

Heat Wave Impact on Children: Addressing Vulnerability and Implementing Adaptation Strategies

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Abstract: Heat waves pose a significant threat to public health, particularly to children, who have a limited thermoregulatory capacity. With climate change exacerbating, extreme weather events, heat waves are becoming more frequent and intense. Exposure to extreme heat can lead to serious health issues in children, such as hyperthermia, heat stress, and renal dysfunction. This study employs a mixed-method approach to investigate the challenges faced by school children in Munirka, Delhi, during extreme heat events. Data was collected through student surveys (grades six to twelve), using semi-structured interviews with teachers and school administrators, and policy analysis of government interventions. The study evaluates school preparedness, identifies research gaps, and assesses policy effectiveness to inform decision-makers about necessary interventions. By assessing children's vulnerability to heat waves in Delhi, this research contributes to the broader understanding of how extreme heat impacts child health, education, and well-being, offering recommendations for climate adaptation in educational settings.

Keywords: heatwaves; climate change; child vulnerability; heat stress; adaptation

1. Introduction

Climate change has intensified the frequency and severity of extreme weather events, including floods, droughts, and heat waves. Among these, heat waves pose a significant threat to human health, particularly in tropical and subtropical regions like India ([World Meteorological Organization \[WMO\], 2023](#)). According to the Global Climate Risk Index, India ranked tenth among the most climate-affected countries in 2022, experiencing an average of 114 heat wave days annually ([Eckstein et al., 2022](#)). Data from the India Meteorological Department (IMD) further indicate a rising decadal trend in heat wave occurrences, exacerbating health and economic vulnerabilities ([IMD, 2023](#)).

Heat waves are often termed "silent killers" because their health impacts are not always immediately visible but contribute to increased morbidity and mortality over time ([Patz et al., 2021](#)). Between 2010 and 2016, central and northwestern India witnessed a significant increase in heat waves, with rising global temperatures driven by anthropogenic greenhouse gas emissions ([Intergovernmental Panel on Climate Change \[IPCC\], 2023](#)). Official data show that heat-related deaths surged from 3,014 (2001–2005) to 5,157 (2011–2015), highlighting the urgent need for targeted mitigation and adaptation strategies ([National Disaster Management Authority \[NDMA\], 2022](#)).

Children are among the most vulnerable groups to extreme heat due to their developing thermoregulatory systems, higher metabolic rates, and greater outdoor exposure ([Basu et al., 2020](#)). Studies suggest that children generate more internal heat, absorb more environmental heat, and sweat less per kilogram of body weight than adults, increasing their susceptibility to heat-related illnesses ([Sheridan & Kalkstein, 2019](#)). Heat stress also impacts cognitive performance, school attendance, and mental well-being, potentially leading to long-term developmental consequences ([Parkinson et al., 2022](#)). Despite these concerns, limited research has been conducted on the direct impact of heat waves on children's health and education in India ([Srivastava et al., 2021](#)).



This study aims to fill this research gap by investigating the specific challenges faced by school children in Munirka, Delhi, during extreme heat events. It evaluates school infrastructure, preparedness strategies, and government policies designed to mitigate heat-related risks in educational settings. Furthermore, the study examines how heat exposure influences children's hydration, concentration, and academic performance. By employing a mixed-methods approach, this research provides data-driven insights to strengthen school adaptation measures and inform policy interventions for child-centered climate resilience.

A growing body of research establishes that heat waves significantly impact human health, leading to increased hospitalizations, dehydration-related complications, and mortality (Vanos et al., 2020). Children, in particular, are at greater risk of heat stress, cognitive decline, and kidney disease, given their unique physiological responses to extreme temperatures (Jay et al., 2021).

Most prior studies on heat-related mortality and morbidity have focused on adults and the elderly, with limited attention given to children (Gasparrini et al., 2022). In the United States, research has shown that school infrastructure—including air conditioning, shaded outdoor areas, and access to drinking water—plays a crucial role in mitigating heat stress (Cedeño-Laurent et al., 2019). European studies have similarly highlighted that poor classroom ventilation and inadequate hydration facilities exacerbate heat-related risks in students (Lavigne et al., 2021).

However, India lacks region-specific research on children's vulnerability to heat waves (Rohini et al., 2022). While some studies have examined the general health impacts of extreme heat, such as rising heat stroke cases and hospital admissions, little research has been conducted on the direct consequences for school children, their learning environments, and adaptation strategies (Bandyopadhyay et al., 2020).

