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Innovative strategies for early detection and prevention of cardiovascular disease in a global context: an integrative review

Abstract

Cardiovascular disease (CVD) remains the leading global cause of mortality and disability, with more than 18.6 million deaths annually and persistent disparities affecting low- and middle-income countries (LMICs). Updated global estimates from the GBD 2021 study reinforce the urgency of addressing rising CVD prevalence in resource-constrained settings. This review synthesizes evidence on global CVD burden, emerging early detection technologies—including genomics, biomarkers, artificial intelligence (AI), wearables, and imaging—population-level preventive strategies, precision prevention, and implementation science. Genomic and biomarker screening, AI-enhanced ECG and imaging interpretation, and wearable monitoring offer promising avenues for early detection, while community-based screening and multisectoral policies remain essential for equitable prevention. Pharmacogenomics and precision prevention further enhance individualized care, though challenges remain regarding cost, access, and clinical evidence. Scaling these innovations requires robust surveillance systems, task shifting, public–private partnerships, and international collaboration. Coordinated global action is necessary to reduce premature CVD mortality and achieve 2030 targets.

Keywords: cardiovascular disease, global burden of disease, early detection technologies, artificial intelligence, precision prevention, low- and middle-income countries

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Introduction

Cardiovascular disease continues to impose a disproportionate global burden, accounting for more than 18.6 million deaths annually according to updated GBD 2021 estimates. Recent analyses show that while high-income countries (HICs) have achieved sustained reductions in CVD mortality, many LMICs face stagnation or worsening trends due to demographic transitions, urbanization, and rising prevalence of modifiable risk factors. These disparities underscore the need for innovative, scalable, and context-appropriate strategies for early detection and prevention.

Methods

This narrative review synthesizes evidence from epidemiological studies, global health reports, clinical trials, and implementation science literature.

- Databases searched: PubMed, Scopus, Web of Science, Google Scholar.

- Search period: January 2005–December 2023.

- Search terms: “cardiovascular disease,” “early detection,” “genomics,” “wearables,” “implementation science,” “precision prevention,” “pharmacogenomics,” “global health.”

- Inclusion criteria: peer-reviewed articles, global health reports, and clinical studies addressing early detection or prevention of CVD.

- Approximate number of studies included: ~210 screened; ~120 included.

Results

Global burden and epidemiological trends

CVD accounts for 31% of global deaths, with more than 82% occurring in LMICs. Updated GBD 2021 data confirm persistent regional disparities, particularly in Sub-Saharan Africa and South Asia.

Early detection technologies

Genomic and Biomarker-Based Screening: High-throughput genomic technologies and biomarker profiling enable assessment of inherited CVD risk and early detection of subclinical disease.

Artificial intelligence in ECG and imaging analysis: AI-enhanced algorithms have demonstrated high accuracy in detecting arrhythmias, left ventricular dysfunction, and early ischemic changes from standard 12-lead ECGs. Examples include deep learning models for atrial fibrillation detection, AI-assisted echocardiography, and machine learning applied to coronary CT angiography.

Wearables and digital health monitoring: Wearables now provide continuous monitoring of heart rate, ECG, oxygen saturation, and physical activity.

Clinical validation examples:

- Apple Heart Study (2019): >400,000 participants; validated smartwatch-based AF detection.

- Fitbit Heart Study (2021): validated photoplethysmography-based AF detection in >450,000 users.

- mSToPS trial: patch-based ECG monitoring improved AF detection compared with usual care.

Imaging and non-invasive diagnostics

Coronary artery calcium (CAC) scoring, myocardial perfusion imaging (MPI), and PET provide complementary prognostic information, though access remains limited in LMICs.

Population-level preventive strategies

Includes policy interventions, community-based risk assessment, and lifestyle modification programs.

Precision prevention and pharmacogenomics

Risk Stratification: Precision prevention integrates individual-level risk prediction with population-level targeting.

Pharmacogenomics: Genetic polymorphisms influence response to β-blockers, statins, and anticoagulants.

Limitations:

- High cost of genetic testing.

- Limited availability in LMICs.

- Incomplete clinical evidence for many gene–drug interactions.

- Equity concerns due to underrepresentation of non-European populations.

Implementation science and global partnerships

Task shifting, public–private partnerships, and global frameworks such as ACT-A and GFF support scalable CVD prevention strategies (Tables 1&2).[1-10]

Table 1 Global distribution of CVD burden and key risk factors

Region	CVD mortality trend	Major risk factors	Key challenges
High-income countries	↓ Significant decline	Aging, obesity	Plateauing improvements
Sub-Saharan Africa	↑ Rising	Hypertension, diabetes	Limited diagnostics
South Asia	↑ Rising	Tobacco, dyslipidemia	Urbanization
Latin America	↔ Minimal change	Obesity, diabetes	Health system fragmentation

Note: Data synthesized from WHO 2021 fact sheet and GBD 2021 regional estimates.

Table 2 Emerging technologies for early CVD detection

Technology	Application	Advantages	Limitations
Genomic screening	Polygenic risk scoring	Early risk identification	Cost, equity concerns
Biomarker profiling	Inflammation, lipidomics	High specificity	Requires lab capacity
Wearables	Continuous monitoring	Scalable, low-cost	Data governance
Imaging (CAC, PET)	Atherosclerosis detection	Strong prognostic value	Limited access in LMICs

Note: Applications and limitations derived from Circulation (2020), ESC ATLAS (2021), and Lancet Digital Health (2022).

Conclusion

Early detection and prevention of CVD require an integrated approach combining technological innovation, population-level strategies, and implementation science. Future research should prioritize AI-driven risk prediction models, cost-effective genomic testing, large-scale wearable-based screening trials, strengthened global surveillance systems, and equitable policy frameworks.

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