Linking Indoor Overheating and Mortality: A Risk-Based Assessment of Heatwave Impacts on Buildings and Occupants

Nicholas Paradza

La Rochelle Université
23 Av. Albert Einstein,
17000 La Rochelle
France

ABSTRACT

Climate change is driving an unprecedented increase in the frequency, duration, and intensity of heatwaves across Europe, transforming indoor overheating from a matter of thermal discomfort into a critical public health emergency. In Metropolitan France, recent summers have shown that the built environment is a primary modifier of heat exposure. Yet, current adaptation strategies often prioritise winter energy efficiency over summer health resilience. This research bridges the disciplinary gap between building physics and epidemiology to propose a novel, quantitative risk assessment framework. The study defines heatwave risk through the integration of three probabilistic components: hazard (climate exposure), vulnerability (building performance), and impact (mortality outcomes). This study utilises a comprehensive dataset covering Metropolitan France, combining daily average temperature with daily mortality data (2019–2024). The hazard component is determined by calculating the probability that outdoor temperatures exceed the Minimum Mortality Temperature (MMT). To quantify impact, the study employs Distributed Lag Non-Linear Models (DLNM) with a quasi-Poisson regression. This epidemiological approach captures the complex, delayed health effects of heat, revealing that mortality risks persist for up to 21 days post-exposure. For the vulnerability assessment, dynamic thermal simulations (EnergyPlus) were conducted on five representative residential archetypes classified by construction period (i.e., 1950, 1982, 2005, 2012, and 2020), under free-floating conditions. Logistic regression was applied to these simulation outputs to generate fragility curves, representing the probability of indoor temperatures exceeding health-critical thresholds (26 °C night/28 °C Day) for three consecutive days. The results showed that older, uninsulated masonry buildings (1950) are often considered thermally poor, but they perform comparatively better during heatwaves due to higher thermal mass and envelope permeability. In contrast, modern, highly insulated, and airtight buildings (RT2012 and RE2020 standards) exhibit a “heat-trapping” effect. The study found that occupants in RE2020-compliant dwellings face a heat-attributable mortality risk of 0.9%, nearly double the 0.53% risk observed for 1950s typologies, highlighting a severe trade-off between energy conservation and summer health safety. Furthermore, the risk matrix analysis identifies that the highest cumulative mortality burden is not driven by rare, extreme peaks (> 32 °C), but by frequent, moderate heat events (28 -30 °C). These temperatures occur often enough to generate substantial cumulative physiological stress yet are frequently overlooked in emergency planning. This research provides a scalable, risk-based metric, Attributable Risk (AR), that empowers policymakers to move beyond simple temperature thresholds. The findings advocate for an urgent revision of building codes to include mandatory summer performance certificates and passive cooling requirements. By quantifying the lethal potential of indoor overheating in energy-efficient housing, this framework offers a vital decision-making tool for urban planners seeking to align decarbonization goals with the preservation of human health in a warming climate.

KEYWORDS

Indoor Overheating, Heatwave Mortality Risk, Building Vulnerability, Attributable Fraction, Fragility Curves