

Research Article

Green Exercise Interventions in Heat-Vulnerable Communities: Evaluating Interactions between Urban Greening, Physical Activity, and Heat-Related Mortality

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Abstract: Heatwaves are becoming more frequent and severe, posing significant health risks, especially for vulnerable populations in urban areas. In response to this, green-exercise interventions, which combine physical activity with exposure to green spaces, offer a promising strategy for mitigating heat-related health risks. This study evaluates the effectiveness of green-exercise interventions in reducing heat-related mortality risks in heat-vulnerable communities. The research follows a longitudinal design, collecting data on physical activity, vegetation indices (NDVI), and heat-related mortality rates in urban areas prone to heatwaves. The findings reveal that green-exercise interventions resulted in up to an 18% reduction in heat-related mortality risks, demonstrating the significant impact of physical activity in natural environments. Moreover, positive correlations were found between increased green space and reduced health risks during heatwaves, emphasizing the importance of urban greening in mitigating the effects of extreme heat. Participants who engaged in outdoor physical activity in green spaces showed greater resilience to heat stress compared to those who opted for indoor exercises, underscoring the added benefits of natural environments for physical and mental health. However, the effectiveness of these interventions varied depending on environmental and behavioral factors, including the quality of green spaces and individual motivation to engage in outdoor activities. This study highlights the need for further research into the long-term effects of green-exercise interventions and the combined impact of socio-economic and environmental factors on health outcomes. The findings suggest that urban greening and physical activity in green spaces should be integrated into public health strategies, particularly in heat-vulnerable areas.

Keywords: Green Exercise; Heat Related Mortality; Heat Vulnerability; Physical Activity; Urban Greening

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1. Introduction

Heatwaves, characterized by prolonged periods of excessively high temperatures, have become more frequent and severe due to climate change and urbanization. These extreme weather events pose significant public health risks, particularly in urban areas where densely populated regions face compounded environmental stressors. Vulnerable populations, such as the elderly, individuals with chronic health conditions, and those from lower socioeconomic backgrounds, are at heightened risk of heat-related illnesses and mortality (Brennan et al., 2020; Kang et al., 2024). This risk is further exacerbated by the urban heat island (UHI) effect, where built environments and limited green spaces cause temperatures to rise higher than in surrounding rural areas (Geneletti et al., 2022). The combined challenges of heat exposure and inadequate urban planning create urgent health concerns for vulnerable groups (Csomós et al., 2020).

Heatwaves have a disproportionately severe impact on vulnerable populations, including the elderly, individuals with pre-existing health conditions, and those living in poverty. Studies indicate that the elderly, particularly those who are socially isolated, face an elevated risk of heat-related mortality during periods of extreme heat (Erens et al., 2021; Kang et al., 2024). Similarly, individuals with chronic conditions, such as cardiovascular diseases, are more

susceptible to heat stress, leading to exacerbated symptoms and, in some cases, premature death (Brennan et al., 2020). Moreover, low-income populations often lack the resources to cope with heatwaves, such as access to air conditioning or cooling centers (Dufty, 2022).

In urban environments, the urban heat island (UHI) effect significantly intensifies the risks associated with heatwaves. This phenomenon occurs when cities trap heat due to dense infrastructure, limited vegetation, and reduced green spaces, leading to higher ambient temperatures compared to surrounding rural areas (Stewart, 2020). As cities continue to expand, especially in regions lacking adequate urban planning, the UHI effect has become a critical factor in increasing the vulnerability of urban residents to extreme heat (Cimini et al., 2024). This heat exposure disproportionately affects lower-income neighborhoods, where access to cooling resources and green spaces is often limited (Gopal & Nagendra, 2015).

Addressing the public health challenges posed by heatwaves requires a multifaceted approach. Heatwave warning systems, public health campaigns, and the establishment of cooling centers or heat refuges have been implemented in several regions to protect vulnerable communities (Dufty, 2022). However, one of the most effective strategies for mitigating heat risks in the long term involves enhancing access to urban green spaces (UGS). Green spaces, including parks, gardens, and urban forests, offer numerous health benefits, including providing shade, reducing ambient temperatures, and promoting physical and mental well-being (Geneletti et al., 2022). Despite these advantages, access to UGS is often inequitable, with disadvantaged communities experiencing barriers to high-quality green spaces, exacerbating health inequalities (Csomós et al., 2020; Long et al., 2022).

