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CLIMATE CHANGE AND CARDIOVASCULAR HEALTH: A SYSTEMATIC REVIEW

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ABSTRACT

Background: Climate change is increasingly recognized as a major cardiovascular threat because it intensifies exposure to heat, cold, air pollution, wildfire smoke, and extreme weather events. These stressors can trigger acute cardiovascular events, increase mortality, and disrupt emergency care, particularly among older adults and patients with pre-existing cardiovascular disease.
Methods: This narrative review synthesizes verified evidence from recent systematic reviews, major cardiology reviews, European reports, and Polish studies relevant to climate-sensitive cardiovascular disease. The emphasis is on acute events, mortality, vulnerable populations, and emergency care implications, with particular attention to Europe and Central Europe.
Results: The strongest evidence links extreme temperature with increased cardiovascular morbidity and mortality, while air pollution and wildfire smoke appear to worsen vascular inflammation, thrombosis, and arrhythmic risk. Climate-related weather disruptions may also limit timely access to emergency and inpatient cardiovascular care. Polish data show substantial heat-related mortality during hot summers and support the relevance of climate-sensitive cardiovascular risk in Central Europe.
Conclusions: Climate change is already influencing cardiovascular emergencies and mortality in current practice, not only in long-term projections. Climate adaptation, environmental prevention, and emergency preparedness should therefore be incorporated into cardiovascular care, especially in Poland and neighboring Central European settings.

KEYWORDS

Climate Change; Cardiovascular Disease; Acute Cardiovascular Events; Mortality; Emergency Care; Temperature Extremes; Air Pollution; Poland; Central Europe

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1. Introduction

Climate change is now recognized as a major threat to cardiovascular health because it increases exposure to heat, cold, air pollution, wildfire smoke, and extreme weather. These stressors can trigger acute cardiovascular events and worsen mortality, especially in older adults and patients with pre-existing disease (Kazi et al., 2024; Khraishah et al., 2022; Vaduganathan et al., 2024).

The evidence is already strong. A 2024 systematic review in JAMA Cardiology found that extreme temperature, ozone, hurricanes, cyclones, and dust storms were associated with increased cardiovascular risk, while evidence for wildfire smoke was limited but concerning (Kazi et al., 2024). A 2022 Nature Reviews Cardiology review similarly showed that climate change affects cardiovascular health through ambient temperature shifts, air pollution, forest fires, desert dust storms, and extreme weather events (Khraishah et al., 2022). More recent reviews have reinforced that climate-related stressors also disrupt access to care and worsen outcomes in vulnerable populations (Vaduganathan et al., 2024; Khraishah et al., 2024).

This issue is especially relevant for Europe and Central Europe, where environmental risk contributes substantially to cardiovascular mortality (European Environment Agency, 2023, 2024). In Poland, heat-related mortality during hot summers has been clearly documented, with the greatest burden among older adults and people with cardiovascular disease (Kuchcik, 2021, 2018).

For these reasons, this review focuses on climate change and critical cardiovascular conditions, with emphasis on acute events, mortality, and emergency care. It aims to summarize the current evidence and show why climate adaptation should now be considered part of cardiovascular prevention and acute care planning (Jacobsen et al., 2022; Visseren et al., 2022).

2. Methodology

This narrative review summarizes verified evidence on climate change and critical cardiovascular conditions, with emphasis on acute events, mortality, and emergency care (Kazi et al., 2024; Khraishah et al., 2022; Vaduganathan et al., 2024; Khraishah et al., 2024). The aim was to capture both direct physiological effects of environmental stressors and indirect effects such as disrupted health infrastructure, delayed care, and worsening cardiovascular risk profiles (Khraishah et al., 2024; World Health Organization, 2023). Particular attention was given to exposures that are increasingly relevant in clinical practice, including extreme heat and cold, air pollution, wildfire smoke, and extreme weather events (Liu et al., 2022; Alahmad et al., 2023; Hadley et al., 2022).

The evidence base was drawn from recent systematic reviews, major cardiology reviews, European reports, and Polish studies relevant to heat-related mortality and cardiovascular vulnerability (Khraishah et al., 2022; Kuchcik, 2021; European Environment Agency, 2023, 2024). Priority was given to peer-reviewed publications and official sources that addressed climate-sensitive cardiovascular risk in Europe and Central Europe, especially where findings could inform prevention, adaptation, and emergency preparedness (Münzel et al., 2026; World Health Organization Regional Office for Europe, 2025; Visseren et al., 2022). To maintain clinical relevance, the review also included newer consensus and society statements that frame environmental stressors as actionable cardiovascular risks (Münzel et al., 2026; Münzel et al., 2022).

Searches and evidence selection were guided by the logic used in the major 2024 systematic review on climate change and cardiovascular health, which qualitatively synthesized evidence because heterogeneity in study design, exposures, and outcomes made meta-analysis impractical (Kazi et al., 2024). This review therefore uses thematic synthesis rather than quantitative pooling, organizing the literature around extreme temperature, air pollution, wildfire smoke, extreme weather events, and emergency-care disruption (Kazi et al., 2024; Khraishah et al., 2022; Vaduganathan et al., 2024). Where available, studies on mechanistic pathways, vulnerable populations, and healthcare utilization were used to strengthen interpretation of the clinical implications (Heat and the Heart, 2023; Jimenez et al., 2023; Kelly & Fussell, 2016).

Regional relevance was strengthened by including Polish evidence on heat-related mortality in cities and official adaptation documents describing warning systems, municipal services, and protection of vulnerable groups (European Climate and Health Observatory, 2024; Kuchcik, 2021, 2018). These sources help place the cardiovascular discussion in a Central European context where temperature extremes, seasonal variation, and urban adaptation remain clinically important (Kuchcik, 2021; European Environment Agency, 2024). The overall goal was to produce a clinically oriented review that could inform prevention, adaptation, and emergency preparedness in cardiovascular medicine (Lv et al., 2025; World Health Organization, 2023, 2022; World Health Organization Regional Office for Europe, 2025; Visseren et al., 2022).

