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THE IMPACT OF CLIMATE CHANGE ON THE HEALTH OF URBAN POPULATION

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Introduction

As IPCC (2012) points out, risk due to climate change influence arises both from the evolving characteristics of physical hazards and the extent to which society is exposed and vulnerable to those hazards. Factors such as demographic shifts and changes in social, economic, and political systems continuously modify global population dynamics, impacting future exposure and vulnerability to these hazards. However, research on climate risk often focuses primarily on the potential changes in the intensity, frequency, and distribution of physical hazards, with less emphasis on how societal factors might change.

During the 21st century, the intensity and frequency of heat extremes are expected to rise due to climate change (e.g. Collins et al., 2013; Kharin et al., 2013). Although the link between climate change, heatwaves, and adverse health impacts is well-documented (Luber & McGeehin, 2008; Li et al., 2012), the IPCC's 5th Assessment Report (2014) indicates that there is limited research on quantifying potential future changes in human exposure and vulnerability to extreme heat (Smith et al., 2014). Moreover, little is known about how much exposure and vulnerability are influenced by changes in both the physical nature of heat extremes and demographic or social factors under different future scenarios.

Exposure, defined as direct experience of hazardous conditions, is a prerequisite for vulnerability, which is typically understood as a combination of exposure, sensitivity, and a population's capacity to adapt (Turner et al., 2003). A key research objective is to comprehend the potential range of future climate risks, the uncertainties involved, and the primary factors influencing these risks to better inform research priorities and risk management strategies (IPCC, 2012). To support this goal, this study projects future exposure to heat extremes on global, regional, and local scales, considering both climate and demographic changes and assessing their relative contributions to overall risk and uncertainty.

Heatwaves represent some of the most serious climate-related dangers affecting both developed and developing nations. For instance, the 2003 heatwave in Europe and the extreme heat events in India during the spring of 2015 caused tens of thousands of deaths. The IPCC (2012) indicates a high likelihood that the average number of hot days and nights per year has already increased globally and is expected to continue rising throughout this century (Oleson et al., 2015).

Heat impacts human health directly by causing conditions such as heat exhaustion and heat stroke, and indirectly by worsening existing health problems like cardiovascular and respiratory diseases. Factors such as age, education, and economic status have been linked to varying levels of vulnerability to heat extremes (Basu & Ostro, 2008; Anderson & Bell, 2011), though the specific relationships between these factors across different regions and communities are not yet fully understood (Smith et al., 2014).

Research on extreme heat often uses diverse physical metrics to identify key indicators of excess illness or death within certain populations or areas (Barnett et al., 2010). However, no single metric has proven to have significantly greater predictive accuracy across large populations and geographic areas, as different measures are often closely related (Barnett et al., 2010). Additionally, studies show that significant fluctuations in summer temperature patterns or rapid changes in average temperatures are strongly linked to increased mortality, emphasizing the importance of both environmental conditions and location (Basu, 2009).

Research aim

The aim of this doctoral research is to assess the future risks of heatwave exposure by integrating climate and demographic projections. This study will explore how changes in the frequency and intensity of heat extremes, combined with demographic shifts, will influence human exposure and vulnerability on global, regional, and local scales.

Specific research objectives

1. **To quantify future changes in heatwave frequency, intensity, and distribution** under various climate scenarios using high-resolution climate projections.
2. **To evaluate how demographic factors such as age, socio-economic status, and population density** influence exposure and vulnerability to heat extremes under different Shared Socioeconomic Pathways (SSPs).
3. **To assess the relative contributions of climate change and demographic shifts** to overall heatwave risk and identify key uncertainties in projecting future exposure.
4. **To develop integrated models combining climate and societal factors** to project future heatwave risks and classify populations into risk categories (very high to very low).
5. **To inform risk management and adaptation strategies** by providing detailed insights into how future climate and societal changes interact to influence heat-related health impacts.

Research significance

This research is significant as it addresses the critical gap in understanding how demographic and socio-economic changes intersect with climate change to influence heatwave risks. By focusing on the interaction between physical hazards and societal factors, this study provides a comprehensive assessment of future vulnerabilities, which is crucial for developing targeted adaptation and mitigation strategies. The findings will inform policymakers, urban planners, and public health officials about the most vulnerable populations and help prioritize resource allocation to reduce heatwave mortality and morbidity.

Although the research will be focusing on how extreme temperature affects mortality in specific regions of Asia, Latin America, Eastern Europe, and Africa, which primarily suffers from climate extremes and socio-economic stresses. For instance, Asia has a rapid urbanization, demographic expansion and aging society as well. These factors create a unique challenge in managing heat-related mortality, especially in densely populated megacities. Then, Latin America faced with both socio-economic inequalities and urban-rural divides, which escalate heat vulnerability, mainly in low-income and marginalized communities. Many African countries have inherent exponential population growth, limited healthcare access and extensive poverty, which promote to increased heat-related mortality risks. Lastly, there are aging demographic structures combined with outdated infrastructure in Eastern Europe, resulting in heightening the risk of heat-related health impacts, particularly among the elderly. Highlighting on these continental regions the research can demonstrate how heatwaves affect mortality and help to inform tailored public health and adaptation strategies in some of the most at-risk areas of the world.

