ESC European Journal of Preventive Cardiology (2026) **00**, 1–12
https://doi.org/10.1093/eurjpc/zwag387

REVIEW
Air pollution and environmental science

Preventing cardiovascular disease within the built and living environments: an expert opinion

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Received 10 May 2026; revised 6 June 2026; accepted 18 June 2026; online publish-ahead-of-print 30 July 2026

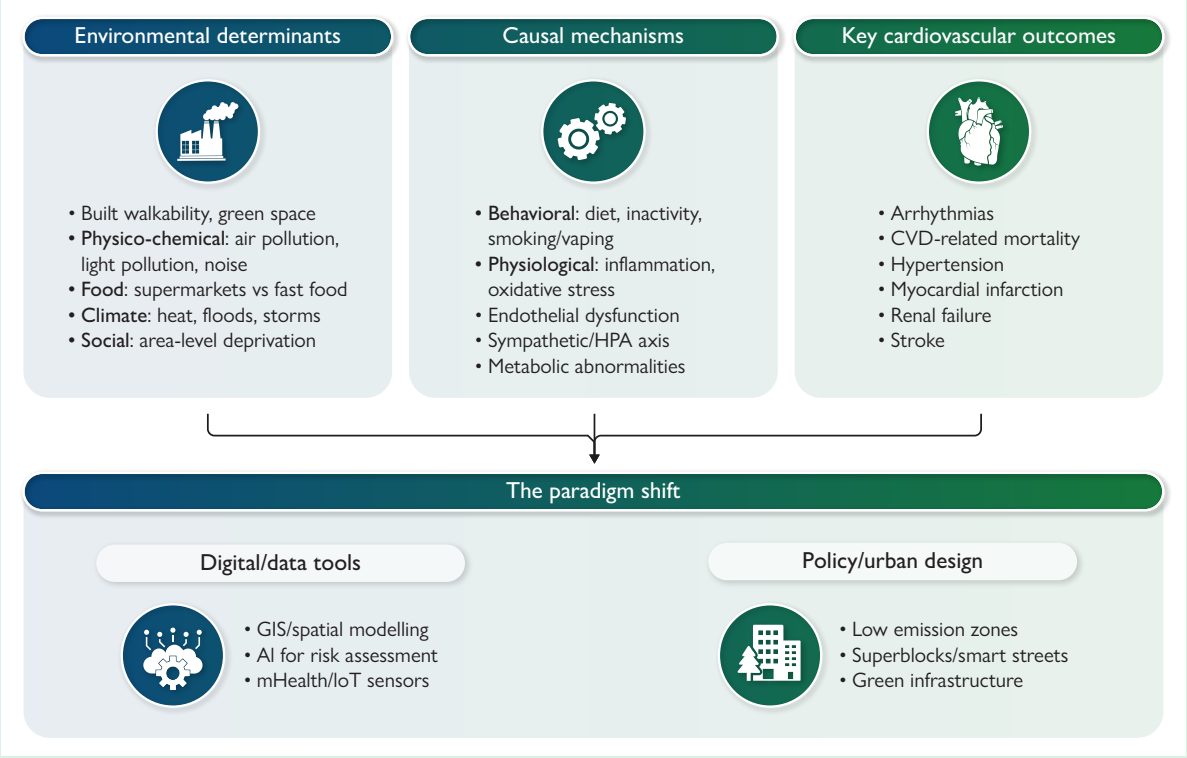
Abstract

Cardiovascular (CV) health is influenced not only by biological factors but also by the environments in which people live. The environment comprises interconnected built, living, and social domains that shape health behaviours, psychosocial well-being, environmental exposures, and access to resources. Within this framework, the built environment, the human-made settings that structure daily life, plays a key role in influencing physical activity, dietary behaviours, social interactions, safety, and overall well-being. Neighbourhoods are embedded within historical, legal, political, cultural, and economic contexts that shape the social determinants of health and contribute to CV health. Growing evidence indicates that characteristics of the living environment substantially influence cardiovascular disease (CVD) and related disorders through multiple pathways. These include access to healthcare, air and noise pollution, availability of healthy foods and green spaces, physical activity, social cohesion, and chronic psychosocial stress. Potential mechanisms include inflammation, oxidative stress, neuroendocrine dysregulation, unhealthy lifestyle behaviours, and persistent stress responses that promote cardiometabolic dysfunction and vascular disease. This expert opinion examines challenges and opportunities related to nutrition, physical activity, environmental quality, community engagement, and occupational as well as social dimensions of the living environment from a public health perspective. This document highlights the importance of designing healthier communities that support CV health and reduce disease burden. Furthermore, neighbourhoods may serve as measurable units for monitoring CVD and broader health outcomes by integrating environmental characteristics with CV metrics, electronic health records, geospatial data, and neighbourhood-level social risk indicators. Addressing environmental determinants across multiple scales supports targeted public health strategies in Europe and globally.