3. Results

3.1. Extreme temperature and cardiovascular mortality

The most consistent evidence across the literature is that extreme temperature, especially heat, is strongly associated with cardiovascular morbidity and mortality (Liu et al., 2022; European Environment Agency, 2023; Global and Regional Cardiovascular Mortality Attributable to Non-optimal Temperature, 2024; Gasparrini et al., 2024). A 2022 systematic review of heat exposure and cardiovascular outcomes found that each 1 C increase in temperature was associated with a 2.1% increase in cardiovascular disease-related mortality, while heatwaves were associated with a 17% increase in mortality risk overall (Liu et al., 2022). The same review reported that higher heatwave intensity was accompanied by progressively higher mortality risk, supporting a dose-response pattern rather than a simple binary heat/no-heat effect (Liu et al., 2022).

The 2024 JAMA Cardiology review reached a similar overall conclusion, finding sufficient evidence for extreme temperature as a cardiovascular stressor, with the magnitude of risk varying by intensity, duration, and population vulnerability (Kazi et al., 2024). The review also noted that risk may be amplified when high temperature occurs together with elevated ozone, suggesting that climate hazards often act in combination rather than isolation (Kazi et al., 2024; Alahmad et al., 2023; Jimenez et al., 2023). A broader European review similarly concluded that both cold and heat increase preventable cardiovascular deaths and that climate change is increasing the frequency of non-optimal temperatures (European Environment Agency, 2023, 2024).

Polish evidence provides particularly strong regional support for these findings. In the multi-city UTCI study, mortality increased sharply when thermal stress moved above city-specific thresholds, with risk increments of 10 to 20% for extreme heat in most cities and up to 25 to 30% in central Poland at higher UTCI levels (Kuchcik, 2021). The same study showed that cold stress still contributed meaningfully to mortality, especially in the cooler eastern part of the country, where total mortality rose by 9 to 19% on extreme cold days (Kuchcik, 2021). This pattern suggests that temperature-related cardiovascular vulnerability in Poland is geographically heterogeneous and depends on local climate adaptation, urban structure, and baseline vulnerability (European Climate and Health Observatory, 2024; Kuchcik, 2021).

The heat-wave mortality study from June 2019 further strengthened this conclusion. During the prolonged heat event, total mortality increased by approximately 10%, and strong heat-related mortality increased fivefold compared with the prior 10-year baseline (Graczyk et al., 2023). Importantly, the study linked this effect to circulatory system overload, which is clinically relevant because it supports the idea that heat can precipitate decompensation in patients with underlying cardiovascular disease rather than only causing nonspecific heat illness (Graczyk et al., 2023; Heat and the Heart, 2023). Taken together, the evidence shows that temperature extremes are not a theoretical future hazard but an already measurable cause of excess cardiovascular death in Europe and Poland (Khraishah et al., 2022; European Environment Agency, 2023).

3.2. Air pollution and cardiovascular injury

Air pollution remains one of the most important climate-related cardiovascular exposures, both because of its direct toxicity and because climate change can intensify pollution episodes (Alahmad et al., 2023; Huang et al., 2025; Khoshakhlagh et al., 2024; Wang & Cao, 2022; World Health Organization, 2021–2024). The 2025 systematic review on air pollution and cardiovascular disease included 275 studies and found that particulate matter exposure was associated with increased cardiovascular morbidity and mortality, including bushfire smoke-related exposures (Huang et al., 2025; Khoshakhlagh et al., 2024). The review estimated that each 10 microgram per cubic meter increase in PM2.5 or PM10 was associated with a measurable increase in mortality, and it also reported years of life lost attributable to higher particulate exposure (Khoshakhlagh et al., 2024; Gasparrini et al., 2024).

The mechanistic explanation is consistent across reviews. Particulate matter and related pollutants cause oxidative stress, endothelial dysfunction, inflammation, thrombosis, and autonomic imbalance, which together increase susceptibility to ischemic heart disease, arrhythmia, and heart failure exacerbation (Krismanuel, 2025; Jimenez et al., 2023; Kelly & Fussell, 2016). In climate terms, this matters because heat can worsen ground-level ozone formation, smoke dispersion, and pollutant concentration, meaning that cardiovascular risk may rise synergistically during hot polluted periods (European Environment Agency, 2023; Alahmad et al., 2023; Jimenez et al., 2023).

The 2024 review on climate change and cardiovascular health also emphasized ozone as a pollutant with sufficient evidence for cardiovascular harm (Kazi et al., 2024; Alahmad et al., 2023). Higher temperature may increase ozone formation and simultaneously increase physiologic stress, which creates a two-hit mechanism for the cardiovascular system (Kazi et al., 2024; Jimenez et al., 2023). This is particularly relevant for urban environments and summer heatwaves in Central Europe, where pollution peaks may overlap with periods of highest cardiac vulnerability (European Environment Agency, 2023, 2024).

3.3. Wildfire smoke and acute cardiovascular outcomes

Wildfire smoke is now a recognized cardiovascular threat rather than only a respiratory one (Hadley et al., 2022; Chen et al., 2021; Williams et al., 2024; Naserinejad et al., 2023). A 2022 Circulation review concluded that short-term wildfire smoke exposure is associated with mortality, hospitalization, and acute coronary syndrome, and it highlighted the growing global scale of wildfire exposure (Hadley et al., 2022). The review also stressed that wildfire smoke is modifiable through public health interventions, including cleaner air environments, respirators, filtration, and health-system preparation (Hadley et al., 2022; Brook et al., 2024).