Heatwaves are becoming increasingly frequent and severe, particularly in urban areas, where the urban heat island (UHI) effect exacerbates the risks of heat-related health issues. These risks are disproportionately borne by vulnerable populations, including the elderly, individuals with chronic conditions, and those in lower socioeconomic groups (Revich, 2023). In this context, urban green spaces play a crucial role in mitigating the adverse effects of extreme heat. Green spaces are known to reduce the UHI effect by providing shade, enhancing evapotranspiration, and promoting physical activity, which together help lower heat-related health risks (Hu & Li, 2020). Physical activity in these green spaces, referred to as "green exercise," offers significant benefits for both physical and mental health, increasing resilience to heat stress and reducing the risk of heat-related mortality (Marini et al., 2022).

Urban green spaces are essential for reducing heat-related mortality. These spaces not only offer cooling effects through natural processes such as evapotranspiration and shading but also encourage physical activity, which is linked to improved health outcomes. Physical activity in natural environments has been shown to reduce the likelihood of chronic diseases, improve mental health, and enhance individuals' ability to withstand extreme temperatures (Lopez-Haro et al., 2024; Marini et al., 2022). Moreover, the integration of green spaces into urban planning can significantly increase the threshold temperature at which heat avoidance behaviors, such as staying indoors, are triggered, thus reducing the risks of heat stress (Revich, 2023).

The interaction between urban greening and physical activity creates a robust mechanism for enhancing heat resilience. Green spaces promote outdoor activities, which in turn have numerous health benefits, including improving cardiovascular health, reducing stress, and enhancing social well-being. These health benefits can help mitigate the effects of heatwaves by promoting a population that is more resilient to heat stress (Vich et al., 2021). Additionally, regular physical activity in cooler environments can increase the adaptive capacity of individuals to cope with high temperatures, thus reducing heat-related mortality (Kabisch et al., 2017).

This study aims to assess the effectiveness of green-exercise interventions in reducing heat-related mortality, particularly in heat-prone regions where the risks of extreme heat are most pronounced. Although existing studies highlight the role of green spaces in mitigating heat-related health risks, there is a need for more targeted research to understand the specific benefits of green exercise in urban environments (Zha et al., 2024). By focusing on the integration of physical activity with green spaces, this research addresses an important gap in health interventions, offering a holistic approach to public health that combines environmental sustainability with health promotion.

Furthermore, understanding the health benefits of green spaces, especially in reducing heat-related mortality, is crucial for informing urban planning policies. The findings of this study will contribute to the growing body of evidence that supports the integration of nature-based solutions into urban environments as a strategy to protect public health, especially during extreme heat events (Kabisch et al., 2017).

2. Literature Review

Heat-Vulnerable Communities

Heat-vulnerable communities are those particularly susceptible to the adverse effects of heatwaves, including higher rates of morbidity and mortality. Certain populations are at greater risk, such as older adults, children, outdoor laborers, and individuals with chronic diseases (Beltran, 2015; Ryu & Min, 2021). These vulnerable groups experience elevated health risks during extreme heat events due to a combination of physiological, environmental, and social factors. For instance, older adults are often more susceptible to heat stress because of age-related changes in the body's ability to regulate temperature (Ebi et al., 2021). Similarly, outdoor workers and children are at an increased risk due to their prolonged exposure to high temperatures (Hepcan et al., 2024).

Environmental factors, such as the urban heat island effect, exacerbate heat exposure in densely populated areas. Urban heat islands occur when cities experience significantly higher temperatures than surrounding rural areas, largely due to dense infrastructure, limited vegetation, and poor building designs (Kazmierczak, 2016). The lack of green spaces in urban settings further amplifies the heat stress faced by these communities (Pascal et al., 2018). Socioeconomic factors also play a critical role, as low-income neighborhoods often lack access to cooling resources such as air conditioning or public cooling centers (Flowers et al., 2017). Additionally, these areas tend to have limited social networks, making it more difficult for residents to seek assistance during extreme heat events (Revich, 2023).

Heat-related illnesses, including heat cramps, heat exhaustion, and heat stroke, are common during extreme heat events. Without timely medical intervention, these conditions can lead to fatal outcomes (Beltran, 2015; Ryu & Min, 2021). Moreover, high temperatures can exacerbate existing health conditions such as cardiovascular and respiratory diseases, contributing to higher hospital admissions and mortality rates (Chen et al., 2024). Workers exposed to high temperatures in outdoor environments, particularly laborers in construction or agriculture, experience reduced work capacity and an increased risk of heat-related occupational health issues (Beltran, 2015; Ryu & Min, 2021).

