



Are Buildings Enough? The Role of Caregiver Behaviour in Indoor Environmental Quality and Occupant Health

SUMMARY

Climate change, increasing heat extremes, and the need for healthy indoor environments pose growing challenges for buildings housing vulnerable populations. This comparative investigation combines two complementary components with different data-collection methods: an institution-level survey of elderly care homes addressing overheating and adaptation practices, and a six-month kindergarten case study focusing on ventilation behaviour, indoor CO₂ and illness-related absenteeism. The care-home survey revealed substantial variation in building characteristics and adaptation measures, while the kindergarten study showed pronounced differences in indoor air quality associated with adults' window-opening behaviour. Although the environmental stressors differ, both components examine settings in which vulnerable occupants depend on caregivers to regulate their environmental exposure. The findings highlight the importance of appropriate building operation and caregiver practices for maintaining healthy and resilient indoor environments.

KEYWORDS

Indoor environmental quality (IEQ); Vulnerable populations; Occupant behaviour; Climate change adaptation, care facilities

INTRODUCTION

The increasing frequency of heat extremes and the growing emphasis on healthy indoor environments introduce new challenges for buildings accommodating vulnerable populations (White-Newsome et al., 2012) in a changing climate . Both Children and elderly people are more vulnerable to poor indoor air quality (IAQ) than adults: children breathe a greater volume of air per unit body weight, their respiratory and immune systems are still developing and both groups spend a large share of their day indoors (Daisey et al., 2003; Holgate et al., 2020; Adamopoulos, 2025).The study aimed to investigate how staff-mediated practices influence the indoor environmental exposure of occupants who cannot independently control their environment.

METHODS

The elderly care home component was based on an institution-level survey, conducted in the elderly care facilities in Budapest. The questionnaire was distributed by e-mail to the managers of all 73 identified elderly care institutions in Budapest, followed by telephone contact where necessary. The collected variables included building age and capacity, energy-related renovations, shading, ventilation and cooling equipment, perceived summer thermal conditions, perceived changes in health-related problems during heatwaves, and the operational adaptation measures implemented by staff. Completed questionnaires were received from 30 of the 73 institutions, corresponding to a response rate of approximately 41%. Together, the participating institutions provided accommodation for 3,085 residents.

The kindergarten case study examined the same dependence on caregiver-operated environmental controls, focusing on teacher-mediated window opening and indoor air quality. While care-home staff influence residents' exposure to heat through shading, ventilation, hydration, and daily routines, kindergarten teachers directly affect children's exposure to indoor air pollutants through their window-opening practices. In both settings, the vulnerable occupants have limited opportunities to modify their immediate environment independently.

The kindergarten investigations were carried out in a childcare facility in rural Hungary. The building is renovated, insulation levels and airtightness were increased, but mechanical ventilation was not installed. IAQ measurements were conducted in four group rooms for six months, covering all seasons. The time-series dataset of the monitoring campaign was supplemented by weather data, in-house occupancy, type of absence documentation (institutional aggregated dataset), and also with subjective data: occupant behaviour-related interviews with teachers. Associations between indoor CO₂ exposure and subsequent illness-related absenteeism were evaluated using Spearman's rank correlation coefficient. To evaluate potential delayed effects of poor IAQ, cross-correlation analyses with time lags ranging from one to ten days were also performed. With Abbe and Kruskal-Wallis tests, seasonality and weather trends could be controlled for.

RESULTS AND DISCUSSION

The elderly care homes represented a heterogeneous building stock, 17 reported window replacement, 10 heating-system modernization, and 9 thermal-insulation improvements, often in combination. Nevertheless, 20 institutions (66%) characterized upper-floor rooms as warm or very warm. This suggests that renovations primarily targeting winter energy performance may not provide sufficient protection against summer overheating. In addition, 43% of respondents reported more frequent health-related problems during heatwaves, emphasizing residents' vulnerability to elevated thermal stress.

The availability of technical measures varied considerably. Shading was present in 80% of institutions, while only 26% reported fans, 13% automatic ventilation, and two facilities air conditioning. Consequently, heat protection relied largely on operational practices. All institutions used night-time ventilation, while cold drinks (86%), modified daily routines (83%), and daytime shading (76%) were also common. However, 70% reported opening windows during hot daytime periods, which may increase indoor temperatures when outdoor air is warmer. This highlights that effective heat protection depends strongly on how and when staff operate available building controls.

In the child-care facility, indoor CO₂ levels exceeded 2000 ppm for more than two hours on the majority of monitored days in three of the four rooms which is lower than cat. 4 criteria according to standard EN 13779. Differences in IAQ were consistent with differences in window-opening behaviour reported in the teacher interviews.

The statistical analyses further showed that prolonged exposure to elevated CO₂ concentrations was associated with increased illness-related absenteeism after a delay of approximately 7–10 days. This time lag is consistent with the incubation period of common respiratory infections and the delay between symptom onset and medically confirmed absence.

The findings should be interpreted considering several limitations: only one kindergarten was monitored, 30 of 73 care institutions responded to the survey. The two study components address different vulnerable populations and environmental challenges, and the observed associations should therefore be interpreted with appropriate caution. The care-home component also relies on self-reported institutional information and may therefore be affected by reporting bias. Future work will extend the monitoring campaign to multiple childcare facilities to improve the general applicability of the findings.

CONCLUSIONS

The combined findings demonstrate how building characteristics, operational practices and occupant vulnerability interact in care environments. Technical improvements alone may not ensure healthy indoor conditions: energy renovation without adequate ventilation may be associated with poor indoor air quality, while renovated care homes may remain vulnerable to overheating without effective solar protection, cooling opportunities and operational protocols. Building interventions should therefore be accompanied by evidence-based guidance for staff on window opening, shading, hydration, daily scheduling and the use of cooler spaces. Caregivers and staff consequently form an active part of the building's environmental control system and play a decisive role in translating technical performance into health protection for vulnerable occupants.

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REFERENCES

Adamopoulos IP, Syrou NF, Mijwil M, Thapa P, Ali G, Dávid LD. 2025. A scoping review. *Electron J Gen Med*. 2025;22(2).

Daisey JM, Angell WJ, Apte MG. 2003. *Indoor Air*. 2003;13(1):53–64.

Holgate S, Grigg J, Arshad H, Carslaw N, Cullinan P, Dimitroulopoulou S, et al. 2020. *RCPCH/RCP*.

White-Newsome JL, Sánchez BN, Jolliet O, Zhang Z, Parker EA, Dvonch JT, O'Neill MS. 2012. *Environmental Research*. 112:20–27.