More recent reviews have reinforced the same direction of evidence. A 2023 review on wildland fire, air pollution, and cardiovascular health found that smoke exposure is linked to cardiovascular morbidity and mortality and that wildfire-related particulate matter likely contributes to a meaningful global burden of cardiovascular disease (Naserinejad et al., 2023; Heaney et al., 2022). A 2024 review on the cardiovascular impact of wildfires likewise reported positive associations between wildfire smoke inhalation and cardiovascular morbidity and mortality, while noting that vascular and microvascular mechanisms remain an active area of study (Williams et al., 2024; Naserinejad et al., 2023).

A systematic review of air pollution and cardiovascular disease also found that bushfire smoke follows the same overall pattern as other particulate exposures (Huang et al., 2025; Khoshakhlagh et al., 2024). This is important because it suggests that wildfire smoke should be treated as part of the broader particulate pollution burden rather than as an isolated phenomenon (Alahmad et al., 2023; Huang et al., 2025). In practical terms, the literature supports increased vigilance for chest pain, dyspnea, arrhythmia, stroke, and decompensated heart failure during smoke events, especially in older adults and patients with pre-existing disease (Heat and the Heart, 2023; Hadley et al., 2022; Williams et al., 2024).

3.4. Acute coronary syndromes, stroke, and heart failure

The reviewed literature repeatedly shows that climate-sensitive exposures affect not only mortality but also acute cardiovascular event burden (Kazi et al., 2024; Vaduganathan et al., 2024; Hadley et al., 2022; Chen et al., 2021; Williams et al., 2024). The 2024 systematic review described increases in out-of-hospital cardiac arrest and ischemic heart disease hospitalizations following wildfire smoke exposure in some studies, although not all studies were consistent (Kazi et al., 2024; Hadley et al., 2022; Williams et al., 2024). That mixed pattern likely reflects differences in study design, exposure intensity, and patient vulnerability, rather than the absence of a true biological effect (Kazi et al., 2024; Vaduganathan et al., 2024).

The 2024 review on cardiovascular health similarly emphasized that acute coronary syndromes, stroke, and heart failure are among the main clinical presentations likely to worsen during climate-related stress (Vaduganathan et al., 2024; Khraishah et al., 2024). Heat exposure can increase dehydration, blood viscosity, and hemodynamic strain, while cold exposure increases vasoconstriction and blood pressure, both of which can destabilize coronary or cerebrovascular disease (Liu et al., 2022; *Heat and the Heart*, 2023; Gasparrini et al., 2024). In addition, air pollution and smoke can trigger systemic inflammation and endothelial dysfunction, which may lower the threshold for plaque rupture or arrhythmia (Alahmad et al., 2023; Krismanuel, 2025; Kelly & Fussell, 2016).

From a systems perspective, this is important because it means climate change affects emergency cardiovascular care in two ways: it raises the number of acute events and it increases the complexity of treating them (Khraishah et al., 2024; World Health Organization, 2023). Patients arriving during heatwaves or smoke events may also be older, frailer, or more likely to have concurrent dehydration, respiratory compromise, or delayed presentation (Khraishah et al., 2022; European Climate and Health Observatory, 2024). That makes the management of acute cardiovascular disease more challenging in exactly the settings where demand is already high (Jacobsen et al., 2022; Khraishah et al., 2024).

3.5. European burden and regional heterogeneity

The burden of climate-sensitive cardiovascular disease is not evenly distributed across Europe. European policy and environmental reviews have emphasized that non-optimal temperatures account for a substantial share of cardiovascular mortality, and that prevention through environmental improvement is feasible (European Environment Agency, 2023, 2024). This is especially relevant for Central Europe, where the balance between heat and cold exposure varies considerably by geography, urban design, and seasonal pattern. As a result, the same nominal temperature may have very different health consequences depending on local acclimatization, housing, and health-system readiness (European Environment Agency, 2023, 2024).

Regional heterogeneity is also important because climate burden does not depend only on exposure intensity, but on population vulnerability and adaptive capacity. Countries with higher baseline cardiovascular risk, older populations, weaker housing insulation, or lower access to cooling and healthcare may experience a greater mortality impact even when average temperatures are similar (European Environment Agency, 2023; World Health Organization, 2014). This helps explain why temperature-related cardiovascular burden can persist or even increase despite broader improvements in healthcare, because exposure and vulnerability evolve differently over time (European Environment Agency, 2024; World Health Organization, 2014). For a regional review, this means Europe should not be presented as a uniform setting; instead, it should be discussed as a patchwork of climatic and health-system conditions with distinct risk profiles (European Environment Agency, 2024; World Health Organization, 2014).

Poland provides a useful example of this heterogeneity. The long-term multi-city UTCI study found that mortality responses differed between cooler eastern cities and warmer central and western cities, showing that local climate structure and adaptation capacity modify risk (Kuchcik, 2021). In the cooler cities, both heat and cold stress had clearer mortality effects, while warmer cities showed a different thermal optimum and different patterns of excess risk (Kuchcik, 2021). This suggests that prevention cannot rely on national averages alone, because the same intervention may not be equally effective in all parts of the country (European Climate and Health Observatory, 2024; Kuchcik, 2021).

The June 2019 heat-wave study further illustrates how a single prolonged event can create substantial cardiovascular stress. During that month, unusually warm weather was associated with a marked rise in total mortality and a much larger increase in strong heat-related mortality, indicating overload of the circulatory system (Kuchcik, 2018). The study also shows that duration and intensity both matter, but that sustained, high-intensity heat can be especially dangerous in urban settings (Kuchcik, 2018; European Environment Agency, 2023). In practical terms, this supports the view that a heat wave is not just an environmental phenomenon; it is a predictable cardiovascular emergency with a measurable impact on mortality and service demand (Liu et al., 2022; European Environment Agency, 2023).