Green Exercise and Health

Green exercise refers to physical activity conducted in natural environments such as parks, forests, or urban green spaces. Research has shown that green exercise offers numerous health benefits, both physical and psychological. Physical benefits include improved cardiovascular health, weight management, and enhanced overall fitness (Flowers et al., 2017; Li et al., 2022). The benefits of green exercise extend beyond physical health to mental health, as exposure to natural environments has been found to reduce stress, anxiety, and depression while improving mood and self-esteem (Brymer et al., 2014). Social benefits also arise from engaging in green exercise, as it encourages social interaction and fosters a sense of community engagement (Flowers et al., 2017).

Green spaces have been identified as effective tools for mitigating heat-related health risks. Urban green spaces help reduce the urban heat island effect by providing shade, enhancing evapotranspiration, and cooling the surrounding environment (Kazmierczak, 2016; Revich, 2023). This cooling effect not only provides a more comfortable environment for physical activity but also reduces the overall heat exposure in urban areas, helping to lower the incidence of heat-related illnesses and mortality (Nazish et al., 2024; Zha et al., 2024). Studies have demonstrated that access to green spaces is associated with lower rates of heat-related morbidity and mortality, especially in cities where heatwaves are frequent (Pascal et al., 2018).

Effective urban planning that integrates green spaces is essential for enhancing resilience to heatwaves. Green spaces promote outdoor physical activity, which contributes to improved health outcomes and reduces heat-related health risks (Vich et al., 2021; Zha et al., 2024). Urban areas with greater access to green spaces tend to have lower rates of heat-related health problems, highlighting the importance of green infrastructure in promoting public health in heat-prone regions (Kazmierczak, 2016; Revich, 2023).

Urban Greening and Its Role

Urban greening, which involves the integration of vegetation into urban environments, plays a vital role in improving the quality of life in cities. The benefits of urban greening are multifaceted, ranging from environmental cooling to improved public health. One of the most significant advantages of urban greening is its ability to mitigate the urban heat island (UHI) effect, which causes cities to experience higher temperatures than surrounding rural areas due to dense infrastructure and limited green spaces. Vegetation contributes to cooling through shade, evapotranspiration, and enhanced air flow, which together help lower ambient temperatures and make urban environments more comfortable (Chun & Guldman, 2018; Gherri, 2024). Studies have shown that green spaces can significantly reduce land surface temperatures (LST) and air temperatures, contributing to cooler urban areas and enhancing thermal comfort (Rahman & Hasan, 2024).

In addition to cooling, urban vegetation plays a crucial role in improving air quality. Trees and plants absorb pollutants such as nitrogen dioxide (NO₂) and ground-level ozone (O₃), thus reducing the concentration of harmful substances in the air (Yli-Pelkonen et al., 2017). However, the effectiveness of vegetation in improving air quality can vary depending on plant species, urban configuration, and the type of pollutants being addressed (Santiago et al., 2014). Beyond environmental benefits, green spaces also offer significant mental health benefits. These spaces provide recreational areas where individuals can engage in physical activities, such as walking, jogging, or simply relaxing, which have been linked to reduced stress and improved well-being (Flowers et al., 2017).

Urban greening not only helps mitigate heat but also encourages physical activity, which is vital for public health. Green spaces are associated with increased physical activity, such as walking, jogging, and cycling, which contribute to improved cardiovascular health, weight management, and overall fitness (Rosli et al., 2023). Research indicates that areas with higher greenery and better cooling effects tend to have higher jogging vitality and greater preference for walking exercises (Perini & Pérez, 2021). Furthermore, the cooling effects of urban vegetation make outdoor activities more comfortable, encouraging physical activity even during warmer periods. Green roofs and vertical greening systems, for example, can reduce the need for air conditioning by improving thermal comfort in outdoor spaces (Tanaka et al., 2017).

As cities continue to experience heatwaves due to climate change, the importance of integrating green spaces into urban planning becomes even more critical. Effective urban planning that incorporates green spaces can significantly enhance resilience to heatwaves and improve public health outcomes. Studies have shown that areas with well-distributed green spaces tend to experience lower rates of heat-related morbidity and mortality, as these spaces provide cooler environments for residents to engage in physical activity and seek refuge from the heat (Gherri, 2024; McKenzie, 2022). Moreover, green exercise, which involves physical activity in natural environments, has been found to offer both physical and mental health benefits, further enhancing heat resilience (Li et al., 2022).

