British Cardiovascular Society

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Climate Change: An Urgent Threat to Cardiovascular Health

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Take Home Messages

- Climate change is an important and urgent threat to cardiovascular health, and is likely to worsen with potential catastrophic consequences
- A warming climate and an increase in extreme heat events may increase mortality, particularly increasing rates of heart attack, stroke and heart failure
- Air pollution causes many harmful effects to the cardiovascular system and is particularly prevalent in urban environments
- Tackling climate change through policy change, urban planning and personal actions can help to minimise future destruction of the environment
- Dealing with environment associated risks to health will need to form part of future patient education and cardiovascular disease prevention

Introduction

Climate change is predicted to lead to significantly worse global cardiovascular outcomes in years to come, including increases in myocardial infarction (MI), stroke, heart failure and death (1). Climate change is increasingly being viewed as a medical emergency. The current situation has been described as a 'code red' for humanity in recent UN reports, with billions potentially in danger from its effects (2, 3). There has been a widespread call for emergency action within the medical community to limit global temperature rises and avert catastrophe, with a joint statement published last year in a number of leading journals (4).

Climate change causes many potential threats to human health, including changes in rainfall, flooding, disruptions to food supply and destruction of ecosystems. This article will focus on global warming, air pollution and the urban environment, and their impacts on cardiovascular health.

Global Warming

Global temperature has risen by 1°C since the pre-industrial era (5) and there have been accompanying increases in temperature variability and the frequency of extreme heat events.

Excessive heat adversely affects the cardiovascular system. In response to increased core body temperature, thermoregulation mechanisms result in increased sympathetic activity accompanied by sweating, vasodilation and circulatory shifts. To facilitate this, respiratory rate, heart rate and cardiac output increase, which can place additional strain on the cardiovascular system (6). Thermal stress induces an acute phase response stimulating inflammatory pathways, alters coagulation and causes dehydration. These effects can increase risk of plaque rupture in those with atherosclerotic disease (1, 7). Heart failure patients may have reduced capacity to withstand the additional demand triggered by excess heat (7) and be at risk of acute hospitalisation. It is plausible that repeated long-term excess heat exposure could potentially have further detrimental effects to cardiac health beyond immediate acute events.

The effect of temperature varies between regions and is influenced by the local environment and population adaptation to the local climate, of which part is behavioural. Therefore, the optimal and hazardous temperature ranges vary by region (8). However, the rapid pace of global warming is overstretching the capacity to adapt.

Excessive cold and hot temperatures can both be harmful with a V-shaped relationship between temperature and health (1). The risk from increased heat exposure caused by a warming climate will likely outweigh reduction in cold exposure risks (7). A population-based study in Germany found that heat-related MI risk increased over time from 1987 to 2014, with a significant effect of temperatures greater than 18°C on MI risk observed between 2001-2014 (9). Increased susceptibility to heat-related MI risk was greater in patients with diabetes and hyperlipidaemia, suggesting that the growing number of patients with such comorbidities are even more vulnerable.

Extreme heat events are particularly dangerous. Exposure to these events is continually increasing. The average person over 65 years old experienced 4.1 more days of yearly heatwave exposure in 2020 compared to the 1986 – 2005 average (10). The 2003 summer heatwave in Europe is estimated to have caused more than 70 000 excess deaths (11) and other heat waves, such as the recent Northwest heat wave in North America have also led to significant excess mortality (12).

Air Pollution

Air pollution drives climate change and global warming. It is also itself classified as one of the top five risk factors for global mortality (13). It results in 8.8 million excess deaths per year according to estimates (14) and is one of the 'biggest environmental threats to human health' alongside climate change (15). Over half of deaths linked to air pollution are due to cardiovascular disease, with ischaemic heart disease and stroke being the most common causes (14, 15, 16, 17).

