Monitoring the prevalence and intensity of overheating in English care homes during summer 2022

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ABSTRACT: Summer 2022 was the joint hottest on record in England, with outdoor temperatures >40 °C and five separate Level 3 Heat Health Alerts. During the heat periods excess deaths were 6.2% above the five-year average, with older people being most vulnerable. This paper presents research gathered from 41 care homes across England during summer 2022. Longitudinal monitoring of indoor and outdoor air temperature and relative humidity conducted in multiple locations within each care home allowed investigation of how building characteristics affected propensity for overheating. Spikes in temperature exceeded 40 °C within three care homes and 35 °C within 14 care homes. Mean temperatures in London care homes were nearly 2 °C warmer than those elsewhere. Upper-floor rooms were significantly warmer than ground floor rooms, and urban/suburban care homes significantly warmer than rural care homes. Other characteristics (building age, size, room orientation) showed much less significant differences in temperature distributions between groups. The use of CIBSE overheating metrics (Guide A, TM52 and TM59) revealed endemic overheating across the care homes. This study has identified some differences between rooms/care home types that could help inform the future design and operation of care homes to protect against the negative consequences of overheating.
KEYWORDS: Overheating, residential care, summer, temperature, humidity

1. INTRODUCTION

Summer 2022 was the joint hottest on record in the England, with outdoor temperatures exceeding 40 °C for the first time since records began [1]. The UK Health Security Agency (UKHSA) issued Level 3 Heat Health Alerts for five distinct heat periods from June to August 2022. During these periods, excess deaths were 6.2% above the five-year average [2], with older populations most affected. These statistics are reminiscent of findings from studies following the Europe-wide heatwave of August 2003, when excess mortality during the ten-day heatwave in England was 33% in those aged 75 and over, and only 14% in the under-75's [3, 4], with a quarter of heat-wave-related deaths occurring in care homes and mortality in London increasing by 3% for every 1 °C increase in daily average temperature over 21.5 °C [5].

Public Health England (now UKHSA) identified 24.5°C as the threshold above which excess heat-related mortality may become apparent [6], principally through cardiovascular and respiratory disease. Rising temperatures and heatwaves increase risks to physical and emotional health, but also have significant financial implications in terms of the cost of adapting buildings, operating active cooling systems, and potential reduction in productivity [7].

The Climate Change Committee's 2022 report [8] identified key characteristics that affected whether individual buildings overheat during hot weather: location (London and the south of England experiencing more frequent and intense extreme high temperatures than the rest of the UK); urbanisation (the urban heat island effect); Building type (flats and well insulated buildings having an increased risk of overheating); occupant behaviour (e.g. window-opening and curtain-closing patterns).

The UK Government's Climate Change Risk Assessment report [9] and the 2018 National Adaptation Programme [10] have identified summertime overheating in care settings as a key risk and research priority for the health and social care system. The design and operation of care settings in the UK has historically focussed on keeping residents warm since they are vulnerable to cold [11]. At the same time, there has been a relative lack of attention to the risk of summertime overheating in unprepared care homes [12].

Summertime overheating is widespread, even in newer buildings [13]. The characteristics of new-build energy-efficient housing – airtight and well insulated – can make them particularly prone to this problem. In addition, features such as heated corridors (common in elderly care settings but not normally found in general housing), and the use of window-opening restrictors, may also contribute to overheating. Increasing thermal mass and improving ventilation can help when designing new care homes, with additional ventilation and solar shading strategies also beneficial [14].

Several studies have investigated care homes using computer simulations with predicted climate scenarios. Others have conducted longitudinal monitoring in a small sample of care homes. This paper presents analysis of longitudinal environmental monitoring gathered from 41 care homes across England, allowing consideration of a wide range of

building typologies and characteristics and how these may affect care homes' propensity for overheating.

2. METHODOLOGY

Hobo MX1101 and MX1102A (accuracy of ±0.21 °C, ±2% RH) devices monitored air temperature and RH in indoor rooms categorised as bedrooms (115 resident rooms, occupancy varying from nights only to 24/7; day hours 07:00-22:00), lounges (46 communal rooms used by multiple residents and staff during the day; occupied hours 08:00-20:00), and offices (34 staff-only rooms; occupied hours 09:00-17:00). Weather-proofed Hobo MX2301 (accuracy of ±0.2 °C, ±2.5% RH) devices monitored outdoor temperature and relative humidity (RH) at each care home. The devices were shielded from radiation. Note that whilst operative temperature is the ideal measure to calculate overheating, differences in operative and dry bulb (air) temperature tend to only be significant in indoor spaces with high levels of exposed thermal mass or high indoor air velocity [15], neither of which applied to the case study care homes. Furthermore, the Hobo devices used cost less and were smaller and more discreet than operative temperature monitors, and therefore more appropriate for deploying over long periods.

Care homes serve as both domestic spaces for the residents and non-domestic spaces for the staff. CIBSE's three overheating metrics were investigated with this in mind. CIBSE Guide A defines overheating when 1% or more of occupied hours exceed 28 °C in living areas or 26 °C in bedrooms. Fixed maximum air temperatures do not allow for occupants' ability to adapt to their environment. Therefore, CIBSE TM52 was considered, deriving threshold comfort temperature $T_{threshold}$ from the running daily mean of outdoor temperatures. The metric has three criteria: (1) no more than 3% of occupied hours (May-Sep) more than 1 °C above $T_{threshold}$; (2) daily weighted exceedance W_e <6 (where $W_e = \Sigma(DT \times H_{DT})$, DT=temperature difference above $T_{threshold}$ and H_{DT}=hours spent above DT); (3) maximum indoor temperature <4 °C above $T_{threshold}$. Overheating is deemed to have occurred if at least two of the three criteria are failed. CIBSE TM59 combined dynamic and static criteria: (A) no more than 3% of occupied hours (May-Sep) more than 1 °C above $T_{threshold}$; (B) No more than 1% of overnight hours in bedrooms over 26 °C annually; (C) no more than 3% of occupied hours > 26 °C annually. Overheating is deemed to have occurred if any of these criteria are failed. Criteria B and C consider proportions of annual hours. The data available therefore provide indicative results for TM59 rather than definitive results.