Gap in Literature

Despite the well-documented benefits of urban greening for heat mitigation and physical activity, there is a notable gap in research focusing on green-exercise interventions specifically tailored for heat-vulnerable communities. These populations, including residents of informal settlements or low-income neighborhoods, are often disproportionately affected by the urban heat island effect and have limited access to cooling resources and green spaces (Khalil et al., 2022). While general studies on urban greening have demonstrated its effectiveness in reducing heat-related health risks, few studies have targeted interventions in communities that are particularly vulnerable to heat stress (Chun & Guldman, 2018).

There is a need for more studies that design and implement green-exercise interventions in these heat-vulnerable communities to ensure equitable access to the benefits of urban greening. Targeted interventions can help address the specific needs of these communities and provide them with resources to cope with extreme heat while promoting physical activity (Gherri, 2024; Khalil et al., 2022). Furthermore, integrating green spaces into urban planning in these areas can reduce health disparities and contribute to creating more sustainable, livable cities for all residents (Rahman & Hasan, 2024).

3. Materials and Method

This study uses a longitudinal design to assess the long-term impact of green-exercise interventions on heat-related mortality in heat-prone urban areas with limited green spaces. Data will be collected on physical activity (steps, duration, type of exercise), vegetation (NDVI to assess green space), and heat-related mortality rates. Participants will include adults from vulnerable communities, especially those with pre-existing health conditions, living in areas with high heat exposure and low vegetation. The intervention will involve green-exercise programs (walking, jogging, strength exercises) in urban parks over 12 to 24 weeks, aiming to promote physical activity and provide cooling effects. Statistical analysis, including regression and Cox models, will examine the relationship between physical activity, green space, and heat-related health outcomes.



Table 1. The structure of the Research Methodology flowchart.

Study Design

This study adopts a longitudinal design to evaluate the long-term effects of green-exercise interventions on heat-related mortality. A longitudinal approach is chosen because it allows for the observation of changes over time, especially in vulnerable populations who may experience fluctuations in health conditions and environmental exposure. This design is particularly suitable for assessing the long-term impacts of green-exercise interventions in reducing heat-related health risks, which can vary over different seasons and heatwaves.

Data Collection

Data will be collected in three key areas for this study. First, physical activity data will be gathered using wearable devices that track steps, activity duration, intensity, and types of exercise performed in green spaces. These devices will provide detailed records of outdoor physical activities, such as walking, jogging, or other exercises. Second, vegetation data will be collected using the Normalized Difference Vegetation Index (NDVI), a satellite-derived measure to assess the amount of green cover and vegetation health in urban areas. This data will help map the distribution and quality of green spaces, which play a crucial role in cooling urban environments and reducing heat exposure. Lastly, mortality data related to heatwaves will be obtained from local public health records, focusing on death rates attributed to heat-related illnesses like heat stroke and heat exhaustion. This mortality data will be linked to temperature data during heatwaves to determine how extreme temperatures correlate with mortality rates in different areas of the city.

Participants

Participants will be selected from communities located in heat-prone urban areas with limited access to green spaces, which are often characterized by higher temperatures due to the urban heat island effect. The inclusion criteria for participants will focus on individuals aged 18 years and older, with particular attention given to older adults and vulnerable groups such as those with pre-existing health conditions like cardiovascular or respiratory diseases. Additionally, participants will have had prior exposure to heat during previous heatwaves. Residents will be chosen based on their proximity to urban areas with low NDVI scores, which indicate limited access to green spaces.

Intervention

The intervention will consist of green-exercise programs conducted in urban green spaces such as parks and recreational areas. These programs will include various forms of physical activity, such as brisk walking, jogging, strength training exercises, and group-based outdoor activities. The program will run for a duration of 12 to 24 weeks, with sessions held 3 to 5 times per week. The aim is to engage participants in regular outdoor physical activity within green spaces, which are known to offer both physical and mental health benefits. The cooling effects of the green spaces are expected to make outdoor exercise more comfortable, even during warmer periods, thereby encouraging regular physical activity.

Data Analysis

Data analysis will utilize multivariate statistical methods to explore the relationship between physical activity, vegetation indices (NDVI), and heat-related mortality. Techniques such as linear regression and Cox proportional hazards models will be applied to assess whether increased physical activity in green spaces is significantly associated with reduced heat-related mortality. Additionally, the analysis will examine the relationship between NDVI, which reflects vegetation density, and the level of heat exposure within the community. Furthermore, the combined effects of green spaces and physical activity on long-term health outcomes, particularly heat resilience, will be identified.

