenvironments create together a larger circle called the social environment and include pollution, noise, and socioeconomic status [6]. All of these survive in a diverse geographical ecosystem called the natural environment [6]. The latter comprises the seasons, sunlight, green spaces, and night and day cycles [6]. It is crucial to understand and comprehend the interaction between these domains to conclude their influence on cardiovascular susceptibility.

It is well-known that the risk of CVDs comprises genetic susceptibility and exposure to multiple environmental factors. The genetic risk is strong with a heritability estimate of 40%–60% and up to 100 identified genomic regions for CVD outcomes. According to the World Health Organization (WHO), 12.6 million deaths each year account for unhealthy environments such as poor air quality and ambient air pollution with particulate matter, and among these 8.2 million are due to NCDs of which CVDs are the largest proportion [7]. The environmental aspect of CVD susceptibility is strengthened by the change seen in the prevalence of CVDs in the absence of major genetic changes, which was demonstrated by a study in China between 1984 and 1999, that revealed the age-adjusted CVD mortality rates in Beijing heightened by 50% for males and 27% for females because of environmental modifications [8]. In addition, in a study in the United States, a 44% decrease in CHD from 1980 to 2000 could be attributed to environmental factors [9]. Additionally, various large cohort studies, focusing on the nongenetic aspects and risk factors, demonstrated the importance of preserving and maintaining a healthy lifestyle reducing cardiovascular susceptibility by 80%–90% [10, 11].

The environmental aspect of CVDs is associated with the preventability of CVDs. If environmental factors affect the risk for CVDs, it is important to know the mechanism and strength of the effect of these factors on cardiovascular health [6]. Furthermore, there is a gap in knowledge about the importance of the relationship between environmental factors and cardiovascular susceptibility in creating personalized prevention strategies. In this analysis, we will provide up-to-date insights on the relationship between environmental factors and cardiovascular susceptibility, the importance of preventive strategies, and the use of artificial intelligence in mediating personalized prevention plans.

2 | Methodology

The main objective of this review is to weigh AI- medicated personalized prevention designs centered on Environmental Factors to downgrade Cardiovascular Disease Susceptibility. PubMed and ScienceDirect databases were used, and the examined terminologies prone included patterns of "Cardio-Vascular-Disease," "Environmental Factors," "Personalized Prevention," "Artificial Intelligence". The review included articles with or have addressed the link or connection concerning environmental factors and cardiovascular susceptibility as well as the personalized prevention targeting this connection. In addition, it included findings in the studies with more investigations on the possibility of AI in personalized prevention for CVD. All articles not written in English were excluded. Then, key points about identified recurring three themes- Environmental risk factors for CVD, the significance of personalized prevention designs in alleviating these risks, and artificial Intelligence role in developing and applying personalized prevention strategies- were extracted. However, because this is a narrative review, the selection of articles doesn't implicate a systemic review of data and thus some relevant papers may be missed with a bias in the selection.

3 | Environmental Factors and Cardiovascular Susceptibility

Environmental factors that influence cardiovascular health can include but are not restricted to those considered in this review.

3.1 | Air Pollution and Airborne Nanoparticles

Global estimates link air pollution to 7 million premature deaths annually according to the WHO [6]. Chronic exposure accelerates atherosclerotic lesions, affecting blood pressure regulation, thrombosis, endothelial function, and insulin sensitivity [6]. For instance, airborne magnetite nanoparticles and particulate matter (PM2.5) may be significant environmental risk factors for atherosclerosis [12] These nanoparticles can translocate into circulation and accumulate at sites of vascular inflammation, posing further cardiovascular risks [13]. In addition, they can disrupt lipid metabolism, leading as a result to vessel wall thickening, macrophage infiltration, and foam cell formation, particularly in high-fat dietary populations [14]. For instance, PM2.5 exposure contributes to atherosclerosis by causing lipid dysregulation and elevated pro-inflammatory cytokines, with persistent effects even after recovery [14]. Collectively, these findings highlight the possible role MNPs and PM2.5 as key contributors to cardiovascular disease, especially among high-risk populations.