By analyzing the experiences of school students in Munirka, this study builds upon existing research while addressing critical gaps in India's heat adaptation policies concerning children's health and education. The findings contribute to climate adaptation policies, ensuring educational institutions are better equipped to protect children from extreme heat events.

2. Methodology

A mixed-methods approach was employed to collect and analyze both quantitative and qualitative data, providing a comprehensive understanding of the impact of heat waves on school children in Munirka, Delhi. This location was selected due to its socio-economic diversity, allowing for a nuanced exploration of how different student groups experience and cope with extreme heat conditions.

2.1. Sample Selection

The study included 100 students from both government and private schools, covering grades six to twelve. While efforts were made to ensure diversity in socio-economic backgrounds and school types, gender representation in the sample was not strictly equal due to participant availability. This is acknowledged as a limitation, and findings related to gender differences are interpreted accordingly.

A convenience sampling strategy was employed to facilitate accessibility while incorporating a broad representation of students from various residential and school environments. Although this approach may introduce selection bias, measures were taken to improve representativeness. Future research could enhance generalizability through randomized or stratified sampling techniques.

2.2. Data Collection Methods

1. Surveys
 - A structured questionnaire was administered to students, assessing their exposure to heat waves, hydration habits, classroom conditions, and heat-related health symptoms.
 - The survey incorporated both closed-ended (multiple-choice, Likert scale) and open-ended questions to capture both quantitative trends and qualitative insights.
2. Interviews
 - Semi-structured interviews were conducted with teachers and school administrators to explore existing heat management strategies, infrastructure challenges, and gaps in policy implementation.
 - The number of interviews varied across participant categories due to availability and willingness to participate. However, thematic saturation was ensured for data validity.
3. Observational Study
 - Researchers conducted school visits to assess physical infrastructure, including classroom ventilation, drinking water availability, cooling mechanisms, and student density.
 - These observations provided contextual evidence to support the survey and interview findings.

2.3. Data Analysis

- Quantitative data (survey responses) was analyzed using descriptive statistics, including frequency distributions and percentage analysis.
- Qualitative data (from interviews and open-ended survey responses) was analyzed using thematic analysis, identifying recurring patterns in student experiences, school preparedness, and policy gaps.
- Given the unequal gender distribution, findings related to gender differences are reported cautiously, with explicit acknowledgment of this limitation.

2.4. Ethical Considerations

- Informed consent was obtained from all participants, with parental/guardian consent secured for minors.
- Confidentiality and anonymity were strictly maintained to protect participants' identities.
- Ethical approval was obtained from the institutional review board, ensuring compliance with research ethics and child protection guidelines.

3. Results

Children are extremely vulnerable to heat waves, facing challenges such as decreased study hours, lower attendance, and difficulty concentrating. The majority of students reported experiencing heat-related illnesses, with symptoms including confusion, nosebleeds, fatigue, fever, muscle cramps, dizziness, headaches, and diarrhea. Sports participants noted decreased efficiency during heat waves, and incidents of students fainting during morning assemblies have increased.

"During morning assembly, I often feel dizzy, and some of my classmates have even fainted," said a 10th-grade student from a government school.

Despite awareness of heat-related symptoms, students often lack knowledge of specific medical terms and management strategies. Many students reported inadequate cooling infrastructure in schools, including insufficient shaded areas in playgrounds, lack of first-aid facilities, and absence of water coolers. In contrast, some schools conduct seminars and webinars to raise awareness about heat waves, but overall, there is an urgent need for effective mitigation and adaptation strategies. Given the reality of climate change, immediate steps must be taken to prevent worsening conditions in the future.