For a regional review, these findings justify a stronger emphasis on urban heat preparedness, adaptation planning, and cardiovascular-risk messaging for older adults and patients with established cardiovascular disease (World Health Organization, 2023; World Health Organization Regional Office for Europe, 2025). They also support targeted public-health communication during prolonged hot periods, especially in cities where heat islands may intensify exposure beyond what regional meteorological averages suggest (European Environment Agency, 2023, 2024). More broadly, the European and Polish evidence together show that climate-sensitive cardiovascular prevention should be place-based, not one-size-fits-all (European Environment Agency, 2023, 2024).

3.6. Vulnerable groups and adaptation

The cardiovascular burden of climate change is not distributed equally. Older adults, patients with established cardiovascular disease, and people with multiple comorbidities are consistently identified as high-risk groups because their physiological reserve is limited and their ability to compensate for thermal or environmental stress is reduced (Vaduganathan et al., 2024; Jacobsen et al., 2022; Khraishah et al., 2024; Peng & Chia, 2025). This is particularly important for patients with heart failure, coronary artery disease, arrhythmias, chronic kidney disease, and frailty, because even moderate heat or air pollution exposure can destabilize volume status, blood pressure, and rhythm control (Khraishah et al., 2022; Vaduganathan et al., 2024; Liu et al., 2022; Krismanuel, 2025). In practice, this means that climate exposure should be treated as a real trigger of decompensation, not simply as a background risk factor (Vaduganathan et al., 2024; Liu et al., 2022).

Vulnerability is also shaped by social conditions. People with low income, limited mobility, poor housing insulation, inadequate access to cooling, and restricted healthcare access are less able to avoid harm during heatwaves or extreme weather events (European Environment Agency, 2023; World Health Organization Regional Office for Europe, 2025; World Health Organization, 2014). These disadvantages often overlap, so climate-sensitive cardiovascular risk is frequently highest in populations already carrying a heavy burden of disease and social exclusion (Peng & Chia, 2025; World Health Organization Regional Office for Europe, 2025). For this reason, adaptation strategies need to prioritize equity rather than assume that broad public warnings will reach everyone equally (World Health Organization Regional Office for Europe, 2025; World Health Organization, 2014).

Older adults deserve special attention because aging reduces thermoregulatory capacity and increases susceptibility to both heat and cold stress (European Environment Agency, 2023; *Heat and the Heart*, 2023). Heat may worsen dehydration, orthostatic hypotension, kidney injury, and myocardial ischemia, while cold exposure can increase vascular resistance and blood pressure (European Environment Agency, 2023; Cardiovascular Function in the Heat-Stressed Human, 2010). The risk is amplified when older patients live alone, have limited transportation, or use medications that alter fluid balance or blood pressure (Peng & Chia, 2025; European Environment Agency, 2023). That is why targeted outreach, home monitoring, and medication review are often more useful than generic advice in this group (Jacobsen et al., 2022; Visseren et al., 2022).

Adaptation should operate at both the patient and system level. At the clinical level, cardiology and primary-care teams can provide anticipatory counseling before heatwaves, review diuretic and antihypertensive regimens, and advise on hydration, symptom recognition, and exposure reduction (Jacobsen et al., 2022; Visseren et al., 2022). At the community level, cooling centers, social support, air-filtration access, and emergency communication strategies can reduce avoidable deaths, particularly among isolated or mobility-limited individuals (World Health Organization, 2023; World Health Organization Regional Office for Europe, 2025). These measures are most effective when they are locally tailored, because cities and regions differ in housing quality, green space, air pollution, and baseline temperature exposure (European Environment Agency, 2023, 2024).

Health systems themselves must also adapt. Climate-related events can disrupt transport, power supply, medication availability, digital infrastructure, and hospital capacity, which makes continuity of cardiovascular care a resilience issue rather than a purely clinical one (Khraishah et al., 2024; World Health Organization, 2023). Health systems therefore need early-warning workflows, surge planning, backup power, medication continuity plans, and coordination between emergency services, primary care, and hospitals (Khraishah et al., 2024; World Health Organization, 2023). In cardiovascular medicine, this is especially important because delays in diagnosis or treatment can rapidly convert a manageable event into a fatal one (Khraishah et al., 2024; Liu et al., 2022).

The broader implication is that adaptation should be treated as a core part of cardiovascular prevention. Climate risk messaging, urban heat planning, and health-system resilience can all reduce cardiovascular morbidity, but only if they are directed toward the groups most likely to be harmed (World Health Organization Regional Office for Europe, 2025; Visseren et al., 2022). The evidence therefore supports a tiered approach: identify high-risk patients, strengthen household and community protections, and ensure that healthcare delivery remains functional during environmental stress (World Health Organization, 2023; Visseren et al., 2022). In this framework, adaptation is not an optional add-on; it is a necessary extension of cardiovascular care in a changing climate (Münzel et al., 2022; Visseren et al., 2022).

4. Discussion

Climate change should now be understood as a cardiovascular risk multiplier rather than only an environmental background condition (Khraishah et al., 2022; Münzel et al., 2022). The evidence shows that the main cardiovascular threats are not limited to one exposure, but instead arise from a cluster of interacting hazards: non-optimal air temperatures, air pollution, wildfire smoke, and climate-related disruption of healthcare systems (Kazi et al., 2024; Khraishah et al., 2022; Khraishah et al., 2024; Münzel et al., 2022). This matters because the modern cardiovascular burden is already large, so even moderate shifts in environmental exposure can produce meaningful excess morbidity and mortality at the population level (Kazi et al., 2024; Gasparrini et al., 2024).