3.2 | Soil Pollution and Microplastics

Presented as a global health concern, microplastics possess a harmful threat against food security especially when polluting agricultural soil with more than third of plastic waste going into soil [15]. Microplastics and nano-plastics (MNPs) may play a role in CVD by causing oxidative stress, inflammation, and endothelial dysfunction. Traces of MNPs from various plastics, including polyethylene and polyvinylchloride, have even been detected in human cardiovascular tissues, such as atherosclerotic plaques, pericardia, epicardial and pericardial adipose tissues, myocardia, and left atrial appendage [16]. Their presence suggests that they could potentially worsen conditions like atherosclerosis with subsequent increased incidence of cardiovascular events [16]. Thereby, MNPs triggering cardiac events, not limited to platelet aggregation and myocardial fibrosis in preclinical animal models, raise further concerns about their potential risk to human cardiovascular health.

3.3 | Light Pollution and Circadian Disruption

Light pollution, especially outdoor light at night (LAN), may be linked to higher cardiovascular and metabolic disease risks by altering the ones circadian rhythm. For instance, the circadian highly affects different aspects of the cardiac function in an individual including blood pressure (decreased at night and increased in the morning), platelets aggregation, and plasminogen activator inhibitor-1 levels [17]. Additionally, the circadian rhythms are found to modulate the epinephrine/norepinephrine levels as well as the vagal stimulation [17]. Thus, light pollution affection the circadian systems influencing the cardiovascular susceptibility of individuals.

Additionally, a cohort study in Hong Kong found that increased outdoor light exposure was associated with a 11% greater risk of coronary heart disease (CHD) hospitalizations (HR of 1.11 [95% CI: 1.03, 1.18]) and a 10% increase in CHD deaths among older adults (HR of 1.10 [95% CI: 1.00, 1.22]) [18]. Another systematic review and meta-analysis revealed that higher LAN exposure correlates with a 21% increased risk of cardiometabolic diseases (CMD). Specifically, those with the highest LAN exposure had a 46% higher risk of diabetes and a 23% increased risk of obesity [18].

3.4 | Water Pollution and Ocean Acidification

The contribution of water pollution to the accumulation of carbon dioxide in seawater is the main determinant of the acidification and lower pH of the oceans [19]. This ocean acidification plays a role in the disruption of the phytoplankton growth which are the primarily responsible for the Omega-3 production [20]. Furthermore, Multiple long-term cohort studies indicate that higher intakes of fish and marine n-3 fatty acids are associated with a reduced risk of CVD, including coronary heart disease and cardiovascular mortality [21]. The consumption of fatty fish and marine n-3 fatty acids (EPA and DHA influence CVD risk factors, such as blood lipids, blood pressure, and inflammation positively. While evidence from randomized controlled trials (RCTs) for primary prevention remains limited, several large RCTs support the use of EPA and DHA, especially in high-risk patients post-myocardial infarction [21]. A recent meta-analysis involving 127,477 participants highlighted their efficacy in reducing cardiovascular events [21]. Key factors influencing trial outcomes include adequate dosing, timing, and study duration. Despite the variable results in trials, recent guidelines endorse marine n-3 fatty acids for managing hypertriglyceridemia and preventing CVD [21, 22]. Thus, ocean acidification and omega-3 deficiency significantly impact heart health and lead to increased cardiovascular susceptibility.

3.5 | Climate Change-Induced Heatwaves

Climate change is increasing the frequency and intensity of heatwaves, probably impacting cardiovascular health, particularly in vulnerable populations like older adults. For instance, aging has been found to affect the thermoregulatory among individuals [23]. In addition, exposure to stress has been associated with higher risks of hospitalization and mortality due to cardiovascular events, such as heart attacks and strokes [23]. Thereby, the exposure to heatwaves, resulting from climate changes, can increase the cardiovascular stress on individuals of higher age groups due to their lower thermoregulatory tolerance. Besides, a systematic review found that each 1°C rise in temperature correlates with a 2.1% increase in cardiovascular disease-related mortality (RR 1.021 [95% CI 1.020–1.023]), with heatwaves linked to an 11.7% increase in risk (RR 1.117 [95% CI 1.093–1.141]) [23]. These findings underscore the heat-related cardiovascular risks resulting from the progressive climate change.

