

Rising Temperatures, Rising Risks: A Review of the Impact of Climate Change on Human Cardiac Health

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Abstract Climate change is one of the most significant threats to human health in the 21st century. Global climate change is part of human-induced global environmental changes caused by emissions of atmospheric greenhouse gases largely due to human activities such as burning fossil fuels aggravated by deforestation and ocean saturation. The change in climatic conditions has a significant impact on human health, including an increased risk of cardiovascular disease (CVD). Climatic stress is anticipated to increase direct and indirect risks to human cardiac health via different pathways and mechanisms. This review aims to explore this relationship and understand the impact of global climate change on cardiac health in humans. The article intends to inspire the readers to advocate the importance of addressing the crisis caused by climate change and encourage communication about the health impacts of climate change.

Keywords: coronary artery disease, climate-change, CVD, temperature, air-pollutants, GIS

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1. Introduction

Climate change is a pressing global issue that is rapidly altering the earth's environment and posing significant threats to human health. One of the most significant impacts of climate change is on human cardiac health. Rising temperatures, changing weather patterns, and increased air pollution are all contributing to an increased risk of heart disease and other cardiovascular illnesses. In this review, the current state of knowledge regarding the impact of climate change on human cardiac health is indicated. This article briefly discusses the ways in which climate and climate change affect human health and wellbeing. The various ways in which climate change is affecting cardiovascular health, including the direct effects of heat on the heart, the indirect effects of air pollution, and the impact of extreme weather events are explored.

2. Climate Change Indicators

Climate is the long-term shifts in temperatures and weather patterns in a given place. The US Environmental Protection Agency (EPA) stated that change in weather can occur in short time, while change in climate develops over longer periods of decades to centuries, which can be defined not only by average temperature and precipitation but also by the type, frequency, duration, and intensity of

weather events such as heat waves, cold spells, storms, floods, and drought [1]. The Intergovernmental Panel on Climate Change (IPCC), an intergovernmental panel established by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) recorded increase in the earth's temperature, which is 1.1 degrees Celsius and it is growing warmer and reported the warmest in the decade between 2011-2020 [2]. Long-term changes in climate can directly or indirectly affect various environmental conditions which in turn affect many aspects of society in potentially disruptive ways. Seasonal temperature, high and low temperatures, heat waves, heavy precipitation, tropical cyclone activity, river flooding, drought, wildfires etc are some of the major indicators towards climate crisis and global warming [3]. Although these shifts may be natural, but since the 1800s, it is observed that the major driving factor of climate change is due to various human activities such as burning of fossil fuels (like coal, oil, and gas). The human-induced global environmental changes include land degradation, ocean acidification, and disruptions and depletions of the stratospheric ozone concentration, soil fertility, fresh-water resources, biodiversity stocks and ecosystem functioning, and global nitrogen and phosphorus cycles that lead to increasing heat-trapping greenhouse gas levels in the earth's atmosphere [4,5]. The United Nations climate change reports stated that fossil fuels such as coal, oil and gas are by far the largest contributor to global climate change, accounting for over 75% of global greenhouse gas emissions and nearly 90%

of all carbon dioxide emissions [6] have significant influence on declining biodiversity. Climate is an integral part of ecosystem functioning and human health and any change or crisis gives rise to imbalance in environment and biodiversity directing towards adverse health implications in human.