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Graphical Abstract



Keywords Cardiovascular disease • Living environment • Lifestyle • e-Health • Food environment

What is already known

- The built environment, defined as the human-made surroundings that structure daily life, plays a critical role in shaping physical activity, dietary behaviours, social interactions, safety, and overall well-being.
- Characteristics of the built environment significantly affect cardiovascular disease and related metabolic disorders.

What this study adds

- City-level 'smart street' and 'smart city' initiatives integrate technology with the built environment, for example by embedding digital signage, urban sensors, and gamification strategies to promote active transport and healthier food choices
- Artificial intelligence can assess aggregated community data to identify high-risk neighbourhoods and environmental stressors, supporting urban planning and public health strategies
- Redesigning cities with green spaces, safe mobility, and social connectivity addresses key social and environmental determinants of health, supporting healthier lifestyles and reducing cardiovascular risk across populations

Cardiovascular prevention; from the 'stone age' to the current era; the role of built and living environments

Recently, the European Society of Cardiology (ESC) Atlas reported 68 million disability-adjusted life years attributable to cardiovascular disease (CVD) in association with more than 3 million deaths per year, identifying CVD as the leading cause of death across ESC member countries.[1] Cardiovascular (CV) health is shaped not only by biological factors but also by the environments in which we live. The built environment, encompassing the human-made surroundings in which people live, work, and engage in daily activities, plays a critical role in shaping physical activity, dietary choices, social interactions, and perceptions of safety.[1–4] Neighbourhood environments are embedded within historical, legal, political, cultural, and economic contexts that influence social determinants of health and structure interpersonal and community relationships.[5] A modern perspective conceptualizes neighbourhoods as multidimensional environments comprising interconnected physical, social, environmental, and socioeconomic characteristics that influence CV health. Neighbourhood features, including walkability, access to amenities, safety, social cohesion, greenness, and environmental quality, affect physical activity, obesity, cardiometabolic risk factors, health behaviours, and psychosocial stress, ultimately shaping

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CVD risk, mortality, and population health outcomes.[6] Viewed through the exposome framework, neighbourhood's characteristics represent a complex array of external exposures, including built, social, chemical, and psychosocial environments that accumulate and interact over the life course. Together, these factors contribute to health trajectories by influencing both behavioural pathways and underlying biological mechanisms. Accumulating evidence suggests that factors related to the built environment significantly impact CV health and related metabolic disorders through various pathways. This influences the living environment by limiting access to healthcare, exposing to environmental hazards, shaping unhealthy lifestyle behaviours, and increasing stress levels. Understanding these complex pathways can inform public health policies and interventions aimed at reducing the burden of CVD in Europe and globally. By examining and designing built and living environments that systematically collect health and environmental data, healthcare systems can gain valuable insights that support more targeted and effective prevention strategies. Integrating neighbourhood-level characteristics into CV prevention efforts may further support early risk identification, address social and environmental determinants of health, and enhance population-level health outcomes.[4]

This opinion review from experts in CV prevention examines the challenges and opportunities related to lifestyle, community affairs, occupation, and their social dimensions in preventing CVD within the built environment from a public health perspective. A key aspect of this approach is to include evidence-based proposals on how to create residential environments that promote a healthy lifestyle and reduce CV risk. The new challenge for modern CVD prevention comes from identifying macro-to-micro environment determinants to establish tailored public health strategies.

Major environmental factors in relation to cardiovascular disease risk

Climate change

Current European CV statistics and literature reviews suggest that several environmental factors interplay with environmental characteristics, substantially increasing CVD risk.[1,4] The interplay between built environment and climate change has been recognized since the 1990s as a major contributor to CV morbidity and mortality, yet health-system adaptation remains limited. Increased exposure to extreme temperatures and severe weather events contributes to CVD through haemodynamic, inflammatory, and thrombotic pathways.[7–10] The built environment contributes to climate change through energy use, transport, and land-use patterns, while also shaping exposure and resilience to climate hazards. Together, natural and built environments influence health via environmental exposures and vulnerability. Moreover, climate change amplifies the CV burden of air pollution. Rising ambient temperatures accelerate the photochemical reactions that generate ground-level ozone, while prolonged heatwaves, droughts, and altered atmospheric circulation patterns favour the accumulation of air pollutants and reduce their dispersion. Climate change also contributes to the increasing frequency, duration, and intensity of wildfires, which have become major sources of fine particulate matter ($PM_{2.5}$) and other toxic pollutants. Consequently, climate-driven changes in air quality may substantially increase population exposure to both $PM_{2.5}$ and ozone, thereby amplifying the burden of CVD.[9,10] These pathophysiological processes increase CV risk, particularly among older adults and socioeconomically disadvantaged populations.[10]

Lifestyle behaviours

Regular physical activity, a key determinant to reduce CV risk and mortality,[11–14] is strongly influenced by the built environment. Neighbourhood walkability, access to green spaces, and safety are associated with higher activity levels, while deprived environments contribute to sedentary behaviour and higher CV risk. Despite these well-established health effects, sedentary lifestyles remain common.[15] The WHO *More Active People for a Healthier World* initiative aims to reduce global inactivity by 15% by 2030, highlighting the importance of policies, infrastructure, and incentives to promote regular physical activities, green, walkable neighbourhoods with accessible parks can significantly boost resident physical activity levels.[16]