3.6 | Endocrine-Disrupting Chemicals

Endocrine-disrupting chemicals (EDCs) are chemical products, found either naturally or synthetically, that can alter the function of the endocrine system by mimicking, blocking or disturbing hormones [24]. On other hand, many hormones, as estrogen, plays a vital role promoting cardiovascular health by modulating inflammatory response along with vascular and myocyte function [25]. Therefore, chemicals disturbing these hormones can significantly contribute to CVD risk. Furthermore, long-term exposure to these chemicals is thought to disrupt normal endocrine function, affecting cardiac development and function [26]. Actually, studies indicate that compounds like bisphenol A (BPA), polychlorinated biphenyls (PCBs), and organochlorine pesticides (OCPs) are associated with increased morbidity and mortality from CVD, with BPA linked to higher blood pressure in children born to mothers exposed during pregnancy [26, 27].

3.7 | Electromagnetic Radiation from Wireless Devices

Electromagnetic radiation (EMR) from wireless devices, radiofrequency electromagnetic radiation (RF-EMR) in particular, is emerging as a potential health risk. Exposure to RF-EMR has surged due to the rise of wireless communication technologies, which may lead to oxidative stress, a known contributor to CVD [28]. A recent study found that exposure to high-frequency EM fields, like Wi-Fi and 4G, altered cardiac autonomic regulation in young, healthy individuals, leading to increased sympathetic activity and reduced parasympathetic activity [29] These findings suggest that chronic RF-EMR exposure could elevate blood pressure and increase the long-term risk of developing CVD [28, 29].

4 | Impact of Age, Race, Gender, and Geography on the Relation Between Environmental Factors and Cardiovascular Susceptibility

Age, race, gender, and geography can be recognized as critical determinants of cardiovascular susceptibility. Older individuals, 65 years and older face a higher CVD risk than younger individuals, while certain environmental conditions amplify vulnerability regardless of age [30]. For example, children are vulnerable to increased BP due to air pollution [31]. Racial minorities, especially blacks, exhibit a heightened risk, and gender differences impact the onset and manifestation of CVD, with men being more likely to develop cardiovascular issues at a younger age compared to women, who are actually at an increased risk of stroke at an older age [31, 32]. Geographic location also affects susceptibility, a cross-sectional study in India indicated that urban South Asians, especially those living in the Western hemisphere, have a higher prevalence of CVD and type 2 diabetes than white populations locally [33].

5 | Importance of Preventive Strategies

Preventive strategies and personalized plans are crucial for reducing the incidence of heart disease. Numerous modifiable risk factors, such as regular physical activity, balanced nutrition, weight management, and abstinence from smoking, significantly lower CVD risk [34]. This modifiable nature of the CVD appears while studying populations in the absence of significant genetic modification concluding by the tremendous influence created by the environment [6]. For example, a 75% reduction in CVD susceptibility in Finland was observed during 2 years as well as a 24% diminution in coronary disease-caused deaths in Poland in 9 years, just due to environmental factors modifications [35]. Considering these statistics, it can be inferred that there is a huge necessity to create personalized prevention plans.

6 | Prospects of Prevention and Challenges in Delivering Personalized Prevention Plans

Prevention of cardiovascular diseases is a multifaceted approach that includes genetic, personal, social, and environmental risk prediction and intervention [36]. The traditional approach to prevention includes lipid-lowering, blood pressure lowering, and antiplatelet therapy [36]. In addition, general nutritional and lifestyle advice has been set to be followed by all patients regardless of personal differences previously [37]. For individuals aged 18–64, at least 150 min of moderate or 75 min of vigorous activity per week is recommended [38]. Furthermore, traditional prevention plans included the role of governments and policymakers by always recommending measures that may protect the environment from further air pollution. These include the call for robust law systems against deforestation and controlling industrial waste production by implementing the use of renewable sources of energy [39].

Personalized medicine is a field of medicine that deals with prevention, diagnosis, and prescription of specific treatments and therapeutics tailored to an individual taking into consideration both genetic and environmental factors that can potentially influence their health [40]. Echoing this, Figure 1 discusses the difference between traditional and personalized prevention among its various aspects (Figure 1).