PARAMETERS	KEY FINDINGS
Participation in Outdoor Activities	• Majority of the students participate in outdoor sports during hot weather • Sports children show better immunity to heat waves compared to non-sports children
Hydration and Heat Illness Experience	• Daily water consumption varies, indicating different hydration habits
Cooling Infrastructure	• Significant number of students have experienced heat-related illnesses (e.g., heat exhaustion, heat stroke) • Inadequate cooling facilities in many schools (e.g., insufficient fans, air conditioning, water coolers)
Awareness of Symptoms and Preventive Measures	• Most students are aware of heat-related symptoms and the importance of seeking medical attention although they were not familiar with the medical terms • Awareness of preventive measures like staying hydrated, appropriate clothing, and avoiding peak heat hours
Impact on Daily Life	• Heat-related illnesses affect focus, school attendance, and physical performance • Reduction in outdoor activities due to heat concerns
School Policies and Preparedness	• Mixed responses on the existence and effectiveness of school policies and preparedness drills • Some schools conduct webinars and seminars to create

	awareness amongst students while, others lack formal procedures
Emergency and Preventive Facilities	• Need for better emergency facilities like ice packs, health drinks, and first-aid kits in schools • Recommendations for shaded areas, proper ventilation, and water coolers at playgrounds

3.1. Participation in Outdoor Activities

Most students participated in outdoor sports during hot weather (Figure 1). Sports children appeared more resilient to heat waves than non-sports students, likely due to better physical conditioning and acclimatization. However, both groups reported a decline in efficiency. Sports students noted decreased physical performance, while non-sports students experienced difficulty concentrating and reduced academic performance due to the heat. "As a footballer, I have adapted to managing heat and conserving energy, unlike non-athletes who may struggle in similar conditions. While anyone can develop these skills, athletes are more conditioned to endure physical challenges. This survey provided valuable insights that will help me improve further," shared a student.

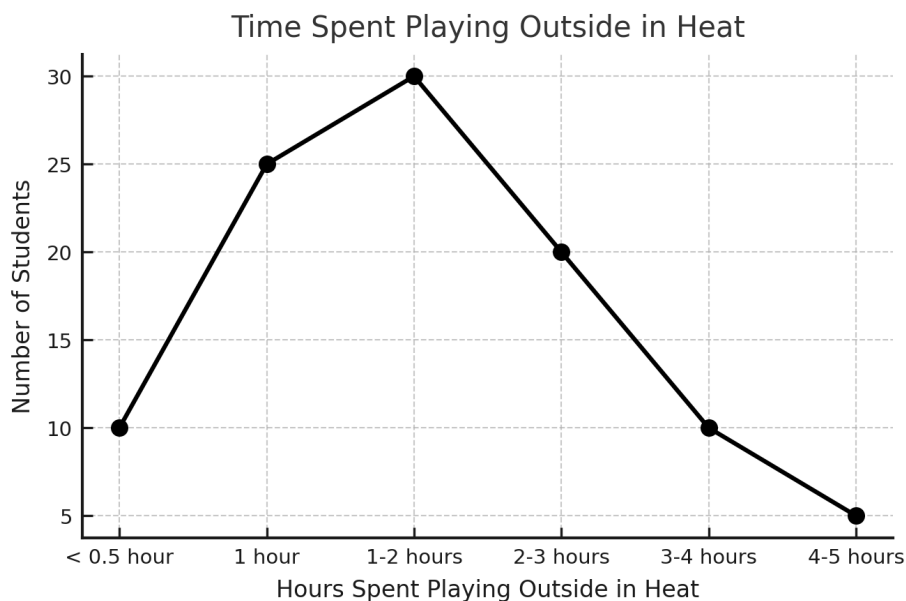


Figure 1. Depicting hours spent by school students playing outside in heat.

3.2. Hydration and Heat Illness Experience

Daily water consumption varied, indicating different hydration habits among students. A significant number reported experiencing heat-related illnesses such as heat exhaustion, heat cramps, and heat rash. Common symptoms included dizziness, headaches, nausea, confusion, nosebleeds, diarrhea, and fatigue during outdoor activities (Table 1).

Table 1. Frequency of Heat-Related Symptoms Reported by Students.

SYMPTOMS	PERCENTAGES OF STUDENTS REPORTING
Headache	68%
Dizziness	54%
Fatigue	47%
Nosebleeds	32%

Confusion	30%
Nausea	64%
Muscle Cramps	29%
Diarrhea	25%

Note: The total percentage exceeds 100% because students reported experiencing multiple symptoms simultaneously. Each percentage represents the proportion of students who experienced a specific symptom, not mutually exclusive categories.