Dietary habits and eating behaviours, cornerstones of CV health, are also influenced by living built environment. Accumulating evidence suggests that in the urban built environment, widespread access to both nutrient-dense foods and highly processed, energy-dense options (i.e. fast-food) has shifted diets towards unhealthier patterns and related to an increased incidence of CVD.[17–20] Health and nutrition literacy are crucial components for shaping healthy dietary behaviours, which are also influenced by the built environment.[21] Time constraints, social isolation, and vulnerability within the living environment have been associated with lower health and nutrition literacy, hindering the adoption of healthy dietary patterns.[22–24]

Smoking, active or passive (i.e. second hand), is also influenced by the built environment through neighbourhood socioeconomic conditions, tobacco retail density, advertising exposure, smoke-free space availability, and social norms affecting smoking behaviour.[25–30] As awareness of the adverse health effects of tobacco smoking has increased, electronic cigarettes (e-cigarettes) have gained substantial popularity over the past few years. Often promoted as less harmful alternatives to combustible tobacco products and as tools for smoking reduction or cessation, e-cigarettes are widely perceived as safer options. Nevertheless, growing scientific evidence suggests that e-cigarette use may also have important adverse health consequences, which interact with living environment.[31] Expanding smoking bans to outdoor areas and regulating e-cigarettes and vaping can help strengthen CV prevention within living environments.[32]

Stress

Environmental exposures can also act as stress amplifiers or buffers, influencing CVD risk.[33,34] Air pollution, noise, heat, traffic density, and sedentary travel are consistently associated with higher CVD risk, partly through sympathetic activation, hypothalamic–pituitary–adrenal axis stimulation, oxidative stress, inflammation, and vascular dysfunction.[9,35–38] In contrast, access to green spaces, walkable neighbourhoods, and low-noise environments are linked to less stress activation, improved well-being, and lower risk of CVD.[39–43] Urban planning that reduces harmful exposures while promoting restorative environments is therefore important for CV prevention.

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Knowledge gaps

Despite strong evidence linking environmental exposures to lifestyle behaviour and CVD, research gaps persist in establishing causality through longitudinal designs, defining age and sex-specific sensitivities, modelling complex non-linear behavioural responses, and addressing how socioeconomic contexts influence the impact of urban infrastructure on CV health. Moreover, research often isolates single exposures, lacks longitudinal and intervention studies, and rarely integrates acute and chronic stress pathways.

Modifiable characteristics of built and living environments

Health-friendly characteristics at macro area-level

Traditionally, a geographical macro area refers to a large territory defined by shared characteristics, such as physical environment, economic and social development, or geopolitical borders (e.g. the EU or North Africa). In this paper, we define macro area-level as a borough, a district, eventually an entire city or an administrative region. A major methodological challenge in evaluating health-friendly macro environmental characteristics is the accurate measurement of area-level exposures and their spatial distribution across populations. In assessing health-friendly area-level characteristics, data are often aggregated at pre-existing administrative spatial scales, such as for neighbourhoods, postal code areas, and census blocks.[44] Consequently, all residents within the same area are assigned identical exposure data, overlooking variations in exposure within the area. Moreover, such areas are often delineated by arbitrary boundaries that may not accurately reflect continuous spatial features.[45] Geographic information systems (GIS) are designed to capture, store, manipulate, analyse, combine, and present all types of spatial data.[46] Instead of relying solely on administrative areas, data from multiple sources can be combined within Euclidean or street-network buffers around residential addresses or other locations, providing standardized exposure areas and more accurate representations of the environments to which people are exposed.[45,46] Geographically referenced information can be derived, for instance, from geodata registers, street-view images, measurements from monitoring stations, and outputs from spatial models. GIS enable the assessment of single environmental factors, such as accessibility of green space or fast-food outlet density, as well as the identification of spatial hotspots or clusters where multiple exposures, such as air pollution, traffic noise, and lack of recreational infrastructure, converge. These systems are powerful tools for assessing health-friendly area-level characteristics.[45]

Shaping health-friendly built environment at micro-level

Micro-level areas vary from a small number of buildings to boroughs. At the micro-level, health-friendly built environments can be promoted through neighbourhood designs that encourage walking, cycling, social interaction, and access to green spaces, healthy food outlets, and essential services. Such interventions can improve physical activity, reduce psychosocial stress and environmental exposures, and ultimately contribute to better CV and overall health. Various reviews have indicated that safe, walkable, and aesthetically pleasing neighbourhoods, with access to general and specific destinations and services, may positively influence physical activity in (older) adults.[46–49] For instance, access to more green space and a higher level of land-use mix (i.e. the availability of diverse destinations) within neighbourhoods is associated with a lower risk of obesity, hypertension, type 2 diabetes mellitus, CVD events, including mortality.[50,51] Particularly, neighbourhood walkability has recently gained interest as a potential upstream determinant of CV health.[3,50–54] This parameter reflects the extent to which an area is conducive to walking and is often measured by an index combining multiple built environmental factors, such as population density, land-use mix, and street connectivity.[50]