Personalization of environmental risk can be done via existing risk prediction tools such as the Framingham Heart Study score, the Reynolds Risk Score, or the SCORE algorithm [41]. Risk prediction also involves the genetic aspect as cardiovascular diseases are largely heritable [41] This is where genetics comes into play, genetic variation and germline genetic mutations can be helpful in risk predilection and selecting treatments and preventive strategies [41]. Reduction of environmental risks such as air and noise pollution appears to involve a complex economic and geopolitical consideration and may have significant challenges in the short term [7]. Despite this evidence, only 5% of individuals achieved "ideal cardiovascular health" according to the American Heart Association (AHA) Strategic Plan for 2020 [42]. This has largely been shown to have limited success due to patient compliance or failing public health organizations [37]. Enhancing adherence to known risk reduction strategies emerges as a critical challenge for future cardiovascular risk reduction [34].

Individualized prevention of the individual patient can face to be challenging for physicians as they have to interpret large scientific evidence from multiple clinical trials and apply it in the treatment of the individual [36]. A clinical trial shows that

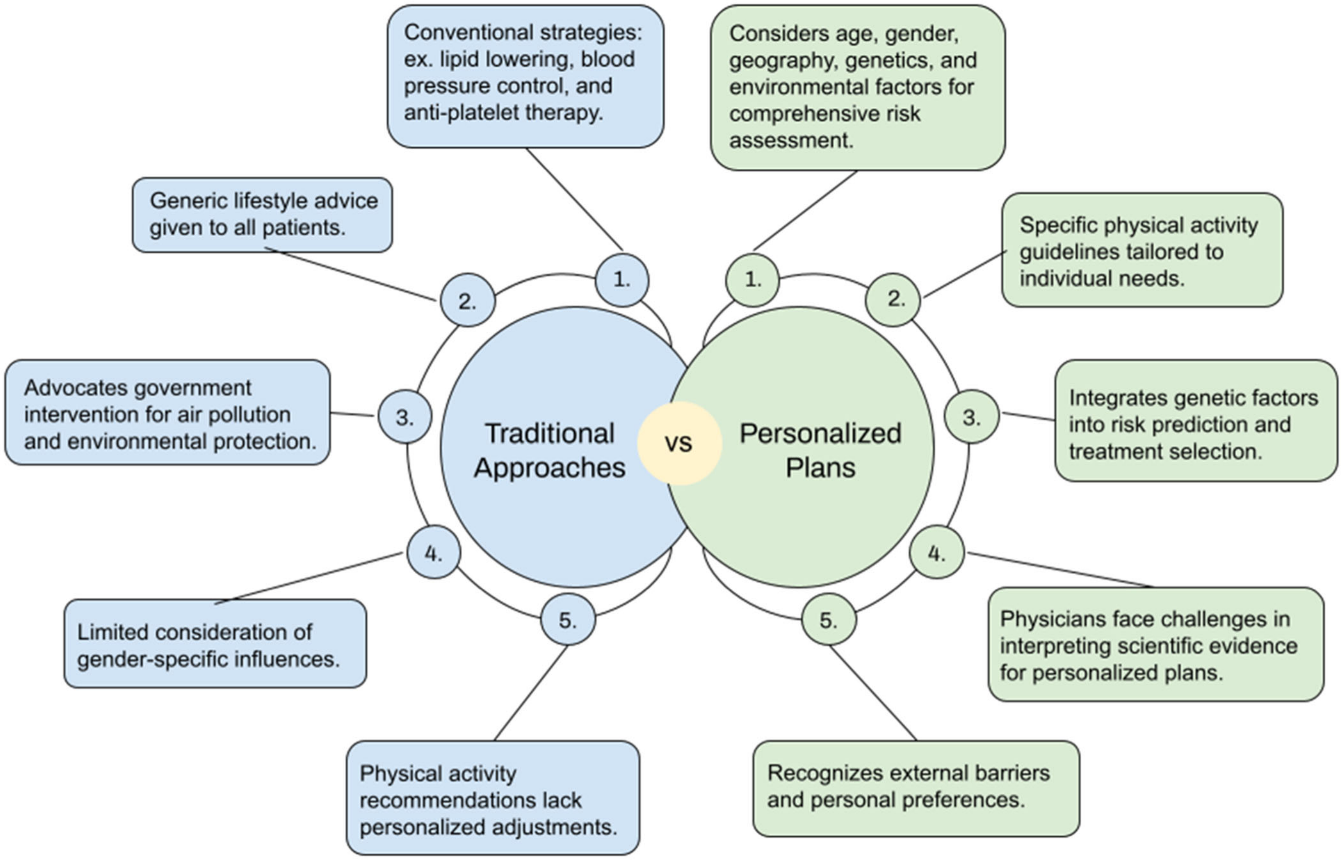

FIGURE 1 | Traditional approaches versus personalized plans in cardiovascular prevention.