Human activity produces a complex mixture of harmful gaseous pollutants, liquids and particles. These include carbon monoxide, sulphur dioxide, nitrogen oxides, ozone, lead and heavy metals, benzenes and particulate matter amongst thousands of others (16, 18). Common sources of air pollution include transport emissions, industrial fossil fuel use, agriculture and domestic energy use. The increase in wildfires caused by climate change also contributes to increased particulate matter in the environment. The relationship between exposure to air pollution and cardiovascular disease is "supralinear" (16). Even low concentrations of ambient pollutants confer an added risk of disease and mortality. Additionally, the harmful effects of increased ambient temperature may be further multiplied in areas with high concentrations of air pollution (19).

Recently updated World Health Organisation (WHO) guidelines on air quality offer the opportunity to slow climate change and protect health (15). It is estimated that nearly 80% of global deaths related to fine particulate matter could be avoided if current pollution levels were reduced in line with this guidance (15). However, many countries continue to have ambient air pollution levels well above these recommended standards. In 2019, over 90% of the global population lived in areas in which particulate matter concentrations exceeded the 2005 WHO standard (15). Though some countries such as Canada and Australia have set strict targets to reduce particulate matter, current targets in Europe fall short of meeting the WHO standards and in places are more than double the WHO recommended levels (20, 21).

Particulate matter is of specific concern in cardiovascular disease and has been extensively studied. These vary in size and are often described according to their maximum diameter. For example PM_{10} refers to particles with a diameter <10 μm and $PM_{0.1}$ to those <100nm (also

referred to as nanoparticles). Nanoparticles are not adequately measured by current monitoring but are copiously produced by road traffic vehicles and may be particularly harmful (16).

Air pollution may cause increased oxidative stress, inflammation and affect cell signalling (16). The neuroendocrine system may be affected through an increased stress response, with consequent detrimental effects on autonomic balance including reduced heart rate variability and increased blood pressure. Nanoparticles can cross the alveolar-capillary membrane and may directly enter the circulation via the lungs. These can then accumulate in the vasculature, and deposit at sites of injury and inflammation (22, 23). In a study of patients undergoing carotid endarterectomy after recent stroke, gold nanoparticles inhaled 24 hours prior to surgery were detected in the circulation and within excised carotid plaques (22). The effects of air pollution can lead to increased thrombus formation, platelet aggregation, impaired fibrinolysis, endothelial dysfunction and arrhythmia (16).

Many constituents of air pollution such as carbon monoxide, nitrogen dioxide, sulphur dioxide and $PM_{2.5}$ have been shown to increase the risk of myocardial infarction (24). In a study of over 4000 people investigating the effect of residential traffic, coronary artery calcification was increased by 7% by halving the distance between home and the main road (25). Further, in a study of patients undergoing exercise testing, exposure to diluted diesel exhaust fumes caused significantly greater ST-depression and ischaemic burden compared to exposure to filtered air (26). Long-term exposure to particulate matter has also been shown to increase carotid intimal-media thickness measurements (27, 28) and coronary plaque (29).

Exposure to air pollutants may also increase heart failure hospitalisation and death even in the short-term and risk increases with increasing exposure (30). Observational data also suggests that increased particulate matter exposure may increase the risk of atrial fibrillation (31) and out-of-hospital cardiac arrest (32). Furthermore, air pollution exposure worsens cardiovascular risk factors, such as diabetes (33), hypertension (34) and obesity (35), which further exacerbates the risk of cardiovascular disease.

The Urban Environment

Over half the world's population live in cities and urban areas, with this figure projected to reach 75% by the year 2050 (36, 37). Cities consume more than two-thirds of global energy use and produce over 70% of global greenhouse gas emissions (37, 38). Urbanisation has many significant economic and societal benefits, and may improve access to healthcare, however there are also risks involved. Inhabitants may be particularly susceptible to climate-associated health risks (10). Given such a large proportion of the world's growing population are affected, it is critical to address the specific risks posed by exposures in the urban environment.