Creating a health-friendly physicochemical environment

The physicochemical environment refers to the totality of external physical and chemical exposures from natural and anthropogenic sources, including air pollution, noise, ambient temperature, and light pollution. Air pollution increases CVD risk via systemic inflammation, oxidative stress, and endothelial dysfunction. Noise and extreme temperatures can trigger hypertension, vasoconstriction, and tachycardia, while light pollution may disrupt circadian rhythms and sleep, leading to metabolic dysregulation and elevated blood pressure.[35] Substantial evidence links air pollution to CVD morbidity and mortality. A recent umbrella review and meta-meta-analysis confirmed the association between several air pollutants and CVD events, with strong evidence that higher $PM_{2.5}$ levels are related to a higher CVD mortality, ischaemic heart disease mortality, and stroke risk.[35] Similarly, greater noise exposure has been consistently linked to adverse CV outcomes, including higher risks of ischaemic heart disease and CVD mortality.[9,35,55,56] Extreme ambient temperatures have also been associated with elevated CVD risk.[35] Moreover, artificial light at night is linked to increased risk of coronary heart disease (CHD), including higher CHD mortality and hospitalization rates.[54] At the micro-level, a health-friendly physicochemical environment can be achieved by reducing exposure to air and noise pollution, improving indoor and outdoor air quality, enhancing thermal comfort, and increasing access to green spaces. These measures help mitigate inflammation, oxidative stress, and chronic stress responses, thereby supporting health and well-being.

Shaping a health-friendly food environment

The geographical access to food in communities or neighbourhoods is known as the food environment.[56,57] Evidence, mostly from residential settings, suggests that greater availability of fast-food and convenience stores are associated with lower diet quality, including higher intake of (ultra)processed foods, snacks, and sugar-sweetened beverages. Conversely, greater availability of supermarkets and healthy food outlets is linked to healthier diets.[57,58] A recent systematic review found that a higher density of fast-food restaurants was most consistently associated with a higher CVD prevalence, incidence, and mortality.[57] Nonetheless, associations with myocardial infarction or

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stroke were less consistent. Evidence for other aspects of the food environment, such as density of food service restaurants and unhealthy food outlets, remains limited.[57,58] Importantly, prospective studies are scarce. A recent nationwide prospective cohort study in the Netherlands showed that changes in exposure to a healthier food environment over 14 years were associated with reduced CVD hospitalizations and mortality, particularly in urbanized areas, among younger adults, and in those with higher incomes.[58]

Social environment

The social environment refers to the relationships and contexts in which people live and interact, encompassing several dimensions at micro-level, including: (i) economic and social disadvantage, (ii) social relationships and norms, (iii) social cohesion and social capital, (iv) crime and safety, (v) civic participation and engagement, and (vi) disorder and incivilities.[59–61] These dimensions operate at different levels, from personal networks to neighbourhood contexts, and may influence CV health through coping abilities, lifestyle behaviours, and psychological mechanisms.[49,60] A recent systematic review and meta-analysis revealed that adverse social environments are associated with unfavourable cardiometabolic risk profiles.[59] Most evidence focused on dimension 'economic and social disadvantage', such as area-level deprivation, which was associated with higher CVD risk scores, impaired glucose metabolism, and other CV risk factors. Another comprehensive work, summarizing 281 studies and 1108 associations, evaluated the evidence on the association between the social environment and cardiometabolic health outcomes.[60] Specifically, the 'economic and social disadvantage' dimension was associated with higher risks of hypertensive diseases, type 2 diabetes, and heart failure, while poorer 'social relationships and norms' were related to a higher risk of ischaemic heart disease.[60–62]

Integrating neighbourhood and healthcare system strategies for effective cardiovascular disease prevention

Effective CVD prevention requires moving beyond a sole focus on individual-level risk factors and addressing environmental determinants operating at both macro- and micro-levels, while integrating these upstream influences into healthcare systems.[49,61] Incorporating comprehensive environmental exposure assessments into healthcare systems can enable earlier identification of at-risk individuals, support more precise risk stratification, and guide interventions tailored to environmental contexts. This requires appropriate environmental health education and the development of tools, data infrastructures, and clinical workflows that enable healthcare professionals, such as general practitioners, physiotherapists, and dieticians, to systematically consider environmental exposures alongside traditional risk factors in lifestyle advice and treatment.[49] For instance, tools mapping neighbourhood walkability can inform both patients and (para-)clinicians about areas supportive of walking, enabling shared decision-making for personalized lifestyle interventions that take the patient's local living environment into account.