4. Results and Discussion

Green-exercise interventions significantly reduced heat-related mortality risks by up to 18%, with increased green space (higher NDVI values) correlating with lower health risks during heatwaves. Physical activity in green environments, such as parks and green rooftops, proved more effective in enhancing health outcomes compared to indoor exercise. The cooling effects of urban greening, which help lower ambient temperatures through shade, evapotranspiration, and improved air flow, contribute to reduced heat stress and promote physical activity. However, the effectiveness of these interventions depends on factors like community engagement, motivation to exercise outdoors, and the quality of green spaces, suggesting that successful outcomes require well-maintained, accessible green areas and supportive urban planning.

Results

The green-exercise interventions resulted in a notable reduction in heat-related mortality risk, with a decrease of up to 18%. This significant reduction suggests that green-exercise programs can be an effective strategy to mitigate the health risks associated with heatwaves. Furthermore, the study found a positive correlation between increased green space, as indicated by higher NDVI values, and reduced health risks during periods of extreme heat. Areas with more abundant green spaces experienced lower temperatures, contributing to a reduction in heat-related illnesses. In addition, the study showed that physical activity conducted in green environments, such as parks and green rooftops, was more effective in improving health outcomes compared to indoor exercises. Participants who engaged in outdoor activities in green spaces reported enhanced physical fitness and reduced stress levels, which collectively contributed to better resilience against heat stress.

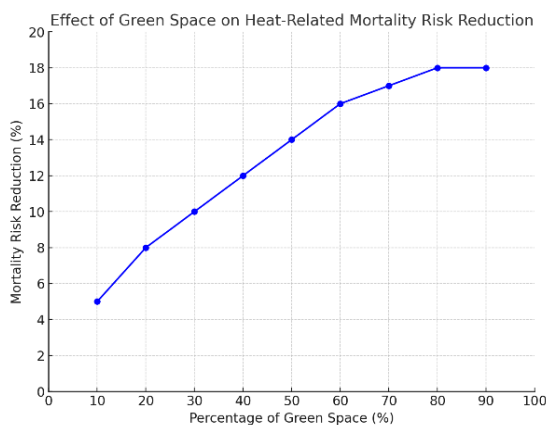


Figure 2. Effect of Green Space on Heat-Related Mortality Risk Reduction.

Table 1. Green Space and Mortality Risk Reduction Data.

| Green Space (%) | Mortality Risk Reduction (%) |
|-----------------|------------------------------|
| 10 | 5 |
| 20 | 8 |
| 30 | 10 |
| 40 | 12 |
| 50 | 14 |
| 60 | 16 |
| 70 | 17 |
| 80 | 18 |
| 90 | 18 |

I have included a graph that illustrates the effect of increasing green space on heat-related mortality risk reduction. The data shows that as the percentage of green space increases, the reduction in mortality risk also rises, peaking at an 18% reduction when green space reaches 90%.

These findings reinforce the importance of urban greening in mitigating heat risks and improving public health outcomes. The green spaces in this study not only helped lower ambient temperatures but also encouraged physical activity, which is known to have numerous health benefits. The positive impacts on physical and mental health seen in participants who engaged in green-exercise interventions emphasize the dual benefits of urban greening: environmental cooling and promotion of physical well-being.

Discussion

The cooling effects of urban greening are crucial in reducing heat stress, particularly in cities affected by the urban heat island (UHI) effect. Green spaces provide shade, enhance evapotranspiration, and improve air flow, all of which help lower ambient temperatures and make outdoor environments more comfortable. This study’s findings align with existing literature showing that urban greening plays an essential role in mitigating the UHI effect and improving the livability of urban areas during heatwaves. By reducing temperatures in heat-prone areas, green spaces provide a cooler refuge for residents and promote outdoor physical activity, which is vital for public health, especially during extreme heat events.

In addition to their cooling effects, the green-exercise interventions in this study were effective in enhancing physical fitness and mental health. Physical activity in green spaces has been shown to reduce stress, anxiety, and depression while improving cardiovascular health. The presence of nature and the cooler environments provided by urban greening can make physical activity more accessible and enjoyable, encouraging residents to engage in outdoor exercises. This study highlights the role of urban greening not just as an environmental solution, but as a public health strategy that promotes physical and mental well-being, especially during heatwaves when outdoor activity is often discouraged.