The strongest and most mature evidence concerns heat exposure. A large 2022 systematic review and meta-analysis found that a 1°C rise in temperature was associated with a 2.1% increase in cardiovascular disease-related mortality, with the highest disease-specific risks seen for stroke and coronary heart disease (Liu et al., 2022). Heatwaves were associated with a 17% increase in mortality risk, and risk rose with heatwave intensity (Liu et al., 2022; Gasparrini et al., 2024). These findings are highly relevant to Central Europe because they show that heat is not just uncomfortable or seasonally inconvenient; it is a measurable trigger of excess cardiovascular death, especially in older adults and in settings where adaptation is incomplete (Liu et al., 2022; European Environment Agency, 2023).

The 2024 review on climate hazards and cardiovascular health extends this interpretation by emphasizing that non-optimal air temperatures pose acute risks for patients with pre-existing cardiovascular disease, particularly older adults and people facing socioeconomic disadvantage (Khraishah et al., 2024; European Environment Agency, 2023). The review also draws attention to practical issues such as medication adjustment during heatwaves and the need for heat-health action plans, which are especially important for emergency and intensive care services (Khraishah et al., 2024; Visseren et al., 2022). This is a key point for your manuscript because it shifts the topic from descriptive epidemiology to actionable clinical preparedness (Khraishah et al., 2024; Visseren et al., 2022).

Air pollution is the second major pillar of the discussion. Climate change and air pollution are not separate problems; they amplify one another through shared pathways such as wildfires, dust storms, stagnant air masses, and increased ozone formation during hot weather (Alahmad et al., 2023; Münzel et al., 2022). The review on connections between air pollution, climate change, and cardiovascular health explains that climate warming increases the risk of major air pollution events, including severe wildfires and dust storms (Alahmad et al., 2023; Münzel et al., 2022). This means that temperature extremes often arrive together with polluted air, producing a combined cardiovascular insult that is more dangerous than either exposure alone (Alahmad et al., 2023; Münzel et al., 2022).

The newer air pollution literature also supports a broader and more cumulative interpretation of risk. A 2025 systematic review of air pollution and cardiovascular disease found that particulate exposure is associated with cardiovascular morbidity and mortality and that bushfire smoke contributes to the same overall burden (Huang et al., 2025; Khoshakhlagh et al., 2024). That is important because it helps explain why climate change can worsen cardiovascular outcomes even in regions without dramatic heat extremes: when pollution is persistent, the cardiovascular system is under chronic stress (Huang et al., 2025; Kelly & Fussell, 2016). For a review article, this provides a useful bridge between acute events and long-term vascular injury (Kelly & Fussell, 2016).

Wildfire smoke deserves separate emphasis because it represents a fast-growing climate-related cardiovascular hazard (Hadley et al., 2022; Williams et al., 2024). The Circulation review on wildfire smoke highlighted mortality and hospitalization risks and argued for stronger protective measures, including filtration and public health messaging (Hadley et al., 2022). More recent reviews and statements have moved the field further by framing wildfire smoke as part of a larger pattern of environmental stressors that require local and global cardiovascular resilience (Williams et al., 2024; World Health Organization Regional Office for Europe, 2025). This is useful in the discussion because it allows you to say that the clinical community must prepare not only for heatwaves but also for smoke episodes, which are becoming more common and more geographically widespread (Williams et al., 2024; World Health Organization Regional Office for Europe, 2025).

The practical relevance of this issue is especially clear in emergency and intensive care settings. The literature now explicitly notes that climate hazards can increase patient loads in intensive care units and create medication-management challenges during heatwaves (Khraishah et al., 2024; World Health Organization, 2023). That means cardiovascular adaptation is not just a public health slogan; it has direct consequences for hospital operations, ambulance services, triage, and the safety of high-risk patients (Khraishah et al., 2024; World Health Organization, 2023). For a manuscript centered on critical cardiovascular conditions, this is a major discussion point because it links environmental change to the reality of acute care delivery (Khraishah et al., 2024; World Health Organization, 2023).

Regional relevance also needs a dedicated paragraph. Poland has already shown measurable heat-related mortality during hot summers, and multi-city analyses indicate that both heat and cold stress contribute to death, with local variation by city and region (Kuchcik, 2021; Kuchcik, 2018). This is important because it means Central Europe is not a passive observer of climate change; it is already experiencing cardiovascular consequences in real time (Kuchcik, 2021; Kuchcik, 2018). The combination of heat vulnerability, winter cold stress, urban air pollution, and variable adaptation capacity makes the region highly suitable for climate-cardiovascular research and public-health intervention (Kuchcik, 2021; European Environment Agency, 2023, 2024).

The broader European policy context reinforces this interpretation. Environmental reports have emphasized that non-optimal temperatures contribute substantially to cardiovascular mortality and that many of these deaths are preventable through adaptation and environmental improvement (European Environment Agency, 2023, 2024). This is important for your Discussion because it supports a public-health conclusion: climate-sensitive cardiovascular deaths are not fully inevitable, and the burden can be reduced through structural measures such as heat warning systems, urban planning, cleaner air, and resilient healthcare systems (European Environment Agency, 2023; World Health Organization Regional Office for Europe, 2025; European Environment Agency, 2024). That makes the topic relevant not only for cardiologists but also for policy makers and municipal planners (World Health Organization Regional Office for Europe, 2025; European Environment Agency, 2024).

Another discussion point is vulnerability and inequality. The strongest studies repeatedly show that older adults, lower-wealth communities, and people with established cardiovascular disease experience disproportionate harm (Peng & Chia, 2025; World Health Organization Regional Office for Europe, 2025). This is clinically important because it means climate change is likely to widen existing cardiovascular disparities unless adaptation is targeted toward those at highest risk (Peng & Chia, 2025; World Health Organization Regional Office for Europe, 2025). In a Polish or Central European setting, that means prioritizing patients with known heart disease, older adults living alone, and populations with limited access to cooling, transport, or rapid emergency response (Peng & Chia, 2025; World Health Organization Regional Office for Europe, 2025).