Currently, clinical guidelines include limited recommendations related to the exposome (i.e. the totality of environmental exposures across a person's life, including external factors, e.g. pollution, diet, climate, and the built and social environment, and internal biological responses, e.g. inflammation and metabolism). Advice may exist for air pollution exposure, but other environmental factors are not well addressed and appreciated.[62,63] While integrating comprehensive environmental exposure assessments into healthcare systems may support improved risk stratification and earlier identification of vulnerable CVD individuals (*Table 1*), such approaches must be considered in the context of already strained and resource-limited health systems. Given these constraints and the broader drivers of population health, greater public health impact may be achieved by prioritizing upstream interventions that reduce environmental pollution and hazardous exposures at the source. Accordingly, strengthening environmental regulation and urban planning may offer a more efficient and scalable strategy for CVD prevention than expanding healthcare-based exposure monitoring alone.[64]

Knowledge gaps

To enable the shift from neighbourhoods to healthcare systems and develop wide-reaching CVD prevention strategies, the evidence base on environmental determinants of CVD must be strengthened and knowledge gaps addressed. First, most existing studies rely on cross-sectional data, highlighting the need for longitudinal studies to evaluate the impact of environmental changes on lifestyle behaviours and CVD outcomes over time.[63] Second, research has mainly focused on residential exposures, often overlooking influences at other places (e.g. workplaces and recreational settings). Incorporating time-activity-weighted exposures could provide a more accurate assessment of total environmental risk.[62] Third, studies frequently use a single-exposure approach, whereas individuals are exposed to multiple factors simultaneously. Using a composite exposure approach, such as indices combining multiple factors, can better capture co-occurring exposures, providing a holistic assessment of the environment that shapes lifestyle behaviours and subsequent disease risk.[54,57] Fourth, environmental factors may affect CVD risk differently across population subgroups (e.g. by sex, age, ethnicity, and socioeconomic position). Examining multiple environmental attributes alongside multiple behaviours and risk factors across subgroups can provide insights into these differential effects.[53] Fifth, underlying mechanisms remain insufficiently understood, particularly regarding mediation through lifestyle behaviours and direct physiological pathways.[53] While evidence is substantial for some factors (e.g. air pollution), many exposures remain understudied (e.g. plastics, food delivery services, and various social environment dimensions) and require further investigation to assess their impact on CVD risk.

Modern technology within the context of built and living environments

The role of smart technology in promoting healthy behaviour

Smart technology offers novel opportunities to foster healthier lifestyle behaviours at scale by embedding prevention into daily

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Table 1 Determinants of cardiovascular health in the built and living environments

Domain	Determinants/exposures	Mechanisms/pathways	Cardiovascular outcomes/impact
Built environment	Poor neighbourhood walkability, inadequate green space availability, limited access to active transportation infrastructure	Shapes health behaviours (physical activity and diet), influences psychosocial well-being and stress, modifies environmental exposures, and affects social connectedness	Higher prevalence of obesity and hypertension, increased cardiometabolic risk, and elevated incidence of CVD and related mortality
Climate change	Extreme temperatures, air pollution, and severe weather events	Induces inflammation, oxidative stress, vascular dysfunction, and haemodynamic and thrombotic alterations	Higher incidence of arrhythmias, coronary events, stroke, heart failure, and cardiovascular mortality
Ambient environment	Noise pollution, air pollution, traffic exposure, limited green space access	SNS and HPA axis activation, hormonal dysregulation, inflammation, and vascular dysfunction	Hypertension, atherosclerosis, coronary heart disease, stroke, and acute cardiovascular events
Living environment	Food-deserts, fast-food density, access to healthy food outlets physicochemical, and social environmental factors	Behavioural, psychosocial, and physiological pathways; shapes dietary behaviour and nutrition quality	Major upstream determinant of CV risk and CV health outcomes
Social environment	Socioeconomic disadvantage, low social cohesion, poor neighbourhood safety, limited social capital	Behavioural influences, chronic stress, reduced healthcare access, and lower treatment adherence	Higher prevalence of hypertension and diabetes, increased risk of heart failure and cardiovascular disease

This table summarizes key environmental, behavioural, and technological determinants of CV health and their proposed mechanisms and impacts based on current scientific evidence.
CVD, cardiovascular disease; SNS, sympathetic nervous system; HPA axis, hypothalamic–pituitary–adrenal axis.

routines.[65] Smartphone applications for diet tracking and exercise promotion have demonstrated potential for improving dietary quality and physical activity through real-time feedback and behavioural nudges.[66–68] City-level 'smart street' and 'smart city' initiatives integrate technology with the built environment, for example by embedding digital signage, urban sensors, and gamification strategies to promote active transport and healthier food choices.[67,68] Pilot projects such as Barcelona's *Superblocks* (Cerdà urban plan of Barcelona was designed in 1860) and Singapore's *Smart Nation Healthier SG* illustrate how combining digital tools with urban design can reduce sedentary behaviour and encourage active commuting.[69,70] Importantly, merging personalized apps with citywide digital infrastructures may allow synergistic improvements in lifestyle modification, thereby advancing CVD prevention.[66]

