School Buildings & Education Pathway
MMC Heat Preparedness Plan Heat Health Research Brief

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Social determinants of health are the conditions in which people live that affect a wide range of health risks and outcomes. Our social context, economic situation, and built environment can buffer climate impacts by providing us a means to cope or adapt. They can also amplify climate impacts, especially among communities that have been subjected to structural racism and other inequities. MAPC identified six social determinant pathways through which people experience climate-driven extreme heat impacts. For each pathway, MAPC conducted a brief literature review and summarized the findings into a short memo.

Key Insights

- Most Americans spend 90 percent of their time indoors, with children spending more of that time in school buildings than in any other setting other than their home. Young children are more susceptible to heat stress because they are less able to regulate their body temperature compared to adults and are more dependent on others for adaptation.
- Education is the primary pathway to better, more stable jobs that pay higher incomes and that allow families to accumulate wealth. Education is also associated with greater adherence to health-promoting behaviors and longer, healthier lives.
- Most studies on the effect of heat in school environments focus on impacts to cognitive functioning and student academic performance, rather than direct effects to students' health. Studies consistently found that exposure to high temperatures impairs cognitive function, learning, and academic performance. Lower classroom temperatures and improved thermal comfort were associated with better performance on standardized exams and assessments of cumulative learning outcomes. Studies also found cumulative and potentially synergistic effects of ventilation and indoor temperatures.
- Field surveys of classroom temperatures over the last five decades have found that these standards are inconsistent with students' thermal preferences, such that classroom temperatures are often warmer than temperatures conducive to students' comfort and academic performance. Using adult-based thermal standards results in greater heat exposures for children, who are less able to cope with higher temperatures relative to adults.
- Building tightening and insulation, combined with safety related restraints on opening windows and lack of external shading may increase heat retention during warmer seasons. Researchers warned against a "single-sided" view of reducing heating loads without appropriate consideration of ventilation and year-round occupant thermal comfort.

Recommendations

- Conduct local assessments of heat impacts in childcare and school settings to understand how climate-driven heat affects occupant health and academic performance. Assessments should analyze heat impacts in association with other indoor environmental quality factors, specifically ventilation and indoor air quality.
- Improve ventilation and cooling in school buildings and prioritize indoor environmental quality, including year-round thermal comfort, in school building energy retrofits and new construction. Schools should take advantage of funding opportunities in the region and at federal level to apply for grants aiming to promote climate resiliency. [Example: Funding Opportunities for Mass. Schools to Invest in Indoor Air Quality & Heat Resilience (mapc.org)]

Research Summary

Most Americans spend 90 percent of their time indoors, with children spending more of that time in school buildings than in any other setting other than their home. Exposure to high temperatures at school can undermine children's health and academic performance. Young children, especially, are more susceptible to heat stress because they are less able to regulate their body temperature compared to adults. They are also more likely to depend on adults and institutions for adaptive behaviors, such as access to water or the freedom to change location or clothing. High density of people within classrooms may also exacerbate exposures.[1,2] School buildings are also workplaces, influencing the health and job performance of educators and other school personnel. This brief summarizes research on health impacts in the context of education. Occupational exposures are not emphasized in this brief, which are explored separately in the Employment Pathway Brief.

Connections Between Health and Education

People with higher levels of educational attainment live longer and healthier lives. Education is the primary pathway to better, more stable jobs that pay higher incomes and that allow families to accumulate wealth. [OBJ] Adults with higher education attainment are also more likely to adopt healthy behaviors, such as nutritious diets and exercise, and enjoy greater levels of social support. Alternatively, adults with fewer years of schooling report worse general health, more chronic and mental health conditions, experience more functional limitations and disability. They are also more likely to smoke, have unhealthy diets, and exercise less frequently. [3] Education has

[1] Teli, D., Bourikas, L., James, P.A.B., Bahaj, A.S. (2017). Thermal Performance Evaluation of School Buildings using a Children-Based Adaptive Comfort Model. Procedia Environmental Sciences, 38, 844-851.