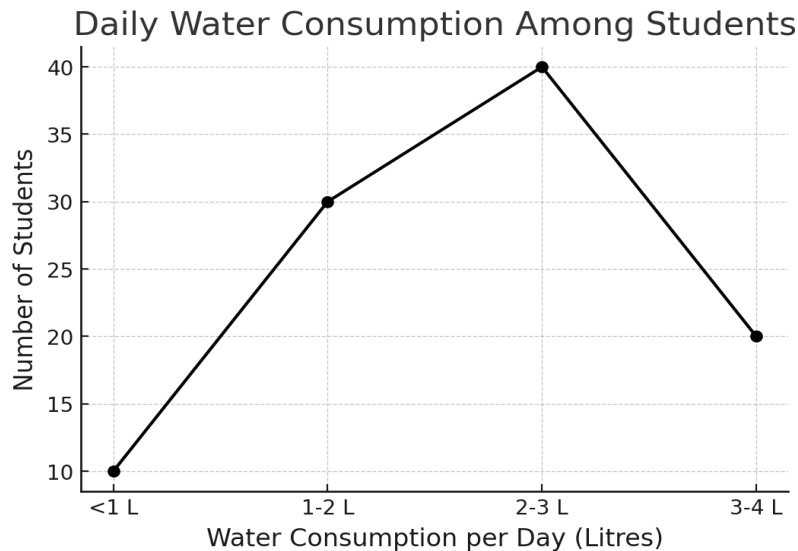


Figure 2. Depicting water consumption in litres per day by the students.

Some students reported that consuming electrolytes enhanced their ability to cope with heat stress by maintaining hydration and preventing fatigue (Figure 2). This aligns with existing literature, which emphasizes the role of electrolyte intake in thermoregulation and reducing the risk of heat-related illnesses (Sawka et al., 2007). Proper hydration, particularly with electrolyte solutions, has been shown to improve endurance and cognitive function in hot environments (Casa et al., 2010).

3.3. Awareness of Symptoms and Preventive Measures

Most students were aware of heat-related illness symptoms and the importance of seeking medical attention. They recognized the significance of staying hydrated, wearing appropriate clothing, and avoiding outdoor activities during peak heat hours.

3.4. Impact on Everyday Life

Heat-related illnesses significantly affected students' ability to focus on studies and attend school regularly. Many reported reducing outdoor activities due to heat concerns. High temperatures also negatively impacted their physical performance and endurance.

"We try to keep classroom windows open, but the heat makes it difficult to concentrate," noted a teacher from a private school.

3.5. Cooling Infrastructure

Many students reported inadequate cooling infrastructure in schools, including insufficient fans, air conditioning, water coolers, and shaded areas. Similar issues were noted at home, with some students lacking proper cooling facilities, increasing their vulnerability during heat waves.

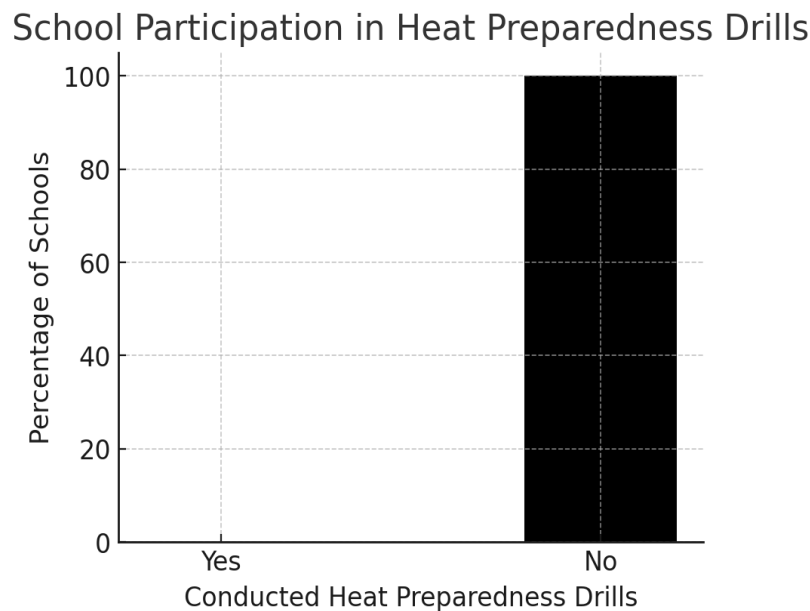
3.6. School Policies and Preparedness

A majority of students stated that their schools lacked effective policies and preparedness drills for heat-related emergencies. While some schools conducted regular heat-related webinars, others had no

formal training.