Urban environments are subject to heat island effects. The high number of buildings and impervious construction materials, for example in roads, accompanied by the loss of trees, green space and reduced ventilation causes a heat accumulation phenomenon that increases heat exposure of the local population (37, 39). A retrospective study evaluating the risk factors contributing to excess mortality during the 2003 heat wave in France, found that higher surface temperature in the surrounding areas to home correlated with mortality, while the presence of vegetation was protective. Housing characteristics were also important. Factors leading to increased heat exposure such as lack of thermal insulation and sleeping on the top floor increased the risk of death. Cooling behaviours such as dressing lightly, using cooling techniques, and devices such as air conditioning units were protective. Lack of mobility and those with pre-existing conditions were also at increased risk, reinforcing the notion that certain groups are particularly vulnerable to the consequences of heat effects (37, 40).

Urban environments are also prone to poor air quality. Transport emissions are the largest contributor to air pollution in cities (37). However other sources include construction, factories, power plants, business and industry related emissions and residential fuel use. According to projections, increasing urbanisation is likely to lead to increased population exposure to air pollutants such as particulate matter and a significant increase in premature mortality (37).

Urban environments present other potential health risks. Light pollution is prevalent in cities and in fact over 80% of the world's population live under light-polluted skies (41). It may disrupt circadian rhythm and contribute to the development of cardiovascular risk factors including type 2 diabetes, and coronary artery disease (37, 42, 43). Noise pollution is a further hazard. Exposure

to transportation noise is associated with increased risk of ischaemic heart disease and may also increase risk of stroke and obesity (37, 44, 45, 46).

As urbanisation takes place at a rapid pace across the globe, the degree to which local health outcomes is affected will depend on the way in which urbanisation occurs and city design is therefore crucial.

Taking Action *(See Figure 1)*

Human activity has caused global warming of 1°C above pre-industrial levels. This is increasing at a rate of approximately 0.2°C per decade due to past and ongoing emissions, and if it continues at the current trajectory, it is likely to reach 1.5°C between 2030 and 2052 (5). Climate change already leads to increased risk of cardiovascular disease and is likely to cause greater morbidity and mortality as this progresses, even in the best case scenario (7). Limiting the rise in temperature to below 1.5°C may prevent significant numbers of adverse events and save lives (4). Therefore, tackling climate change and protecting patients against its consequences, are increasingly becoming crucial components of cardiovascular prevention. The elderly and those with co-morbidities, are growing in number, and are particularly vulnerable to the adverse effects of climate change (10).

Whilst action by individuals can have a positive impact, policy action at an international and government level is required for large-scale significant change. Current efforts are widely considered insufficient to tackle the problem and protect the earth from future cycle of climate instability and catastrophe (4). Professional societies can influence policies to make a positive impact.

Healthcare itself has a large environmental footprint. The NHS has become the world's first health service to commit to achieving carbon net zero. As part of the Greener NHS plan, each trust will need to set out its plans for carbon reduction (47).

Food systems are thought to contribute to a third of greenhouse gas emissions, which includes livestock-associated emissions (48). On an individual level, pursuing a plant-based diet may positively impact the environment and also be beneficial in reducing cardiovascular mortality

(49). This diet is consistent with many of the components of the heart-healthy Mediterranean diet widely advocated for our patients.

Patients can protect themselves from air pollution through the use of face masks and air filtration systems. Ear plugs or noise-cancelling headphones can guard against some of the effects of noise pollution (37). The devastating impact of high temperatures has sometimes gone under the radar, even during extreme heat waves (11). Heat warning systems and increased vigilance will be increasingly important to allow patients to respond appropriately and minimise the risk from excess heat exposure. This may include the use of air conditioning systems and cooling behaviours.

Urban design has an enormous impact on the population exposure to environmental risks and the impact of human activity on the environment. The concept of a 'heart-healthy city' involves accommodating the needs of a growing population through cities that promote local living, working and physical activity (37). Cities with shorter travel distances may encourage walking and reduce transport emissions. An example is the '15-minute city', in which work, school, food and drink, and other important activities are reachable within 15 minutes walking distance from home. There are plans to introduce this concept in Paris (37, 50). A shift to 'active transport' systems will help to create more sustainable and liveable cities. Building the infrastructure to encourage convenient use of public transport, cycling and walking will reduce emissions and has the added benefit of improving health through increased physical activity. Mortality could be further reduced in cities by increasing green space and urban vegetation near buildings, improving building insulation and using building materials that do not exacerbate local heat effects (40).