each patient is different in characteristics, therefore the creation of a personal prevention and management plan for each patient can be challenged by the variations in the human mind and mood [36]. For instance, many patients stated that low-fat food and fitness clubs are costly and undesired [43]. his further affects the average risk as well as the overall benefit from a therapeutic intervention [36]. Therefore, the use of various models used for treatment effect prediction to personalize treatment would reduce the number of patients receiving unnecessary treatment and reduce treatment-associated harm and healthcare costs [36].

7 | Role of Artificial Intelligence in Mediating a Personalized Prevention Plan

Artificial intelligence (AI), aiming to mimic human cognitive functions, refers to the utilization of particular mathematical algorithms enabling machines' decision-making and problem-solving [44]. AI has been only recently implemented in cardiovascular medicine, in both machine learning (ML) and deep learning (DL) forms, although it was invented five decades ago [45]. The main aim of using AI in cardiovascular medicine is to tackle the most valid diagnosis, predict the most accurate outcome, or come to the best management or preventive plans, thereby enhancing patient care most cost-effectively [46]. In cardiovascular medicine, AI has been implemented in electrocardiogram analysis, echocardiography analysis, and cardiac imaging and imaging interpretation providing a diagnostic aspect of AI [47]. Cardiac anesthesia and interventional cardiology are also fields in which artificial intelligence is advancing [47]. In addition, AI along with precision medicine plays an important role in pharmaceutical drug discovery and development of cardiovascular treatment measures with minimum side effects [48]. This is because of the utilization of population genetics and risk factors [48].

AI holds significant promise in advancing the field of personalized medicine [49]. For instance, a recent study provided a machine-learning personalized statin treatment plan (PSTP) platform aiming to optimize the use of statin for cardiovascular prevention in contrast to ASCVD score and to create the ultimate personalized prevention plan with minimal harm produced by statin-associated symptoms and withdrawal [50]. Furthermore, the integration of AI-powered precision medicine is providing healthcare workers with the power to develop individualized cardiovascular plans against environmental factors and is, with time, beginning to shift the whole healthcare and public health system towards a new holistic paradigm [51]. For instance, AI- mediated geospatial analysis models can be developed by integrating the satellite technologies, that can provide data about the climate changes, air quality, temperature alterations, green spaces, and other relevant environmental factors, with the hospital databases, concerning all aspects of cardiovascular health, to create predictive models that can highlight cardiovascular hotspots. A study conducted in South Korea on Machine learning and GIS-based spatial analysis implemented similar multiple types of AI to examine the relationship between environmental factors and cardiovascular diseases and mortality [52]. The study concluded that Machine learning-based spatial analysis can identify latent regional risk factors and be used by public health officials in decision-making regarding cardiovascular disease-related initiatives [52].

On the other hand, CardioSight is AI-based system that works on consolidating key point in the electronic medical records on cardiovascular health with real-time cardiovascular risk factors data aiming to improve prevention in Singapore [53]. These data are then visualized and analyzed establishing proactive interventions for patients with high risk [53]. The personalized plans provided are set to address and optimize various risk factors including psychological threats, medical risks by cardioprotective medicine, and environmental health risks [53]. The Chronic disease Management Program (CHAMP) uses AI-mediated tools along with healthcare programs to achieve targeted management for chronic conditions including cardiovascular ones [53]. CHAMP includes an AI-based clinical decision support system and EPIC electronic medical records systems to provide tailored recommendations and directions for physicians regarding the therapeutic management of the patient including medication and life style changes based on his medical picture [53]. Besides, CHAMP also employs EndeavourAI the empowers WhatsApp chatbot. This is used for additional guidance on the personalized prevention plans by offering reminders on healthy practices, guidance of lifestyle modifications and home blood pressure monitoring [53]. In addition, EndeavourAI permits the analysis of the patients' information from the electronic medical records, controlling the clinical decision support and chatbot to give the best personalized prevention plans and direction as DASH diet for hypertension management [53]. Moreover, when combined with CardioSight, CHAMP can bridge the risk factors for an even better prevention plan [53].