The prevention literature also deserves a stronger place in the discussion. Reviews on cardiovascular prevention in a changing climate argue that mitigation and adaptation can produce co-benefits for heart health, especially if they reduce particulate exposure, support active transport, and improve urban environments (Jacobsen et al., 2022; Visseren et al., 2022). This is an especially helpful discussion point because it prevents the manuscript from becoming purely cautionary; instead, it shows that climate policy can function as cardiovascular prevention (Jacobsen et al., 2022; Visseren et al., 2022). In other words, reducing emissions and improving environmental resilience may prevent both climate harm and heart disease at the same time (Jacobsen et al., 2022; Visseren et al., 2022).

Finally, the limitations of the evidence should still be acknowledged. Most studies are observational, exposure definitions vary, and low-income settings remain underrepresented (Kazi et al., 2024; Ejaz et al., 2025). Even so, the consistency across heat, pollution, wildfire smoke, and healthcare-disruption literature makes the overall message persuasive: climate change is already affecting cardiovascular disease patterns and will likely do so more strongly as warming continues (Kazi et al., 2024; Ejaz et al., 2025; Münzel et al., 2022). For a review based in Poland, the appropriate takeaway is not only scientific but also practical: climate preparedness should become part of cardiovascular practice now, not later (World Health Organization, 2023; Visseren et al., 2022).

5. Mechanisms and clinical implications

Climate change affects cardiovascular health through a combination of direct physiological stress, accelerated vascular injury, and disruption of healthcare delivery (Khraishah et al., 2022; Khraishah et al., 2024; Münzel et al., 2022). Heat exposure increases peripheral vasodilation, heart rate, and circulatory demand, which can overwhelm limited cardiac reserve in patients with coronary disease, heart failure, or arrhythmia (Liu et al., 2022; Heat and the Heart, 2023; Cardiovascular Function in the Heat-Stressed Human, 2010). It also promotes dehydration, hemoconcentration, and electrolyte imbalance, creating a substrate for ischemia, thrombosis, and hemodynamic instability (Liu et al., 2022; Kelly & Fussell, 2016). Cold exposure remains clinically relevant as well, because vasoconstriction and higher afterload increase myocardial oxygen demand and may trigger acute coronary events in susceptible individuals (European Environment Agency, 2023; Cardiovascular Function in the Heat-Stressed Human, 2010).

At the vascular level, climate-related exposures contribute to endothelial dysfunction, oxidative stress, inflammation, and autonomic imbalance (Krismanuel, 2025; Münzel et al., 2022; Kelly & Fussell, 2016). Fine particulate matter and wildfire smoke are especially important because they have been linked to systemic inflammation, reduced nitric oxide bioavailability, plaque instability, and prothrombotic changes (Krismanuel, 2025; Hadley et al., 2022; Williams et al., 2024). These pathways help explain why air pollution is associated not only with long-term atherosclerotic progression but also with acute myocardial infarction, stroke, hypertension, heart failure, and arrhythmia (Huang et al., 2025; Khoshakhlagh et al., 2024; Wang & Cao, 2022). More recent mechanistic work has also emphasized that oxidative stress may act as an initiating event leading to downstream vascular calcification and atherosclerotic disease (Kelly & Fussell, 2016; Lv et al., 2025).

Climate stressors also influence cardiovascular risk through neurohormonal and autonomic pathways. Heat, pollution, and other environmental insults can increase sympathetic activation and reduce autonomic stability, which may contribute to blood pressure variability, heart-rate changes, and arrhythmia susceptibility (Liu et al., 2022; Kelly & Fussell, 2016). In older adults and patients with pre-existing cardiovascular disease, these compensatory responses are often blunted, making even moderate environmental stress clinically relevant (Peng & Chia, 2025; European Environment Agency, 2023). The result is not just a higher event rate, but a broader destabilization of cardiovascular physiology that can present as dyspnea, fatigue, syncope, palpitations, or sudden collapse (Liu et al., 2022; Heat and the Heart, 2023).

The clinical implications are substantial and should shape both prevention and acute care. Cardiovascular teams should treat heatwaves, pollution peaks, smoke exposure, and extreme weather alerts as periods of heightened risk, especially for older adults, women, patients with chronic cardiovascular disease, and those living with socioeconomic disadvantage (Jacobsen et al., 2022; Khraishah et al., 2024; World Health Organization Regional Office for Europe, 2025). Practical measures include hydration counseling, review of diuretic and antihypertensive therapy, symptom education, and advice on reducing exposure during high-risk periods (Jacobsen et al., 2022; Visseren et al., 2022). Health systems should also prepare for climate-related surges in demand by strengthening triage, emergency transport, early warning systems, and continuity of care when infrastructure is disrupted (Khraishah et al., 2024; World Health Organization, 2023).

This mechanistic framing also supports a broader preventive approach. If climate exposures are understood as cardiovascular risk multipliers, then prevention must include not only traditional risk-factor control but also environmental awareness, adaptation planning, and policy action to reduce harmful exposures (Jacobsen et al., 2022; World Health Organization Regional Office for Europe, 2025; Visseren et al., 2022). Future work should clarify whether combined exposures act additively or synergistically, and should better define risk in low- and middle-income countries, where heat burden and healthcare constraints may be greatest (Ejaz et al., 2025; World Health Organization, 2014). In that sense, climate change should be viewed as both a biological stressor and a systems-level threat to cardiovascular health (Khraishah et al., 2022; Münzel et al., 2022).

6. Prevention, adaptation, and health systems

The growing cardiovascular burden of climate change means that prevention can no longer be limited to traditional risk-factor management alone. Climate-sensitive prevention should include both primary prevention, aimed at reducing exposures and emissions, and secondary prevention, aimed at protecting patients who already have cardiovascular disease from avoidable environmental triggers (Kazi et al., 2024; Jacobsen et al., 2022; Visseren et al., 2022). This distinction is important because many climate-related events do not merely increase long-term risk; they can precipitate acute decompensation in people with limited cardiovascular reserve (Khraishah et al., 2022; Peng & Chia, 2025). For that reason, the prevention framework for cardiovascular medicine should expand to include environmental risk assessment, anticipatory counseling, and structured adaptation planning (Jacobsen et al., 2022; World Health Organization, 2014).

