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ENVIRONMENT, CLIMATE CHANGE, AND CARDIOVASCULAR HEALTH

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Current state of knowledge

Environmental pollution is a significant contributor to diseases and premature deaths. It constitutes a major part of the global disease burden, with cardiovascular diseases being particularly prominent. Particulate matter (PM), one of the most extensively researched air pollutants, is classified based on its aerodynamic size. The categories include 1 µm, 2.5 µm, and 10 µm. These particles are predominantly associated with the combustion of fossil fuels and biomass[1].

Using satellite estimates and ground-level chemical transport models, global average concentrations of particles with an aerodynamic diameter less than 2.5 µm (PM 2.5) and ozone are calculated with an approximate resolution of 11 km. x 11 km.

Smaller fractions exert greater effects due to their ability to penetrate deeply into the lung alveoli and from there, into the bloodstream. Urban PM has a complex and varied composition, including elemental carbon, ammonium, nitrates, sulfates, ozone (O3), organic compounds and heavy metals[2,3]. Exposure to PM can be acute (24 hours or less) or chronic (annual)[4].

The United Nations characterizes climate change as enduring alterations in temperature and weather patterns. Since the 19th century, these changes have been primarily driven by human activities, particularly the combustion of fossil fuels like coal, oil, and gas. The primary cause of climate change is linked to these fossil fuels, which emit greenhouse gases and short-lived climate pollutants[5]. Climate change triggers environmental disasters such as large-scale fires and heatwaves, which increase PM 2.5 levels or lower, leading to harmful effects[6].

From a societal perspective, the rise in poverty poses a risk, as the most vulnerable populations often reside in areas with higher environmental risks. These are areas often lacking in basic living conditions, including access to clean drinking water, are typically overcrowded, high unemployment and scarce community infrastructure, directly impacting the community development and increasing the levels of inequality and inequity[7].

Risks

Research has identified significant links between exposure to urban PM and cardiovascular diseases, including myocardial infarction and stroke. PM has both acute effects, such as changes in heart rate and elevated blood pressure, and chronic impacts on the cardiovascular system, such as the exacerbation of atherosclerosis. These effects encompass vascular dysfunction, heightened susceptibility of the heart to ischemic damage, and an increased tendency for thrombosis[8].

Exposure to air pollution has been associated with a heightened risk of arteriosclerosis, as evidenced by premature aortic and coronary calcification. Short-term spikes (lasting hours) in air pollution levels have been linked to an increased risk of myocardial infarction, stroke, and acute heart failure[9,14]. Extreme air pollution conditions have adverse effects on blood pressure and insulin resistance[15].

Several distinct biological pathways seem to underpin these effects, with oxidative stress and inflammation being central. From a pathophysiological perspective, once PM (2.5 or less than 1 µm) enters the bloodstream via reactive oxygen species, it triggers endothelial dysfunction, monocyte activation, and proatherogenic changes in lipoproteins, which initiate plaque formation. Additionally, air pollution promotes thrombus formation due to an increase in coagulation and platelet activation factors [8, 9].

The findings indicate that while humans can adapt to varying climatic conditions, extreme temperatures and elevated levels of air pollution may impact health outcomes. In such scenarios, climate change adversely affects the cardiovascular system, with individuals at high risk of cardiovascular diseases being the most vulnerable[16].

Mortality rates progressively rise when the external air temperature deviates above or below 20-25 degrees Celsius. A study investigating the correlation between daily mortality and daily temperatures in the Netherlands from 1979 to 1987 found that 57% of the “unexplained” cold-related mortality and 26% of the “unexplained”’ heat-related mortality were attributable to cardiovascular diseases[17].

In a separate study conducted across 652 cities in 24 countries, it was found that, on average, a rise of 10 µg per cubic meter in PM 10 concentration, representing the average of the current and previous days, was associated with a 0.44% daily increase in all-cause mortality, a 0.36% daily increase in cardiovascular mortality, and a 0.47% daily increase in respiratory mortality[18].

Exposure to household air pollution was linked to a higher prevalence of Chronic Obstructive Pulmonary Disease (COPD), especially among women. This is likely to be a significant population-attributable risk factor for COPD in low-resource settings[19].

To mitigate the health impacts of these phenomena, it's crucial to consider different populations based on their unique characteristics and/or existing comorbidities, which expose them to specific risks[11]. When faced with average PM 2.5 values of 35 µg/m^3 or more over a 24-hour period, these populations face increased cardiovascular and cerebral risks. They are classified as follows[4]:

- Very High Risk: cardiovascular disease, recent hospitalization for acute coronary syndrome, COPD or asthma.
- High Risk: diabetes or kidney disease stage III or higher.
- Special populations: older adults, pregnant women, transplant recipients.

Climate change also impacts cardiovascular health due to the stress induced by environmental changes (such as severe storms, fires, loss of water sources, habitat loss, and migrations), the effects of heatwaves, and the combined impact of air pollution and heat[20,21]. These changes can lead to new diseases or exacerbate pre-existing cardiovascular conditions, with a wide range of manifestations including heat stroke, arrhythmias, acute myocardial infarction, and/or decompensation of heart failure, among others. The mechanism of action primarily involves the exacerbation of the detrimental effects of air pollution on health through various pathways, such as the formation of ground-level ozone, for instance[22].