Methodology

1. **Data Collection**: The research will use the climate projections outputs of the Coupled Model Intercomparison Project (CMIP6), which include multiple Representative Concentration Pathways (RCPs) combined with different SSPs to model future heatwave scenarios including the possible demographic changes.
2. **Modeling Approach**: Integrated models will be developed to combine climate and demographic projections. The models will simulate various future scenarios (e.g., SSP1-2.6, SSP2-6, SSP3-8.5) to assess the combined impact of climate and socio-economic changes on heatwave exposure and vulnerability.
3. **Risk Assessment**: The doctoral research will classify future populations into risk categories based on projected exposure and vulnerability metrics. Statistical analysis will identify key drivers of risk and evaluate the extent to which societal factors modify exposure.
4. **Scenario Analysis**: Sensitivity analyses will be conducted to explore uncertainties in climate and demographic projections and assess the robustness of risk estimates across different scenarios.
5. **Validation and Comparison**: The models will be validated using historical data on heatwave events and associated health outcomes. Comparisons will be made with existing studies to ensure the reliability of the findings.

This approach will provide a comprehensive understanding of the evolving risks associated with heatwaves and highlight the need for adaptive strategies that address both environmental and societal dimensions of climate change.

Discussion and Implications

The projected increase in heat extremes presents a critical public health challenge, particularly in urban areas where heat exposure is intensified due to the urban heat island (UHI) effect. Urban environments exacerbate heatwave impacts due to the high density of buildings and paved surfaces, which absorb and retain heat, reducing nighttime cooling. As urban populations continue to grow, the number of people at risk of heat-related health issues will likely rise, especially in cities with limited green spaces and inadequate cooling infrastructure.

Vulnerable Populations

The effects of heat extremes are not distributed equally across populations. Vulnerability to heatwaves is heightened in certain demographic groups, such as the elderly, children, individuals with pre-existing problematic health conditions, and low-income populations. These groups often lack access to air conditioning, proper healthcare, or the ability to relocate during extreme heat events. Moreover, socio-economic disparities can worsen heatwave outcomes, as those with fewer resources are less able to adopt protective measures or recover from the consequences of heat-related illnesses. This study's emphasis on integrating demographic projections with climate scenarios is crucial for identifying which populations will be most at risk in the future. For instance, aging populations in many parts of the world may become increasingly vulnerable to heatwaves due to their higher susceptibility to heat-related conditions such as heat stroke and cardiovascular diseases.

Urban Planning and Public Health

Urban planning plays a critical role in mitigating the health impacts of heat extremes. Expanding green spaces, enhancing building designs for better insulation, and improving access to cooling centers are essential strategies for reducing urban heat exposure. Cities can also implement early warning systems and heat action plans, which have been proven to reduce mortality during heatwaves. For example, cities such as Ahmedabad in India have successfully introduced heat action plans that include public awareness campaigns, early warnings, and provisions for emergency healthcare services (Hess et al., 2018). Additionally, improving public health infrastructure is key to addressing the health impacts of climate change. This involves strengthening healthcare systems to respond more effectively to heat-related illnesses and ensuring equitable access to cooling solutions and healthcare services, especially in vulnerable communities.

Adaptation and Mitigation Strategies

The findings from this research can inform adaptation strategies that address both the physical and societal dimensions of heat risk. Cities and regions can prioritize investments in heat-resilient infrastructure and design climate-resilient healthcare systems. Furthermore, governments should focus on reducing greenhouse gas emissions to mitigate future heatwave intensification. Climate adaptation strategies, such as retrofitting homes with better insulation or designing climate-smart cities, can significantly reduce exposure to extreme heat. Public policies must also consider the projected demographic shifts, such as population aging and urbanization, to adequately address future heatwave risks. Integrating these factors into public health planning will allow for more targeted interventions that protect the most vulnerable groups. Moreover, adaptive measures should be inclusive, ensuring that low-income and marginalized communities are not left behind in efforts to combat the health impacts of climate change.

Conclusion

Climate change will increasingly expose urban populations to more frequent and intense heat extremes, with significant implications for public health. This study highlights the importance of integrating climate and demographic projections to assess future risks more accurately. Vulnerable populations, particularly in urban areas, will face greater health risks from heatwaves, necessitating comprehensive adaptation and mitigation strategies that address both environmental and societal challenges. By developing integrated models that account for both climate and demographic changes, this research provides critical insights into future heatwave risks and helps inform policymakers, urban planners, and public health officials. As the frequency and severity of heatwaves continue to rise, proactive measures will be essential to protect populations, particularly those most vulnerable to the health impacts of extreme heat.

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