3.6.1. Lack of Awareness and Training

The absence of preparedness drills suggests that many students and staff may not be adequately trained to recognize and respond to heat-related illnesses, leading to delayed emergency responses and increased health risks (Figure 3).



Note: Both government and private schools do not conduct heat preparedness drills.

Figure 3. Depicting school participation in Heat Preparedness drills.

3.6.2. Inconsistent Safety Measures

The disparity between home and school environments in terms of heat-related safety measures leaves students vulnerable. While many parents take precautions at home, the absence of similar measures in schools undermines these efforts.

3.6.3. Potential Health Risks

Without proper training, students may not recognize heat-related symptoms or know the immediate steps to take, increasing the likelihood of severe health impacts.

3.7. Parental Precautions Against Heat-Related Illnesses

Most students reported that their parents or guardians took precautions to mitigate heat-related risks, demonstrating a proactive approach to children's safety.

3.7.1 Installing Cooling Infrastructure

Many families installed fans, water coolers, and air conditioning units to maintain a cooler indoor environment, reducing heat exposure and preventing heat-related illnesses (Figure 4).

3.7.2. Ensuring Hydration

Parents emphasized hydration, providing water, electrolyte drinks, and fluids to prevent dehydration and heat exhaustion. Hydration is crucial for thermoregulation and preventing heat-related illnesses, as dehydration impairs the body's ability to dissipate heat, increasing the risk of heat exhaustion and heat stroke (Sawka et al., 2015). Proper hydration enhances fluid balance, exercise performance, and resilience to heat stress (Kenefick, 2018). Studies indicate that individuals with better hydration habits adapt more effectively to high temperatures, reducing the adverse effects of heat exposure (Nuccio et al., 2017). These findings support the study's results, highlighting hydration as a key strategy for mitigating

heat stress in students.

3.7.3. Providing Appropriate Clothing

Parents ensured children wore light, breathable clothing to help regulate body temperature and prevent overheating.

3.7.4. Education and Reminders

Parents regularly reminded children to drink water and take breaks during outdoor activities to maintain hydration and prevent heatstroke.

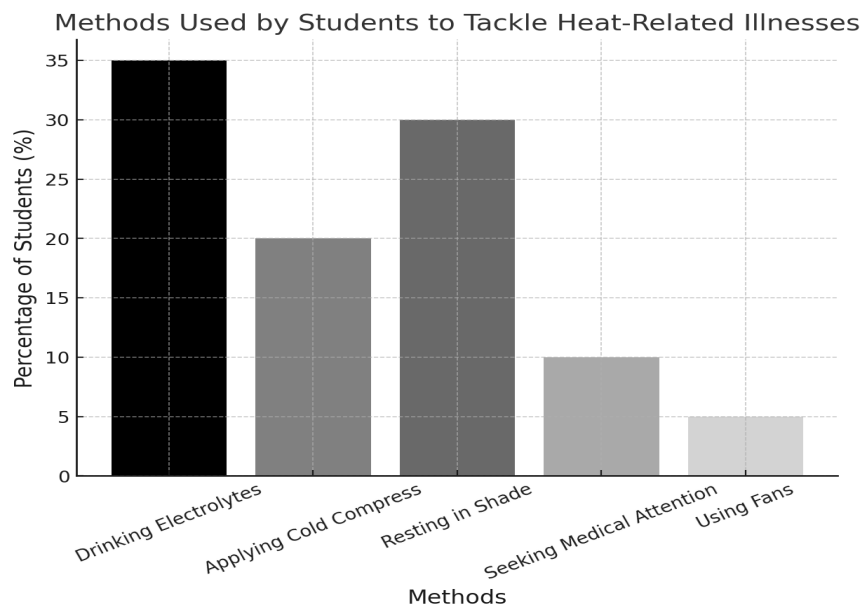


Figure 4. Depicting methods used by students to combat heat.

4. Discussion

The increasing frequency and severity of heat waves due to climate change underscore the urgent need for targeted interventions to protect schoolchildren. Heatwaves significantly impact children's physical and mental health, limiting outdoor activities, reducing concentration, and increasing susceptibility to heat-related illnesses. This study found that students frequently experience heat stress symptoms, including dizziness, fatigue, and headaches, particularly in schools with inadequate cooling infrastructure. Government schools reported higher classroom temperatures and poorer ventilation compared to private institutions, with many lacking adequate cooling solutions. Some schools faced water scarcity, exacerbating dehydration risks and negatively affecting students' academic performance.