Recommendations

Numerous studies have demonstrated that air pollution and climate change are among the primary contributors to the global disease burden, particularly in low- and middle-income countries. Interventions can be implemented through preventive measures and/or specialized care actions[1,4,8]. For these actions to be effective, they should be incorporated into a government management process that addresses all levels of decision-making and intervention[1,4,8]. Within this framework, scientific associations, and universities, ideally under government leadership, should develop educational, preventive, and action programs at both individual and collective levels[23].

For government strategies, it is recommended to prioritize actions that can transform productive processes from using polluting energies to low-polluting renewable ones. This includes promoting the use of low-emission vehicles, encouraging active transportation (such as walking or cycling), avoiding the design of mixed residential/industrial urban areas, promoting research on mitigating climate change and the health risks of pollution and climate change, systematically measuring and monitoring pollution through air quality sensors in cities, and implementing advertising campaigns about the dangers of these phenomena[1,4]. Once the risk has been established and according to the air quality (if the pollution level exceeds 35µg/m^3 over 24 hours) and the exposure is acute, it is suggested that governments promote the use of N95 masks outside the home, encourage the closing of doors and windows, and facilitate the use of HEPA filters inside homes as much as possible[4]. In areas with chronic exposure levels (PM 2.5 greater than 12 µg/m^3 annual average), it should be recommended that susceptible individuals avoid outdoor activities, governments should ensure access to filters in air conditioners and cars and implement measures to avoid traffic congestion[4].

At the healthcare level, an environmental medical history or at least a brief history of exposure to pollution, both at work and in daily life, should start to be included, evaluating susceptibility, and providing guidance. The World Health Organization (WHO) believes that the environmental impact on health must be addressed from early life and urges the implementation of strategies that allow addressing, disseminating, and solving environmental health problems in health services[4]. In all cases, it is suggested to recommend avoiding the use of private vehicles and encouraging the use of bicycles as a mode of transportation.

There is also a need to lessen the impact of the health sector on both climate change and pollution[23].

Specifically, regarding cardiovascular disease, the recommendations are targeted as follows[22]:

- Identify individuals who are most susceptible to the effects of climate change and provide them with appropriate care and/or preventive measures to reduce or prevent health impacts. These individuals may include those with a history of heart disease, high blood pressure, comorbidities, or the elderly, among others.
- Be aware that certain medications, such as diuretics or antihypertensives, can have their side effects intensified during heatwaves, leading to hydroelectrolyte disorders and hypotension.
- Pay particular attention to heat stroke by promoting increased hydration, monitoring temperature, encouraging the use of light clothing, and modifying diets, etc.
- In medical emergency systems, stay alert to early warnings of climatic and meteorological phenomena, as

episodes of exacerbated cardiovascular diseases may occur more frequently than typically expected.

• Prepare emergency and hospital services to handle cases impacted by climate change and pollution.

From what has been discussed so far, it is clear that health issues related to pollution and climate change are becoming central to population health. In this context, both phenomena underscore the multifaceted role of healthcare teams. They should not limit themselves to individual patient care but must also assume their social role in highlighting the health consequences of production methods that increase pollution levels[7].

Active involvement of Internal Medicine societies and internists across Latin America is necessary for them to play a significant role in addressing climate change and environmental degradation. This sentiment was recently echoed by the European Federation of Internal Medicine[23], which issues recommendations at national, hospital, corporate, and individual levels.

At the national level, measures that reduce greenhouse gas emissions and environmental degradation are recommended. These include the use of renewable energy sources, low-emission vehicles, healthy buildings, behavioral changes in the population, halting deforestation, financing adaptation plans, supporting research to understand and mitigate the health effects of climate change, imposing environmental ethics in organizations, generating policies for health systems to respond to population health problems related to climate change and environmental degradation, and reducing their ecological impact.

At the hospital level and in clinical practice, actions should be defined to reduce the health sector's ecological footprint and implement a sustainable environment. This includes evaluating the use of heating, ventilation, and air conditioning, adapting its use to its intended purposes, adjusting usage hours, improving energy efficiency in the built environment, reducing emissions from hospital fleets, reducing waste, eliminating metered dose inhalers (MDIs) that use hydrofluorocarbons as propellants, adopting low-carbon alternatives to anesthetic gases, replacing single-use equipment and devices with reusable ones, introducing a plant-based diet in hospitals and scientific meetings, avoiding the use of brochures and paper documents, reducing the impact of travel, promoting virtual meetings, avoiding air travel for short distances, encouraging hospitals to adopt "Green Hospitals" certification, promoting hybrid circuits for patients –digital and human touchpoints–, promoting healthy lifestyles in clinical practice, and reducing over-exploration, over-diagnosis, and over-treatment.

At the level of Internal Medicine Societies, they should promote educational activities and develop a set of tools to help internists reduce energy use and greenhouse gas emissions in their practices, prepare internists to act in diagnoses related to climate crisis disasters, improve knowledge to care for citizens who suffer the consequences of climate change and environmental degradation, promote and implement effective actions to reduce the ecological footprint of the health industry, introduce this theme in their conferences, strive to introduce the theme in undergraduate and postgraduate courses.

At a personal level, individuals should be active agents in promoting practices to improve the environment, increasing community awareness about the health risks of climate change and environmental degradation, and serve as role models in the adoption of environmentally friendly behaviors.

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