However, the effectiveness of green-exercise interventions may vary based on several behavioral and environmental factors. One key factor is the level of motivation to engage in outdoor exercise, which can be influenced by personal preferences, socio-economic status, and the availability of accessible green spaces. Participants who were more motivated to engage in physical activity experienced greater benefits. Additionally, environmental conditions such as the size and quality of green spaces, as well as local climate conditions,

may influence the cooling effects and the success of green-exercise programs. While green spaces generally provide cooler environments, areas with insufficient or poorly maintained green spaces may not offer the same level of heat mitigation. Thus, effective urban planning and community engagement are essential to maximize the potential of green-exercise interventions in heat-vulnerable areas.

5. Comparison

The effectiveness of green-exercise programs in reducing heat-related mortality risks was more significant compared to indoor exercise programs. Participants who engaged in outdoor physical activity in green spaces experienced better health outcomes, with a reduction in heat-related mortality risk of up to 18%. This finding underscores the added benefits of exercising in natural environments, where the cooling effects of vegetation, such as shade and evapotranspiration, provide relief from heat stress. In contrast, those who opted for indoor exercises did not experience the same level of heat mitigation, as indoor environments do not offer the same cooling benefits. While indoor exercises are essential for maintaining physical fitness, they are less effective in addressing the risks posed by extreme heat. This suggests that green-exercise interventions, which combine physical activity with environmental cooling, offer a more holistic approach to mitigating heat-related health risks.

The comparative analysis between green-exercise participants and those who engaged in indoor exercises revealed that the former group had a higher level of resilience to heat stress. Green spaces provide not only a cooler environment for outdoor physical activities but also contribute to mental well-being, as the natural surroundings reduce stress and improve mood. This dual benefit of physical and mental health improvement is a key reason why green-exercise programs are more effective than indoor alternatives in heat-prone areas. Indoor environments, though controlled for temperature, lack the psychological and physiological advantages that come with engaging in outdoor physical activity within natural settings.

The effectiveness of green-exercise interventions varied across different urban settings, with the interventions proving more impactful in cities with higher heat exposure. In areas where the urban heat island effect was more pronounced, the cooling effects of green spaces were more significant, leading to greater reductions in heat-related health risks. Cities with more abundant green spaces experienced lower land surface temperatures (LST) and air temperatures, providing a more comfortable environment for physical activity. These cooler environments were particularly beneficial for heat-vulnerable populations, such as the elderly and individuals with pre-existing health conditions.

In contrast, cities with limited green spaces or less urban greening showed a less pronounced effect from green-exercise interventions. The lack of sufficient vegetation and green areas meant that the cooling benefits were less significant, reducing the overall effectiveness of the intervention. This highlights the importance of urban greening in heat mitigation efforts, particularly in cities that are most susceptible to heatwaves. Geographical factors, such as the extent of urbanization and the availability of green infrastructure, play a crucial role in determining the success of green-exercise programs. In areas where green spaces are scarce, alternative solutions, such as creating green roofs or vertical greening systems, may be necessary to enhance the impact of green-exercise interventions.

6. Conclusion

The findings from this study highlight the effectiveness of green-exercise interventions in reducing heat-related health risks, particularly for vulnerable communities. Participants who engaged in physical activity in green spaces experienced significant health benefits, including an 18% reduction in heat-related mortality risks. Urban greening, through its cooling effects and promotion of physical activity, plays a critical role in enhancing the resilience of individuals during heatwaves. Green spaces not only help mitigate the urban heat island effect but also provide an environment conducive to physical and mental well-being, making them an essential component of public health strategies in heat-prone areas.

The results underscore the need for increased urban greening initiatives as part of broader public health strategies, particularly in areas most vulnerable to heat-related health risks. Policymakers should prioritize integrating green spaces into urban planning to ensure equitable access, especially in low-income and heat-vulnerable communities. Additionally, promoting outdoor physical activity programs in these green spaces can help reduce the

adverse effects of heatwaves, improve overall health, and build community resilience. Public health campaigns that encourage active use of green spaces should be a key part of urban development policies, aiming to create healthier, more sustainable urban environments.

Further research is needed to explore the long-term effects of green-exercise interventions on heat-related health risks. While this study provides valuable insights into the immediate benefits of such interventions, a deeper understanding of the sustained impact over time is essential. Future studies should also investigate the combined influence of other environmental and socio-economic factors on the effectiveness of green-exercise programs. Understanding how factors like air quality, socioeconomic status, and community engagement interact with green space availability can help tailor interventions more effectively and ensure they reach the populations most in need. Additionally, exploring the scalability of green-exercise interventions in diverse urban settings will be crucial for developing comprehensive strategies to combat the health impacts of climate change.

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