3. Temperature Extremes and Cardiac Health

Temperature extremes means temperature variations above (extreme heat) or below (extreme cold) normal conditions, which has wide ranged physiological impacts on humans worldwide. The Global Burden of Disease Study has recently introduced nonoptimal temperatures among the leading risk factors of mortality worldwide [7]. The W.H.O. 2018 report stated that exposure to excessive heat often amplify existing health conditions and resulting in premature death and disability. The report found around 125 million people exposed to heatwaves between the year 2000 and 2016, causing emergency services in hospitals and deaths (WHO, 2018). The extreme climate events viz., heat waves and cold waves and its changes in frequency, intensity, and duration can disturbs the normal body's thermal regulation triggering respiratory concerns and cardiovascular disorders [9]. Climate change is expected to increase the frequency and intensity of both heatwaves and cold temperatures and this can lead to dehydration, electrolyte imbalances, adverse cardiovascular events, thereby increasing stress on the cardiac system. Extreme heat can cause vasodilation, leading to hypotension and reduced cardiac output, while extreme cold can cause vasoconstriction, leading to hypertension and increased cardiac workload [10].

There are several studies that revealed the pathophysiologic explanations of effects of extreme temperatures on stroke and CVD events in developed countries. Low temperature causes blood vessels to narrow, which increases blood pressure and the risk of stroke and other cardiovascular events while high temperature causes blood vessels to dilate, which increases cardiac output and risk of decompensate heart failure. Both temperatures extremes put stress on the cardiovascular system, especially among the elderly with limited adaptive responses, and increase the risk of coronary heart disease (CHD) [11,12]. A recent study conducted by Zhao et al. (2021) investigated the impact of temperature on the incidence of CVD in the developing area of Dingxi, North-western China. The study explained diurnal temperature range (DTR) has an adverse effect on CVD morbidity, particularly in women and the elderly. Furthermore, the study indicated inconsistent patterns of association between DTR and CVD owing to differences in geography, climatic characteristics, housing types, use of cooling and heating equipment, and the scale of DTR for overall all-cause mortality [13]. It is presumed that with the existing change in climatic conditions will continue to cause approximately 250 000 additional deaths per year from CVD, malnutrition, malaria, diarrhoea and heat stress alone.

4. Air Pollution and extreme Weather Events on Cardiac Health

Climate change has a strong linkage to air pollution that might also affect human cardiac health.

The Global Burden of Disease (GBD) study estimates that in 2019 pollution was responsible for 9 million deaths worldwide, and 61.9% of which were due to CVD, including ischemic heart disease (31.7%) and stroke (27.7%) [7]. Air pollution includes ambient (outdoor) and household (indoor) pollution, where air contains particulate matters and gaseous primary pollutants such as nitrogen oxides (NO_x), sulphur dioxide, and carbon monoxide, which are released directly into the atmosphere. Higher temperatures lead to an increase in allergens and harmful air pollutants, leading to an increase in ozone (O₃), a harmful air pollutant. Ozone is a highly reactive gas composed of three oxygen atoms, can be referred to as both a natural and a man-made product that occurs in the earth's upper atmosphere (the stratosphere) and lower atmosphere (the troposphere) [14]. On the other hand, environmental pollution cause to have particle pollution or particulate matter (PM) in the air, which are certain pollutants consist of mixture of solid particles and liquid droplets. Scientific literatures showed exposure to fine particulate matter (particulate matter with diameters less than 2.5 µm or PM_{2.5}) such as dust, dirt, soot, or smoke can increase CVD mortality. The association of risk for CVD mortality from PM_{2.5} is 0.2–1.3% higher than that from PM₁₀ [15]. It is believed that exposure to these pollutants can lead to oxidative stress, inflammation, and endothelial dysfunction, which are all risk factors for cardiovascular disease. A medical study confirmed that ambient PM_{2.5} poses a major threat through autonomic imbalance, endothelial dysfunction disturbing the systemic inflammation and thrombotic pathways. Multi-Ethnic Study of Atherosclerosis (MESA) have shown that intima-media thickness of the common carotid artery, as an indicator of atherosclerosis strongly correlates positively with long-term exposure to PM [16]. The correlation of exposure to PM air pollution with subclinical pathologies underlying CVD that include systemic inflammation and oxidative stress, atherosclerosis, thrombosis, endothelial dysfunction, hypertension, cardiac remodeling, and arrhythmia [17]. In India, rural areas of certain states where biomass fuel for cooking is practised in unventilated spaces, a higher prevalence of carotid intima-media thickness (CIMT) index, a marker of atherosclerosis, is observed. Women with such unventilated cooking practices and men above 40 years of age are at higher risk of developing CVDs such as stroke or heart attack [18]. However, the lack of clarity in molecular interactions between climate change and air quality as well as the consequent cardiac health outcomes remain a topic of research and needs further studies.