[2] Zamorodian, Z.S., Tahsildoost, M., Hafezi, M. (2016). Thermal comfort in educational buildings: A review article. Renewable and Sustainabile Energy Reviews, 59, 895-906.

a stronger effect on the health of women than men and on non-Hispanic whites than non-white adults. Persistent inequities in educational opportunity exist across school settings, neighborhoods, race/ethnicity, and family resources.[3] Climate-driven heat may worsen disparities in academic achievement and long-term educational health and financial outcomes. In the US, heat's adverse effect on academic performance was found to be significantly larger for students who are Black, Indigenous, and people of color (BIPOC) and students in lower-income school districts. Financial returns on education are lower for Black, Indigenous, and People of Color (BIPOC) individuals, as evidenced by the persistence of Black-white wage gaps even among adults with advanced degrees.[3] The relationship between health and education can also go both ways. Good health contributes to success in schooling. Regardless, the effects of education on health are significant even when controlling for various other factors. Controlling family social economic status diminishes but does not eliminate the association between kindergarten academic performances and wages later in life.[4] The impacts of education on health are cumulative over the lifespan. Small changes in educational achievement, including those resulting from environmental quality impacts in schools, can result in long felt differences and disparities in health and financial wellbeing.

Impact of Heat on Learning and Academic Performance

Most studies on the effect of heat in school environments focus on impacts to cognitive functioning and student academic performance, rather than direct effects to students' health (e.g., self-reported health, observed health symptoms, illness-related absences). Cognitive function consists of tasks such as memory, attention, and reasoning that are critical for a person's ability to think and problem-solve.[5] Studies consistently found that exposure to high temperatures impairs cognitive function, learning, and academic performance. High temperatures increase fatigue, reduce concentration, and can lead individuals to spend less time on laborious or challenging activities. Similarly, high temperatures may also impact teachers' capacity to teach.[6] Several studies found that lower classroom temperatures and improved thermal comfort were associated with better performance on standardized exams and assessments of cumulative learning outcomes. One study of 12,000 US school districts found that students in school during hotter years scored worse than peers in the same district schooled during cooler periods, even when controlling for changes in school funding and demographic composition, exam-day temperatures, and other factors.[6]

Several studies also suggested that temperature standards for school buildings may not support student thermal comfort. The American Society of Heating, Refrigerating, and Air-Conditioning

[3] Wilson, V. (2016). African Americans are paid less than whites at every education level. Economic Policy Institute. Retrieved from https://www.epi.org/publication/african-americans-are-paid-less-than-whites-at-every-education-level/

[4] Hahn, R. A., & Truman, B. I. (2015). Education improves public health and promotes health equity. *International journal of health services*, *45*(4), 657-678.

[5] Taylor, L., Samuel, L.W., Marshall, H., Dascombe, B.J., Foster, J. (2016). The impact of different environmental conditions on cognitive function: a focused review. Frontiers in Physiology, 6, 372.

[6] Park, R.J., Behrer, A.P., Goodman, J. (2021). Learning is inhibited by heat exposure, both internationally and within the United States. Nature Human Behavior, 5, 19-27.

Engineers (ASHRAE) recommends indoor summer temperatures maintained between 23 and 26 degrees Celsius (73-79° F). These temperature ranges are considered acceptable for sedentary or light active uses of spaces and most consequentially, are based on adult overheating thresholds. ASHRAE does not prescribe a specific recommendation for thermal comfort of children. Field surveys of classroom temperatures over the last five decades have found that these standards are inconsistent with students' thermal preferences, such that classroom temperatures are often warmer than temperatures conducive to students' comfort and academic performance.[7] Using adult-based thermal standards results in greater heat exposures for children, who are less able to cope with higher temperatures relative to adults.[1] Thermal preferences are also sensitive to acclimatization. Students in climates with lower winter temperatures have a harder time adapting to higher classroom temperatures. Studies found that household adoption of air conditioning in warmer, humid climates also decreased the comfort temperature of students over a period of twenty years, suggesting that improved access to cooling at home has raised students' expectations in classrooms.[5]

Across most studies, indoor temperatures comprised one of several indoor environmental quality (IEQ) indicators measured in classrooms. Other IEQ measures commonly included relative humidity, bacteria, dust, and carbon dioxide (as a proxy for ventilation rates and indoor air quality). Poor indoor environmental quality in classrooms has been associated with reduced academic performance, symptoms of chronic conditions, and illness-related absenteeism. Independently, poor ventilation is associated with increased visits to school nurses due to respiratory symptoms and illness-related absences due to increased exposure to indoor air pollutants.[8] Studies also found cumulative and potentially synergistic effects of ventilation and indoor temperatures. Schools with lower, more comfortable temperatures and higher than average ventilation had a higher share of students testing satisfactorily on standardized exams than students in classrooms with high temperatures and poor ventilation. [9] Findings also suggest that students may tolerate higher temperatures with better ventilation. Mechanical fans improve thermal comfort with less energy consumption than air conditioning by improving ventilation within classrooms. Classroom ventilation rates often do not meet ASHRAE standards, even though ventilation alongside temperature regulation is fundamental to student health and academic performance.[5]