There have been multiple works of literature suggesting the use of wearable and implantable devices that can aid in CVD detection and prediction of cardiovascular events [54]. A study regarding the use of PPG based smartwatch for the detection of Atrial Fibrillation revealed Its use in the long-term monitoring of Atrial fibrillation. Its use in monitoring at-risk individuals can also have a great public health benefit as it can pick asymptomatic Atrial fibrillation and lead to proper preventive treatments for individuals [55]. Furthermore, AI and Machine learning were used in the monitoring of patients with heart failure. AI/ML was applied via a wearable chest patch accessed through a smartphone and was able to detect heart failure exacerbation and rehospitalization in the multicenter LINK-HF study [54]. In the future, Smart wearable devices can be used to monitor cardiovascular health by tracking environmental risk exposures and providing personalized prevention plans. Cardiovascular susceptibility scores can be then calculated and these data can be analyzed by machine learning algorithms to devise a plan at the individual as well as population level. For example, it can provide alerts during heatwaves advising patients to leave or rest. It can also help in the discovery of new cardiovascular risk factors in addition to the traditional risk factors [56]. Furthermore, AI-mediated early warning systems can be built where the model works on identifying cardiovascular disruption before the emergence of the clinical picture. Health data, as blood pressure and heart already established to be provided by the wearable devices, can be integrated along with the continuous monitoring the environmental changes to identify and alert any change in the baseline suggesting a possible cardiovascular stress. Thereby, the individual can be guided according to the analyzed data provided by the system to decrease any risk, and feedback on his interaction can be given by the same model.

8 | Conclusion

Tackling cardiovascular susceptibility concerning environmental factors necessitates a paradigm shift towards personalized prevention. With significantly high morbidity and mortality rates, cardiovascular diseases take a toll on global health especially with its association with numerous environmental risk factors, previously under-recognized, as nanoparticles, microplastics, ocean acidification, EDCs, circadian disruption and EMR. Recognizing these environmental exposures, their relation to cardiovascular disease as well as the underlying mechanisms is essential to identify the individual variations in susceptibility, thereby tailoring the best preventive methods that can promise avenues in risk minimizing. Traditional prevention plans were challenged by the presence of various barriers faced by individuals, physicians, and governments. Therefore, the role of artificial intelligence can be recognized in mediating such plans overcoming some of the barriers towards better prevention.

Various AI-based systems including CardioSight, CHAMP and EndeavourAI, are now being employed providing a transformative power enabling more effective preventive strategies and paving the way for the health care providers by supporting their clinical decision. Thereby, clinicians should be well trained and should receive workshops on AI tools available to harness AI in decision making appropriately. Furthermore, wearable AI-associated devices, with high prediction of cardiovascular events, can be used as alarm systems when approaching a risk factor before being clinically evident. Therefore, refining AI algorithms toward a more precise assessment of environmental risk factors, using wearable devices, providing an accurate mechanism influencing cardiovascular susceptibility, therefore creating the ultimate prevention plans with on spot alerts. In addition, AI geospatial models are found to be effective in identifying hotspots for strategic policy development. Therefore, Policy developers should embrace AI tools in public health issues, especially those related to environmental problems, to guarantee evidence-based decisions as these tools can be used to interpret and provision insights into the environment's health problems. However, future research should address the ethical aspects of the use of AI in clinical practice as it requires private information and may be liable to theft. In addition, the requirement of consent and the risk of bias should be studied more when dealing with clinical decisions created by artificial intelligence.

Author Contributions

Fatima Soufan: writing – original draft, data curation, formal analysis, methodology. **Hajar Nasir Tukur:** writing – original draft, methodology, formal analysis, data curation. **Ruth Girum Tamir:** data curation, formal analysis, methodology, writing – original draft. **Ernest Muhirwa:** data curation, formal analysis, methodology, writing – original draft. **Magda Wojtara:** data curation, formal analysis,

methodology, writing – original draft. **Olivier Uwishema:** supervision, data curation, formal analysis, project administration, writing – review and editing, methodology, validation, writing – original draft, investigation, conceptualization.

Acknowledgments

We would like to thank Oli Health Magazine Organization (OHMO)'s members for their contributions and support for this manuscript.

Ethics Statement

The authors have nothing to report.

Consent

The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The authors have nothing to report.

Transparency Statement

The lead author Olivier Uwishema affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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