The manifestations of the changing climate are increase the frequency and intensity of extreme weather events, such as hurricanes, floods, and wildfires. These events can have a significant impact on cardiac health, both in the short and long term. In the short term, extreme weather events can lead to physical injuries and stress, both

of which can trigger cardiovascular events. In addition, extreme weather events can lead to displacement and disruption of healthcare services, which can impact the management of existing cardiovascular conditions. Wildfires can also lead to increased air pollution, which can have an adverse impact on cardiovascular health. More scientific evidence is still required to develop policies for the depletion and prevention of climate-related environmental hazards to human health.

5. Understanding the Impact of Climate Change on Cardiac Health

There are several strategies that can be implemented to prevent the impact of climate change on cardiac health. One of the most important is to reduce greenhouse gas emissions and slow the pace of climate change. This can be achieved through a range of strategies, including reducing reliance on fossil fuels, promoting renewable energy sources, and implementing policies that encourage energy efficiency.

The human body has a normal core temperature between 97°F and 99°F, but on average, a normal body temperature is 98.6°F (37°C). To maintain this temperature without the help of warming or cooling devices, the surrounding environment needs to be at about 82°F (28°C). If any change takes place beyond this will give rise to human health concerns. For example, extreme heat temperatures are the relative humidity in the environment that can affect the temperature which is called the “apparent temperature.” It is found that high environmental temperatures are not favourable to human body. In the range of 90° and 105°F (i.e., 32° and 40°C), a person can experience heat cramps and exhaustion. Between 105° and 130°F (40° and 54°C), it will cause

heat exhaustion and it is reported that an environmental temperature over 130°F (i.e., 54°C) often leads to heatstroke. It is to be understood that rise of internal body temperature over 103°F (39°C), it can cause un-consciousness with experiences of exhaustion or fatigue.

The impact of air pollution on global CV morbidity and mortality is evident from a body of medical studies where the effects of particulate matter and gaseous components on cardiometabolic disease were discussed. As Figure 1 shows, high temperature and fluctuating weather events are inter-related creates environmental imbalance that triggers the risk of developing CVD. Pollution from unwanted material released into the environment by human activity (Figure 1) is another important yet often overlooked risk factor for CVD.

The particulate matter (PM) fraction of air pollution is broadly categorized by aerodynamic diameter: <10 µm (thoracic particles [PM10]), <2.5 µm (fine particles [PM2.5]), <0.1 µm (ultrafine particles), and between 2.5 and 10 µm (coarse [PM2.5-10]), and can be quantified by the particles (mass) contained per cubic meter (µg/m³). [19]. Apart from the ozone layer in the earth's atmosphere, PM in air kind of pollutants is highly prevalent in urban areas and posing the greatest threat to global public health. The impact of air pollution on cardiac health is equivalent to its rivals like obesity, cholesterol, smoking, hypertension and physical inactivity. It causes premature deaths, the main cause for which is cardiovascular diseases in 70–80% of the cases and rest are due to respiratory diseases and malignancies [20]. In the rural setting of India, a large number of populations experiencing a rapid epidemiological transition and a sharp increase in the prevalence of CVD and hypertension, diabetes and obesity due to exposure to high levels of air pollution, both ambient and indoors.