4.1. Health and Academic Impacts

Prolonged exposure to extreme heat can lead to heat exhaustion, disrupt sleep patterns, and increase mortality risk, particularly for children with pre-existing health conditions ([Department of Human Services, 2009](#)). High temperatures negatively impact cognitive performance, reducing concentration, lowering test scores, and increasing absenteeism. Many students reported difficulty engaging in outdoor activities, highlighting the physical toll of excessive heat. Additionally, school closures due to extreme heat disrupt academic schedules, potentially leading to long-term economic implications, such as a less skilled workforce and increased social welfare costs.

4.2. School Infrastructure and Policy Gaps

Despite the risks, India lacks a robust heatwave action plan specifically addressing school preparedness. While some schools conduct awareness seminars, most do not have formal preparedness policies. Teachers and administrators expressed concerns over the absence of structured protocols for heatwave-related school closures or infrastructure improvements. The National Action Plan on Climate Change (NAPCC) and state-level Heat Action Plans provide broad guidelines but fail to address school-

specific vulnerabilities ([Government of India, 2008](#)). Integrating heat resilience strategies into education policy is crucial to safeguarding children from extreme temperatures.

4.3. Adaptation Strategies and Recommendations

To mitigate the risks associated with heatwaves, adaptation strategies must focus on infrastructure improvements, hydration accessibility, and awareness initiatives. Schools should incorporate heat-resilient designs, such as insulated roofs, shaded outdoor spaces, and improved ventilation systems. Government initiatives should fund water coolers, air circulators, and tree plantations to lower indoor and outdoor temperatures. Heat warning systems and structured acclimatization protocols for students engaging in outdoor sports are essential to minimize heat stress risks. Given the significant impact of heat on learning, policymakers should prioritize school-based climate adaptation programs.

4.4. Feasibility and Implementation

While infrastructure improvements require financial investment, government incentives, school infrastructure grants, and public-private partnerships could help bridge resource gaps. Low-cost interventions, such as modifying school schedules to avoid peak heat hours and ensuring access to hydration stations, can be immediately implemented. Future research should explore the feasibility of cost-effective cooling technologies for schools in heat-prone regions.

4.5. Study Limitations and Future Research Directions

This study acknowledges several limitations. The reliance on self-reported data introduces potential bias, as students may underreport or overestimate their experiences. Additionally, the sample was limited to specific schools in Munirka, Delhi, which may affect the generalizability of findings to other regions. Future research should incorporate larger, more diverse samples and employ objective temperature and hydration tracking to enhance data accuracy. Longitudinal studies examining the long-term effects of heatwaves on academic performance and health outcomes would further strengthen the understanding of this issue.

5. Conclusion

Children are among the most vulnerable populations affected by heatwaves, a risk that is intensifying due to climate change and El Niño events. Urban areas like Delhi experience disproportionately severe impacts due to the urban heat island effect, which amplifies extreme temperatures. Given that heatwaves are becoming the new normal, there is an urgent need for proactive adaptation and mitigation strategies to safeguard children's health, education, and overall well-being.

Mitigation strategies should prioritize nature-based solutions such as increasing tree cover, developing rooftop gardens, and integrating climate-responsive infrastructure in schools. Structural adaptations, including the use of reflective wall paints, improved ventilation, and water coolers on each school floor, can significantly reduce heat stress. Shaded playgrounds and pavilions can further enhance heat resilience, allowing children to engage in outdoor activities safely.

Beyond infrastructural changes, policymakers must integrate heatwave preparedness into national and regional climate action frameworks. This includes enforcing heat-action plans for schools, conducting awareness programs, and ensuring access to cooling centers during extreme heat events. Strengthening governance and implementing evidence-based interventions will be critical in minimizing the long-term health and cognitive development risks associated with heat exposure.

Future research should expand the scope of this study to other regions of India, assess the long-term physiological and psychological impacts of heatwaves on children, and evaluate the effectiveness of proposed adaptation measures. A multidisciplinary approach, involving collaboration between policymakers, educators, healthcare professionals, and urban planners, is necessary to build climate-resilient schools and communities.

Addressing the growing threat of heatwaves is not just a matter of climate adaptation—it is a public health imperative. Taking immediate action will not only protect the well-being of children but also contribute to broader efforts in climate resilience and sustainable development.

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