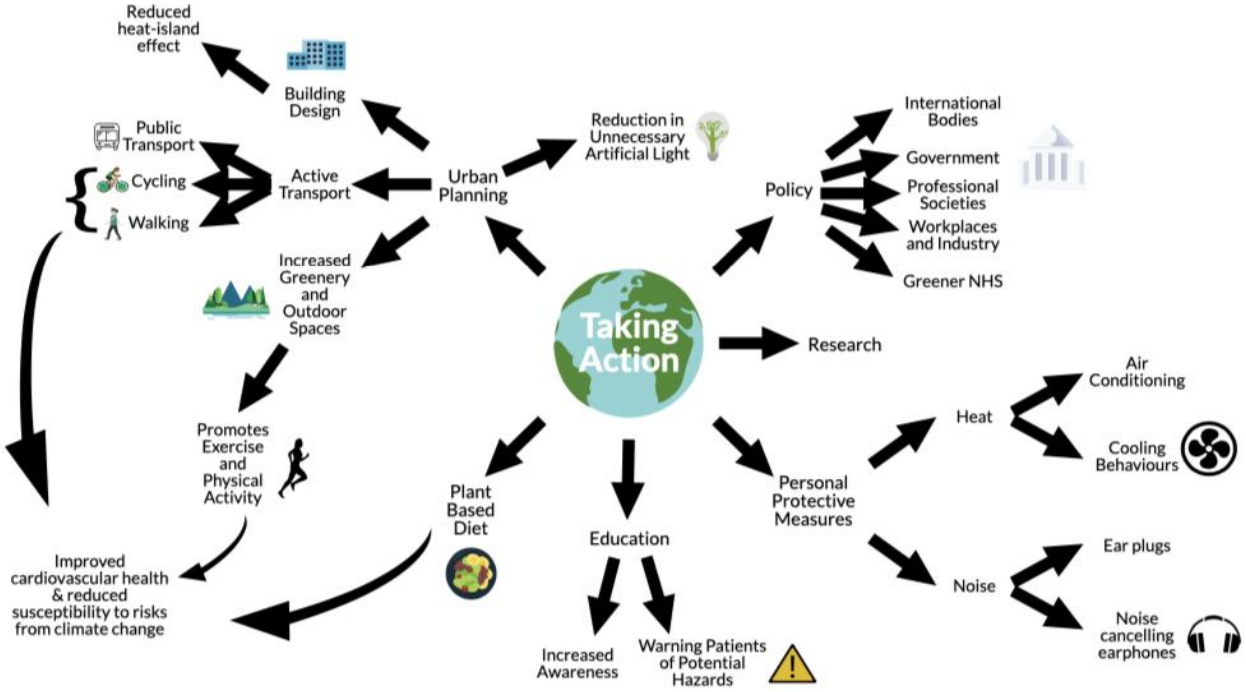

Figure 1. Some of the potential actions to tackle climate change and its health consequences (1, 7, 16, 37)

Conclusions

Climate change is a danger and urgent threat to health, and will increase the future burden of cardiovascular disease. Action is required to minimise further damage to the environment and to protect patients from the impact on their health.

Further Resources

1. Air pollution and cardiovascular disease: the Paul Wood Lecture, British Cardiovascular Society 2021 (Heart Journal)
   https://heart.bmj.com/content/early/2022/01/23/heartjnl-2021-319844
2. Health Emergency of Climate Change | Episode 4: Hazardous temperatures and cardiac health (Royal Society of Medicine) – Webinar (Currently Free to View)
   https://www.youtube.com/watch?v=a7QnPV1fwh4&t=625s
3. Greener NHS Website
   https://www.england.nhs.uk/greenernhs/
4. Environment & the Heart (European Society of Cardiology)
   https://www.escardio.org/The-ESC/What-we-do/Initiatives/environment-the-heart
5. Health and the city: using urban design to promote heart health
   https://www.escardio.org/The-ESC/Press-Office/Press-releases/Health-and-the-city-using-urban-design-to-promote-heart-health

Disclosures

None

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