Mobile health and digital literacy

Mobile health (mHealth) technologies have transformed access to preventive cardiology by providing scalable, low-cost platforms for lifestyle monitoring, medication adherence, and remote coaching.[65,66] Randomized trials such as *TEXT ME* and *mActive* demonstrated improvements in risk factor control and physical activity using SMS and app-based interventions.[71–73] However, the potential of mHealth is contingent on adequate digital literacy. Gaps in health and digital literacy, particularly among older adults, lower socioeconomic groups, and migrants, pose significant barriers to equitable adoption. Initiatives like the WHO's *Be He@lthy, Be Mobile* programme show how targeted training and culturally adapted content can bridge this divide.[74] Integrating digital literacy into health promotion strategies is critical to ensure mHealth tools reduce, rather than exacerbate, CV health inequalities. Strengthening regulatory oversight, data security, and interoperability with electronic health records will further enhance the role of mHealth in CVD prevention.[66,71,72,74–76]

Internet of things

The internet of things (IoT) refers to a network of interconnected sensors and devices that continuously collect, transmit, and analyse data.[77] IoT offers two complementary and practical ways to monitor CV health in both homes and communities. First, it can modify environmental conditions such as temperature, light, humidity, and odour based on individual inputs or measured biological outputs. Second, IoT devices can capture physiological signals, such as heart rate, activity levels, or sleep patterns, through direct or indirect sensors. In home settings, ventilation or lighting can be optimized via IoT data to reduce CV strain. At the community level, aggregated IoT data can help identify environmental risk factors such as air pollution, excessive noise, heat exposure, or lack of green space, all of which are known to influence the risk for CVD. Beyond immediate feedback, IoT systems support early detection of CVD and allow optimizing environmental exposures by linking biological responses to specific conditions. Moreover, IoT technologies combined with machine-learning approaches can accurately detect and monitor CVD.[77] By integrating biological measurements with environmental data, IoT can transform both homes and public spaces into adaptive systems that actively support CV

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health, moving beyond passive monitoring to a pro-active model of disease prevention.

Artificial intelligence and data analytics

Artificial intelligence (AI) is increasingly used in CV research for pattern recognition in complex datasets. In prevention, AI applied to clinical and physiological data, such as electrocardiograms (ECGs), imaging, and wearable signals, may improve early detection of subclinical disease and risk prediction in selected settings, although its impact on real-world outcomes remains uncertain.[78,79] AI has also been used to examine links between environmental exposures and CV physiology, with studies combining wearable and pollution data showing short-term associations with heart rate variability, blood pressure, and arrhythmias. In addition, machine-learning approaches applied to health records and geospatial data can identify neighbourhood-level clusters of CV risk related to socioeconomic and environmental disadvantage.[80] At a population level, emerging work using AI-driven geospatial and 'digital twin' approaches is being explored to simulate environmental and health interactions, including climate-related risks.[81,82] While integration of IoT devices, environmental sensors, and health data offers opportunities for more granular exposure assessment, these applications remain largely in the research domain and have yet to demonstrate consistent effectiveness in reducing CVD burden in routine practice.[83]

Knowledge gaps

The long-term engagement with apps needs more assessment. The impact on health behaviours of cities designed using AI remains to be established. Finally, challenges, such as digital literacy, app usability, and data privacy, and security concerns should not be underestimated. Furthermore, apps are developed by companies which are driven by financial gains; that should also be considered.

Policies and interventions at improving health status across European countries

Action plans for CVD prevention in Europe

Recent European policy developments have increasingly recognized the role of the built environment in shaping CV health outcomes, including the *2024 EU Council Conclusions on Cardiovascular Health and the Healthier Together* initiative.[84] There is evidence of a commitment to address non-communicable diseases through environmental, social, and health-system levers. These frameworks encourage Member States to operationalize CVD prevention by integrating structural determinants into national action plans. Furthermore, programmes like *EU4Health* provide funding pathways that support local governments and health systems in adapting these overarching strategies to their urban contexts. Translational initiatives such as JACARDI and the WHO HEARTS technical package offer additional and more concrete tools for embedding CV prevention into community and neighbourhood systems. Notably, cities across Europe are experimenting with integrating these protocols within walk-in clinics, school health systems, and digital infrastructures embedded in the urban fabric.[85,86]

Integrating measures at neighbourhood level into health-system actions

A growing emphasis on data and equity has prompted the development of tools like the *City Heartbeat Index*, which quantifies city-level CV risk readiness based on key domains, including social determinants, physical environment, health risks, health services, and governance.[87] In doing so, this index offers a comprehensive and policy-relevant framework, which can serve as a benchmarking tool for cross-city comparisons and for assessing the drivers and barriers to CV health at the city-level.[87] The evaluation of the likelihood of success of city-based interventions. City-based approaches are complex interventions, and it would be useful to use/refer to the non-adoption, abandonment, scale-up, spread, and sustainability framework to discuss factors that limit/facilitate adoption, scalability, and spread.[88]

Data tools are dependent on data availability and quality, which could vary across cities and comparability can be challenging because of differing data collection methods and definitions. Also, urban environments change rapidly, but updates may lag real-time conditions. These advances recognize the need for multi-sectoral policy alignment: housing, zoning, transportation, and public safety all shape the daily exposures that modulate CV risk, as has also been recognized by the World Heart Federation.[84] Thus, effective CVD prevention requires policies that actively promote heart-healthy environments. The synergy between urban planning and CV policy represents a cornerstone of future health-system resilience across Europe (*Figure 1*).

