Outdoor Microclimate Variations and Indoor Thermal Stress: Summer Field Measurements in an Elderly Care Facility

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ABSTRACT

Cities are becoming warmer due to climate change, which worsens both indoor and outdoor thermal conditions. This challenge is particularly critical for vulnerable residents of elderly care facilities, where combined indoor and outdoor heat exposure can severely threaten health and wellbeing. This study reports a summer field campaign at an elderly care facility in Ghent, Belgium, designed to evaluate recent heat stress in and around the building. We simultaneously monitored indoor and outdoor thermal environments at 4 spots with typical urban microclimate settings (street canyon, inner courtyard, park area with semi-shaded, park area with exposure) and in 7 resident rooms with different orientations and surrounding microclimates. Rooftop and pedestrian-level weather stations, together with indoor HOBO data loggers, recorded air temperature, relative humidity, wind speed and solar radiation. Outdoor (pedestrian level) and indoor heat stress were quantified using two thermal comfort indices – Physiological Equivalent Temperature (PET) and Standard Effective Temperature (SET). Post-hoc comparison tests were applied to identify significant differences in heat stress between sites and rooms, and an explainable machine-learning approach (SHapley Additive exPlanations) was used to identify the main driving factors. The exposed park spot experienced the highest outdoor heat stress, with total exceedance degree-hours between 600°Ch and 1,100°Ch above different heat stress thresholds (29°C, 35°C, 41°C). The semi-shaded park showed roughly half of this value, demonstrating that tree cover ratio could substantially reduce outdoor heat stress. The street canyon and courtyard showed similar outdoor heat stress levels, with intermediate exceedance degree-hours between those of the two park locations. The machine-learning analysis indicated that air temperature (during day and night) and solar radiation (during daytime) are the dominant drivers of outdoor heat stress at pedestrian level. Indoors, all top-floor resident rooms showed higher heat stress than ground-floor rooms. Top-floor rooms facing the street canyon and the courtyard on the top floor had the most severe conditions, with exceedance degree-hours based on 26°C threshold of 136°Ch and 75°Ch, respectively. In addition, two ground-floor rooms with similar orientation but different surrounding microclimates (facing semi-shaded park and courtyard), showed a difference in indoor heat stress. Their maximum difference in the indoor comfort index reaching about 1.42 °C. This indicates that, beyond room orientation, the neighbouring microclimate around the building may also impact indoor thermal stress. Overall, the findings highlight the need to consider outdoor morphology parameters, such as tree cover ratio and impervious cover ratio that help lower ambient temperature leading to outdoor microclimate variance, when considering indoor heat stress mitigation strategy. Further investigation should be conducted for assessing different factors for indoor thermal stress with building-microclimate coupling simulations.

KEYWORDS

Indoor thermal stress, Outdoor microclimate, Field measurement, Elderly care facility