Two studies discussed classroom heat exposure as a potential unintended consequence of school building energy efficiency improvements. In colder climates focus has efficiency efforts has been on reducing energy consumption related to winter heating needs. Building tightening and insulation, combined with safety related restraints on window opening and lack of external

[7] Zamorodian, Z.S., Tahsildoost, M., Hafezi, M. (2016). Thermal comfort in educational buildings: A review article. Renewable and Sustainabile Energy Reviews, 59, 895-906.
[8] Haverinen-Shaughnessy, U., & Shaughnessy, R.J. (2015). Effects of Classroom Ventilation Rate and Temperature on Students' Test Scores. PloS ONE, 10(8), e0136165.

[9] Haverinen-Shaughnessy, U., & Shaughnessy, R.J. (2015). Effects of Classroom Ventilation Rate and Temperature on Students' Test Scores. PloS ONE, 10(8), e0136165.

shading may increase heat retention during warmer seasons. Researchers warned against a "single-sided" view of reducing heating loads without not appropriate consideration of ventilation and year-round occupant thermal comfort.[1,5] This is becoming increasingly important in Massachusetts, where spring and fall are getting warmer.

Climate-driven heat may worsen disparities in academic achievement and long-term educational health and financial outcomes. In the US, heat's adverse effect on academic performance was found to be significantly larger for BIPOC students and students in lower-income school districts. Potential reasons for these disparities include differences in access to school and home air conditioning and to other resources that could compensate for heat impacts. High indoor temperatures were also found to have larger impacts on academic achievement among younger students.[6] Younger children are more sensitive to heat stress and more heavily reliant on adults and institutions for coping strategies. Researchers also hypothesized that air conditioning may be less available in elementary schools relative to middle or high schools.[6] Given that the effects of education on health outcomes accumulate over the lifespan, small effects of heat on learning could result in large disparities over time.

State of School Buildings in Massachusetts

The most recent statewide assessment of conditions in school buildings occurred in 2016, carried out by the Massachusetts School Building Authority. The survey does not specifically collect data on temperatures, air conditioning, or ventilation quality in school buildings. Instead, it assigns an overall rating for the general conditions of the school's major building systems, such as roofing, HVAC, windows, and flooring. In 2016, 84.1% of schools received a rating of 1 or 2, on a 1-4 scale. 15.7% of schools received the lower rating of 3 or 4, meaning that the site and building conditions require moderate to extensive renovations. Slightly over half of the 3 and 4 ratings went to elementary schools.[10] Within the largest school district in Massachusetts, Boston Public Schools, only about a quarter of schools have central air conditioning and more than half of schools have inadequate ventilation systems according to a 2017 report.[11] A June 2020 heat wave, with multiple days of 90+ degree weather, led many school districts in the region to cancel classes or dismiss students early from classes because schools were unequipped to maintain safe indoor temperatures.[12] Increasing frequency and severity of extreme heat threatens more frequent interruptions to schooling if measures are not taken by school districts to improve access to in classroom cooling or shift class schedules to avoid periods of excessive heat.

[10] Massachusetts School Building Authority. (2016). 2016 School Survey Report.
[11] Vaznis, James. (2017). Many Boston public schools are said to have bad air. The Boston Globe. https://www.bostonglobe.com/metro/2017/03/01/quality-air-schools doubt/3bvfLoTzSepVGXvsL9HKhM/story.html
[12] Kaufman, Amanda (2021). Boston Teachers union denounces classroom temperatures amid heat wave, calls for improvements to school HVAC systems. The Boston Globe. Retrieved from: Boston Teachers Union denounces classroom temperatures amid heat wave, calls for improvements to school HVAC systems - The Boston Globe

Research Needs

- The impacts of heat in education are strongly dependent on contextual factors, suggesting a need for more localized assessments. Impacts vary across climate zones, classroom occupancy levels, differences in occupation periods throughout the day and year, building characteristics, occupant acclimatization, and freedom to adopt adaptive behaviors, such as changing clothing or opening and closing windows and blinds.[5] Few studies have been conducted within the United States, specifically the Northeast, with most studies emerging from Europe and Asia.
- Other gaps we also included impacts associated with out of school time use of educational facilities and early childhood settings, such as in-home childcare and childcare centers. School buildings are increasingly being used throughout the year for community programs and social service provision, and the higher sensitivity of young children to heat impacts suggests that early childhood environments may be high risk settings for climate-driven heat impacts. Heat-related community engagement within the region has highlighted overheating issues experienced by childcare providers, program administrators, and parents in relation to childcare and school buildings.