Policies related to the built environment

Built environment policies targeting upstream determinants of CV health are mechanistically sound but remain understudied regarding their direct effects on CVD outcomes. Nonetheless, emerging examples from European cities suggest that these policies may improve CV health. *Low Emission Zones*, implemented in cities such as Berlin (Germany) and London (UK), have been associated with improved air quality and reductions in CVD outcomes.[89] In Barcelona (Spain), the *Superblocks* initiative reclaims urban space from traffic by reducing car use, increasing greenery, and improving walkability, thereby lowering exposure to air pollution, noise, and urban heat, while promoting active mobility.[90] The project involves restricting vehicle traffic within a defined area (typically nine city blocks), lowering speed limits, and using the reclaimed space for social areas, green infrastructure, and active mobility. This transformation reduces air and noise pollution, encourages active transportation, and fosters social interaction within communities. The goal is to reduce air and noise pollution, increase green spaces, improve public health, and create a more people-centred city. Although reductions in pre-mature mortality have been observed, specific evidence on CVD outcomes is lacking. Similarly, the *15-Minute City* in Paris (France) fosters compact, mixed-use neighbourhoods that encourage active transportation and access to green spaces. Cities like Copenhagen and Amsterdam, which prioritize cycling, walking, and clean air, fostering daily physical activity, and Vienna, which integrates affordable housing with parks and efficient public transit, demonstrate how health-oriented built environments can effectively reduce CV and chronic disease risks. While no evaluations of its effects on CVD risk have yet been conducted, benefits are expected from higher

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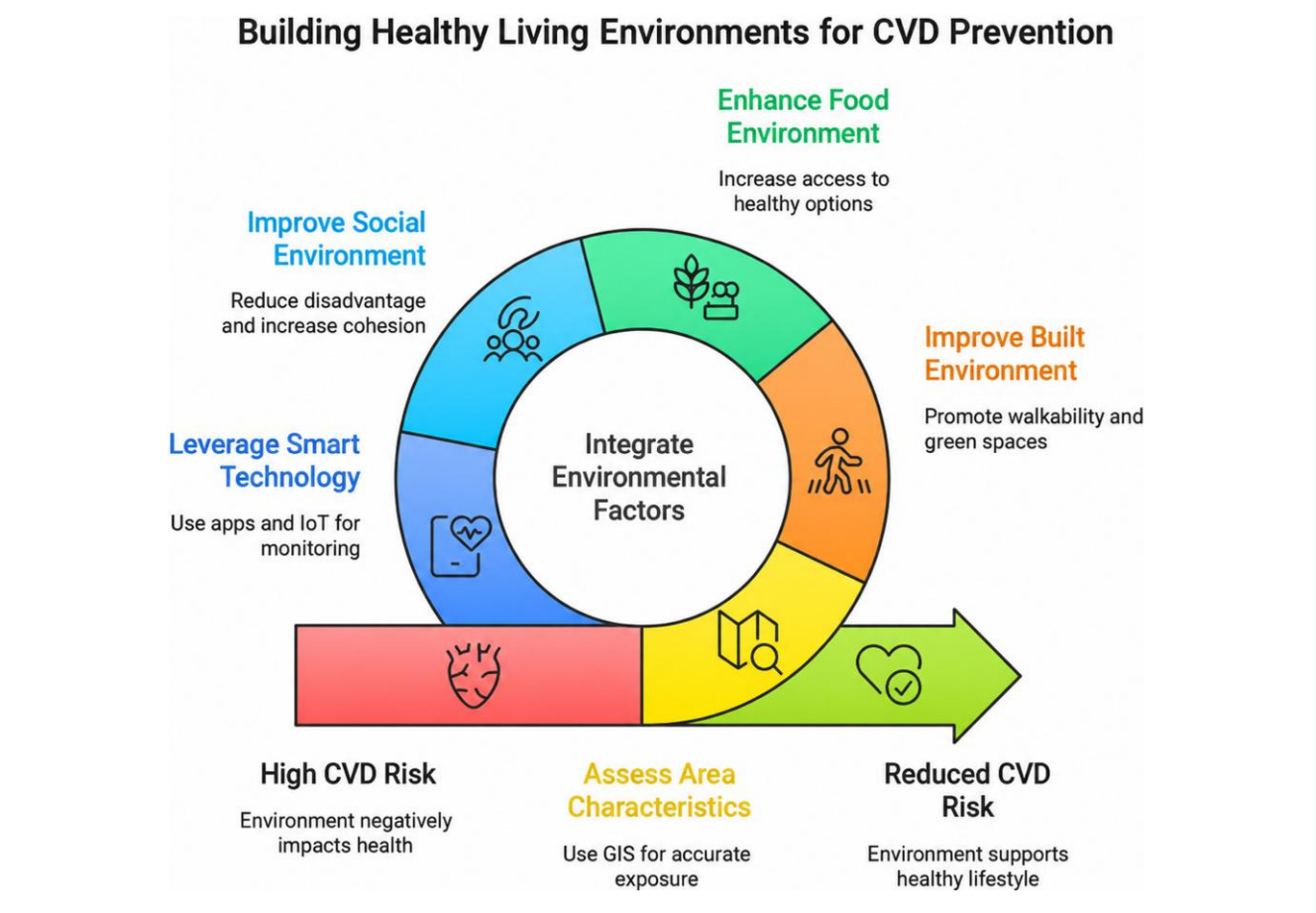