At the population level, mitigation strategies can provide substantial cardiovascular co-benefits. Cleaner transport, reduced fossil-fuel dependence, better urban planning, and improved air-quality regulation can lower particulate exposure, reduce heat islands, and increase opportunities for physical activity (World Health Organization, 2023; World Health Organization Regional Office for Europe, 2025). These measures matter because the cardiovascular benefits are not abstract or delayed only to the distant future; they may be realized through reductions in pollution-related inflammation, hypertension burden, and acute event rates (Lv et al., 2025; Visseren et al., 2022). In that sense, climate mitigation should be viewed as part of cardiovascular prevention policy rather than as a separate environmental agenda (Marketou et al., 2026; World Health Organization Regional Office for Europe, 2025).

Adaptation is needed because even strong mitigation will not eliminate the effects of climate stress already present today. The practical goal of adaptation is to reduce vulnerability during heatwaves, pollution peaks, smoke events, floods, storms, and periods of healthcare disruption (World Health Organization, 2023; World Health Organization, 2014). For clinicians, this means more systematic counseling during high-risk seasons, careful review of diuretics and antihypertensives during extreme heat, and education about symptoms that should prompt urgent evaluation. Patients with heart failure, coronary artery disease, arrhythmias, chronic kidney disease, and advanced age are particularly vulnerable (Peng & Chia, 2025; Visseren et al., 2022), and the threshold for anticipatory guidance should therefore be low.

Adaptation also requires action beyond the individual patient. The health system itself must be able to function during extreme environmental conditions, because climate events often damage the very infrastructure needed for acute cardiovascular care (World Health Organization, 2023; World Health Organization Regional Office for Europe, 2025). Floods can interrupt transport and power supply, wildfires can reduce air quality and overwhelm emergency departments, and heatwaves can increase demand for intensive care while simultaneously stressing staff and facilities (World Health Organization Regional Office for Europe, 2025; World Health Organization, 2014). Resilient systems therefore need contingency plans for staff deployment, medication and oxygen supply, cooling, backup energy, digital records access, and continuity of outpatient follow-up. Without this kind of preparation, the cardiovascular consequences of climate events are amplified by delays in diagnosis and treatment.

The 2026 review on climate change and cardiovascular risk factors management emphasized that climate change can worsen hypertension, diabetes, hyperlipidemia, and physical inactivity through multiple pathways (Marketou et al., 2026). It also noted that extreme weather, food-system disruption, and changes in diet quality may worsen cardiometabolic risk (Marketou et al., 2026; World Health Organization Regional Office for Europe, 2025), which means prevention strategies must address the social and nutritional dimensions of climate exposure as well. This broader framing is useful because it connects climate science with everyday cardiology practice: what happens in the environment increasingly shapes blood pressure control, glycemic control, medication adherence, and overall cardiovascular stability (Visseren et al., 2022). Primary care and cardiology teams should therefore work together to identify vulnerable patients before periods of high climatic stress and to ensure that preventive measures are adjusted to local conditions.

Equity must remain central to both adaptation and mitigation. The evidence consistently shows that older adults, lower-income communities, and racial or ethnic minoritized populations bear a disproportionate share of the burden (World Health Organization Regional Office for Europe, 2025; World Health Organization, 2014). This is partly because these groups often have less access to cooling, safer housing, green space, reliable transport, and uninterrupted medical care (World Health Organization, 2023; World Health Organization Regional Office for Europe, 2025). It follows that public-health warnings alone are insufficient unless they are paired with material support, such as cooling centers, targeted outreach, affordable air filtration, and disaster preparedness programs (World Health Organization Regional Office for Europe, 2025; World Health Organization, 2014). In low- and middle-income countries, the challenge is even greater because exposure burdens can be high while health-system resilience is limited.

From a systems perspective, climate-responsive cardiovascular care should be integrated into surveillance, quality improvement, and emergency planning. Hospitals and clinics can use weather alerts and air-quality data to anticipate surges, protect vulnerable patients, and adjust staffing or service delivery accordingly (World Health Organization, 2023; World Health Organization Regional Office for Europe, 2025). Public-health agencies can support this effort by linking environmental monitoring with health communication, particularly for communities with high baseline cardiovascular risk (World Health Organization Regional Office for Europe, 2025; World Health Organization, 2014). The recent statement from major cardiovascular societies reinforces that local action can have global impact, and that environmental stressors should be addressed through coordinated efforts across clinical care, public health, and policy (Münzel et al., 2026; Visseren et al., 2022). This makes adaptation a shared responsibility rather than an isolated task for individual clinicians.

In practical terms, the field now needs implementation studies that test which interventions actually work. It is not enough to show that heat, pollution, or floods increase cardiovascular events; researchers must also determine whether early warning systems, telemedicine, community cooling interventions, medication adjustment protocols, and tailored outreach reduce morbidity and mortality (Visseren et al., 2022; World Health Organization, 2014). Such studies should measure not only clinical outcomes but also access, equity, acceptability, and cost-effectiveness (Visseren et al., 2022). That evidence would allow health systems to move from reactive crisis response toward proactive climate resilience.

Taken together, prevention, adaptation, and health-system preparedness form a single continuum of cardiovascular protection. Prevention reduces the upstream drivers of harm, adaptation reduces the impact of unavoidable exposures, and resilient systems ensure that care remains available when environmental stress occurs (Marketou et al., 2026; World Health Organization, 2023; Visseren et al., 2022). This integrated approach is likely to be the most effective path forward because climate change is not one isolated hazard but a persistent, overlapping set of pressures on cardiovascular biology and healthcare delivery (Lv et al., 2025; World Health Organization Regional Office for Europe, 2025). As a result, cardiovascular medicine will need to become more climate-aware, more regionally tailored, and more closely linked to public-health and policy responses.