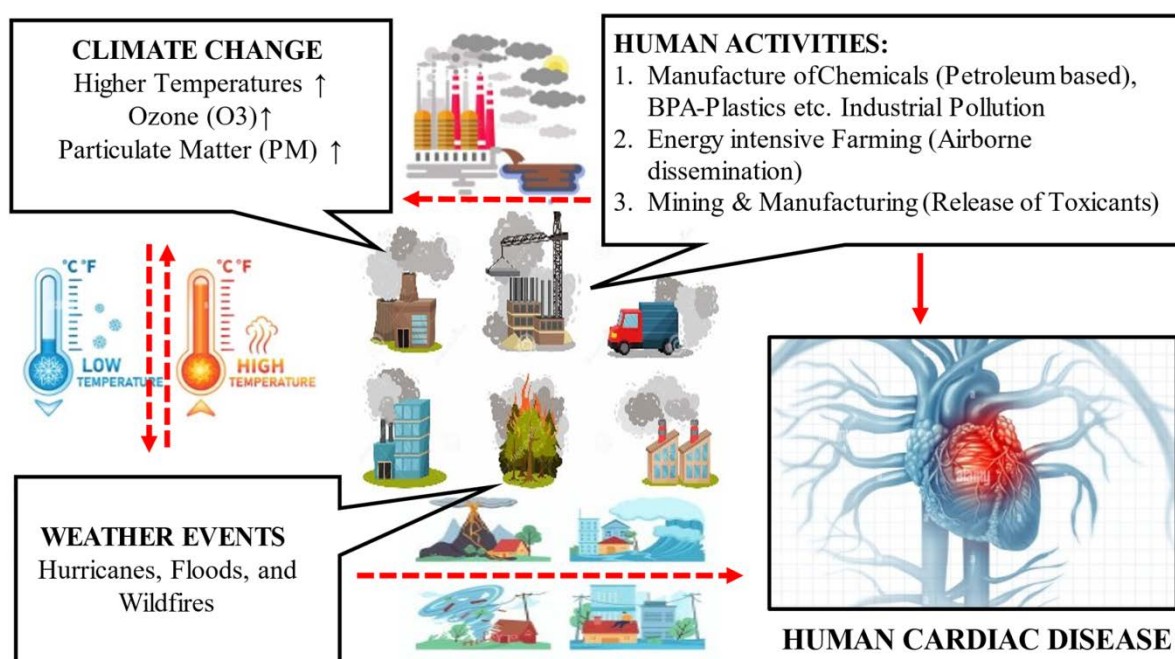


Figure 1. Climate Change, Pollution and Human Cardiac Disease

6. Conclusion

Climate is an integral part of ecosystem functioning and human health and any changes in climate affect the viability and health of ecosystems, influencing shifts in the distribution of plants, pathogens, animals, and even human health (WHO, 2018). The repercussions of global climatic change include not only loss in economy agriculture, production, energy and infrastructure but also significant loss of life and cause serious concerns human cardiac health. The review briefly summarised the association between different climatic crisis such as temperature extremes, air pollution and weather events with pathophysiology of CVD. Studies on climate change and cardiac health is limited and it is challenging to have a complete molecular understanding of the physiological basis of impacts of climatic change on human cardiac health.

The intersections between extreme temperatures and cardiovascular health need to be thoroughly characterized in the present day especially under a changing climate. There are developments in geospatial techniques nowadays in measuring, analysing, modelling, and mitigating climate change and its effects on human lives. It can be of value if developments in geographic information science (GIS) can contribute in health science research to gather and analyse information about the world. Indeed, more research should be focused on multidisciplinary adaptation strategies that incorporate epidemiology, climatology, indoor/building environments, energy usage, and human thermoregulatory models. The nature of seasonal impacts is cumulative and complex but the impacts are measurable. Accounting for weather forecasts considering the hazards and impacts of temperature extremes in co-ordination with healthcare sector can provide not only useful, understandable and timely information for the nation to reduce natural disasters but also it will help the clinicians and other healthcare professionals to take action to prevent climate-change-associated heart disease among their patients.

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