Figure 1 Conceptual framework illustrating the integration of environmental determinants of health to reduce cardiovascular disease risk. The framework highlights the roles of the food environment, built environment, social environment, and smart technologies in assessing areas of high cardiovascular disease risk and supporting healthier urban environments.

levels of physical activity.[91] Previous studies in creating built environments that promote physical activity, reduce pollution, and lower stress have been associated with reduced burden of CVD. From a CV health perspective, *Superblocks* support higher levels of physical activity, lower exposure to pollutants, and reduced stress all contributing to improve metabolic and CV outcomes. Redesigning cities with green spaces, safe mobility, limiting food-deserts, and social connectivity addresses key social and environmental determinants of health, supporting healthier lifestyles and reducing CV risk across populations.[42,92–94]

Knowledge gaps

Despite growing recognition of the role of environmental determinants in CV health, important knowledge gaps remain. Evidence on the long-term effectiveness, scalability, and equity impacts of multilevel interventions across European countries is limited, while harmonized indicators for cross-country evaluation are lacking. Furthermore, environmental exposures are rarely integrated into healthcare systems and routine CV risk assessment, and the potential of geospatial, digital health, and electronic health record data for precision prevention remains underexplored. Additional research is needed to evaluate context-specific policies, climate-related health interventions, and intersectoral strategies that can effectively reduce CVD burden and health inequalities across Europe.

Conclusions; barriers, gaps, and opportunities

CVD prevention has evolved from focusing primarily on individual risk factors to recognizing the influence of environmental, social, and technological contexts on health behaviours (*Graphical abstract*). This review highlights the critical role of the environment, including built and living, physicochemical, food, and social domains, in shaping physical activity, diet, stress exposure, and access to preventive resources, with important implications for population CV health.

Important barriers to translating this evidence into effective prevention strategies include socioeconomic inequalities, limited integration of environmental determinants into healthcare, gaps in digital and health literacy, and insufficient policy co-ordination. Research is further constrained by methodological limitations and an incomplete understanding of causal mechanisms. However, advances in geospatial technologies,

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Figure 2 Systems-based conceptual models of factors influencing cardiovascular disease risk in urban settings. The diagram illustrates the interconnected contributions of the built environment, climate, social determinants, food environment, and digital health technologies for the prevention and management of cardiovascular disease.

mHealth, and AI, alongside integrated urban planning and public health policies, offer promising opportunities to support personalized prevention and create heart-healthy environments.

Recently, ESC has proposed that the exposome framework can act as a conceptual tool to understand the cumulative lifetime impact of environmental hazards on CV health; while special attention should be given to vulnerable populations, including children, the elderly, socioeconomically disadvantaged groups, and patients with pre-existing CVD.[4] Although environmental risk factors generally have smaller effect sizes than traditional CV risk factors, their widespread population exposure confers substantial public health impact. Consequently, effective CVD prevention requires addressing upstream environmental determinants alongside individual risk factors. This can be supported through a *One Health* approach, greater public awareness, environmental health education, and nature-based solutions such as urban greening and blue spaces, which improve air quality, reduce noise and heat exposure, promote physical activity, and alleviate stress. Co-ordinated efforts across research, healthcare, technology, and policy are essential to reduce CV burden and promote equitable and sustainable CV health (*Figure 2*).

Acknowledgements

This manuscript was illustrated with the assistance of AI tools, such as ChatGPT 5 (OpenAI, San Francisco, CA, USA), Gemini (Google,

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Palo Alto, CA, USA), and Napkin AI (Napkin AI, Palo Alto, CA, USA), in keeping with established best practices (G.B.-Z. ChatGPT for Medical Research; Torino: Minerva Medica; 2024). The final content has been thoroughly revised, edited, and approved by the authors. The authors take full responsibility for the integrity and accuracy of the work and retain full credit for all intellectual contributions. Compliance with ethical standards and guidelines for the use of AI in research has been ensured.

Author contributions

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Funding

No funding required for this work.

Conflict of interest: C.C. has been served as advisory board member for Roche Diagnostics, Boehringer, Medtronic. G.B.-Z. has consulted, lectured and/or served as advisory board member and/or expert witness for Abiomed, Advanced Nanotherapies, Amarin, AstraZeneca, Balmed, Cardionovum, Cepton, Crannmedical, Endocore Lab, Eukon, Guidotti, Innova HTS, Innovheart, Menarini, Microport, Opsens Medical, Otsuka Medical Devices Europe, Recor, Servier, Synthesa, Terumo, and Translumina, outside the present work. E.T. is financially supported by the Dutch Heart Foundation, 03-004-2025-0176.

Data availability

No new data were generated or analysed in support of this research.

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