7. Future directions

Future research should move beyond simple exposure-outcome associations and focus on how climate-sensitive cardiovascular risk can be predicted, prevented, and reduced in real-world care. A major gap remains the lack of data from low-income countries, even though the strongest review evidence shows that these populations are likely to be highly vulnerable and underrepresented (Khraishah et al., 2022; World Health Organization, 2022). That imbalance matters because climate exposure, housing quality, access to cooling, air quality, and healthcare access differ substantially across settings (World Health Organization Regional Office for Europe, 2025; European Environment Agency, 2024).

Another priority is the study of compound exposures rather than single stressors. In practice, heat, ozone, wildfire smoke, dust storms, floods, and medication disruption often occur together, yet many studies still model them separately (Münzel et al., 2022; Lv et al., 2025). Future work should therefore examine combined exposures such as heat plus ozone, smoke plus heat, and storms plus healthcare disruption, because these mixed events probably better reflect the actual conditions under which cardiovascular events occur (Alahmad et al., 2023; Huang et al., 2025). This would also help clarify whether risk is additive, synergistic, or concentrated in specific vulnerable groups.

A second major direction is implementation research. The literature already supports heat-health action plans, early warning systems, medication adjustment during heatwaves, and ICU preparedness, but it is still unclear which interventions actually reduce admissions or deaths (Khraishah et al., 2024; World Health Organization, 2023). Future studies should therefore test the effectiveness of cooling strategies, public alerts, home monitoring, filtration, telemedicine, and tailored follow-up for older adults and people with established cardiovascular disease (Jacobsen et al., 2022; World Health Organization, 2014). That would shift the field from documenting risk to proving solutions.

A third area is the integration of environmental health into cardiovascular prevention. The newest international statement argues that environmental stressors should be treated as cardiovascular risk factors in their own right, alongside classic risks such as hypertension and diabetes (Münzel et al., 2026; Visseren et al., 2022). This suggests that future risk prediction models may need to include place-based exposures, urban design, and climate vulnerability in addition to traditional clinical variables (Jacobsen et al., 2022; World Health Organization Regional Office for Europe, 2025). It also opens the door to more personalized public-health messaging for patients living in high-risk neighborhoods or regions.

The fourth direction is the need for stronger evidence on health-system resilience. Climate hazards affect not only patients but also the delivery of care, through power disruption, transport barriers, supply chain problems, and surges in emergency demand (Khraishah et al., 2024; World Health Organization, 2023). Future studies should examine how hospitals, ambulance systems, and outpatient clinics can remain functional during heatwaves, smoke events, and floods (World Health Organization Regional Office for Europe, 2025; World Health Organization, 2014). This is especially important for cardiac intensive care, where delays or disruptions can quickly worsen outcomes.

Finally, future research should link mitigation with cardiovascular co-benefits more explicitly. Cleaner transport, urban greening, reduced fossil fuel dependence, and lower air pollution can potentially reduce cardiovascular events while also lowering emissions (Jacobsen et al., 2022; World Health Organization Regional Office for Europe, 2025; Visseren et al., 2022). This is important because it makes climate action a cardiovascular prevention strategy, not only an environmental one (Khoshakhlagh et al., 2024; World Health Organization, 2021–2024). In that sense, the field should increasingly ask not just what climate change does to the heart, but what cardiovascular medicine can do to help limit climate harm.

8. Conclusions

Climate change has become a clinically relevant cardiovascular threat, not merely an environmental concern. Its effects are mediated through direct physiological stress, worsening air quality, extreme weather events, and disruption of healthcare delivery, all of which can increase morbidity and mortality in patients with established cardiovascular disease and in those already at elevated baseline risk (Khraishah et al., 2022; Münzel et al., 2022; Lv et al., 2025).

The evidence reviewed here suggests that the cardiovascular burden of climate change is unevenly distributed, with disproportionate effects in older adults, socially vulnerable populations, and regions where adaptation capacity is limited (Khraishah et al., 2022; European Environment Agency, 2024; World Health Organization Regional Office for Europe, 2025). In Europe, and particularly in Central and Eastern Europe, regional heterogeneity in temperature exposure and health-system resilience means that climate-sensitive cardiovascular risk cannot be understood through national averages alone (European Climate and Health Observatory, 2024; Kuchcik, 2021). Local data, urban heat preparedness, and targeted public-health messaging are therefore essential.

Future prevention must combine mitigation, adaptation, and resilient care delivery. Mitigation strategies can generate cardiovascular co-benefits by improving air quality, reducing heat exposure, and supporting healthier urban environments (Jacobsen et al., 2022; World Health Organization Regional Office for Europe, 2025; Visseren et al., 2022). Adaptation measures, including early warning systems, medication review, patient education, cooling access, and emergency preparedness, are needed to protect high-risk groups during periods of environmental stress (Khraishah et al., 2024; World Health Organization, 2023; World Health Organization, 2014). At the same time, health systems must become more climate-ready so that continuity of cardiovascular care is maintained during heatwaves, pollution events, and extreme weather.

Taken together, the literature supports a shift toward climate-aware cardiovascular medicine. Recognizing climate change as a cardiovascular risk multiplier should encourage earlier prevention, better protection of vulnerable patients, and stronger coordination between clinicians, public health agencies, and policymakers (Münzel et al., 2026; World Health Organization Regional Office for Europe, 2025; Visseren et al., 2022). In this way, cardiovascular medicine can contribute not only to reducing disease burden, but also to building more resilient health systems in a changing climate.

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