Typology analysis considered the characteristics of the care homes. Building age groups were informed by Standard Assessment Procedure (SAP) building age bands: Pre-1930, 1930-1976, 1977-2002, and Post-2002. 'Locality' consisted of three groups: urban (surrounded by shops, hospitals, offices etc), suburban (residential neighbourhoods), and rural (countryside or small villages). Regional locations were defined as North (from Merseyside to Tyne and Wear); Midlands (Northamptonshire, Warwickshire, Oxfordshire, and Gloucestershire), South (Hampshire, West Sussex, and the Isle of Wight); and Greater London. 'Proximity to coast' defined coastal care homes as those located within 10 km of the coast (a definition used in agriculture to identify the effect of coastal climates). Care home build type considered whether the building was purpose built or converted from a previous use. Care home size was based on number of bedrooms (small: <30, medium: 30-59, large: 60 or more). In addition, the floor and orientation of rooms were considered.

3. RESULTS FOR THE 41-CARE HOME SAMPLE

3.1 Temperature

Monitored indoor temperatures varied widely over the Jun-Aug 2022 period, exceeding 40 °C in three care homes and exceeded 35 °C in 14 care homes (**Error! Reference source not found.**). Outlier low temperatures were in unoccupied (and therefore unheated) bedrooms, indicating that many care homes maintained some level of background heating provision throughout the whole year. Analysis focussed on occupied hours as defined above (all hours for bedrooms). (Average temperatures were 25.2 °C (mean) and 25.0 °C (median), with a quartiles of 23.7 °C and 26.4 °C.

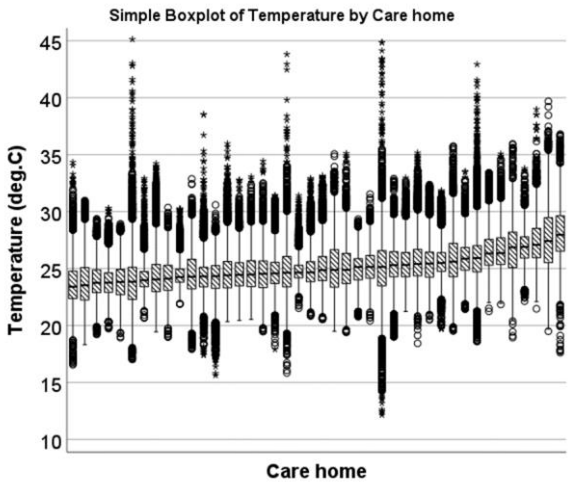

Figure 1 Boxplot showing the distribution of monitored temperatures during occupied hours (lounges and offices) and all hours (bedrooms) across the 41-care home sample.

Analysis of temperatures distributions for monitored locations disaggregated by different

categories revealed interesting findings, both in differences and similarities between the groups.

Disaggregating by location revealed London care homes were 1.8-2.2 °C warmer (mean/median) than those in other regions. The 25th C for London (25.2 °C) was almost the same as the 75th Cs in the north and south care home groups (25.4 and 25.5 °C respectively). Bedroom night-time hours in London were 1.8-2.2 °C (mean) warmer than bedrooms in other regions. There was little to distinguish between temperature distributions in the care homes in the north, midlands and south.

Urban and suburban care homes were 0.8-1.0 °C (mean) warmer than rural care homes. Compared to rural bedrooms, urban and suburban bedrooms were 1.3-1.4 °C (mean) warmer during the day and 1.2 °C (mean) warmer at night. Inland care homes were 1.0 °C (mean) warmer than coastal care homes.

Differences depending on building age were less pronounced. Pre-1930 care homes were 0.5-0.8 °C (mean) cooler than care homes built after 1930. However, these older care homes also had the most extreme outliers, exceeding 45 °C in once instance. Bedrooms in care homes built in the oldest two groups (i.e. pre-1977) experienced the greatest differences between day and night temperatures, a 0.4-0.5 °C drop at night compared to 0.1-0.2 °C drop in bedrooms in the newer care homes, possibly due to thermal mass in older buildings. Grouping care homes by size or build type (purpose built or converted/extended) made no significant difference to indoor temperature distributions.

Ground floor rooms (including rooms in single-storey buildings) were 0.8-0.9 °C cooler than those on middle and top floors. Room orientations were defined thus: rooms facing SE, S or SW were grouped as Southerly, those facing NW, N or NE were Northerly, those facing SE, E or NE as Easterly, and those facing NW, W or SW as Westerly. Some rooms were therefore in two groups, others were internal rooms. Consequently, the sample size was different for this stage of the analysis. Interestingly, southerly orientated rooms were not significantly warmer than northerly rooms, with means, medians and quartiles all within 0.0-0.2 °C of one another. Easterly orientated rooms were around 0.5 °C warmer (mean, median, quartiles) than westerly rooms.

3.2 Relative humidity

Relative humidity (RH) within the monitored care homes varied widely over the Jun-Aug 2022 period, with lows below 30% and highs above 80%. While peaks above 70% were rare, lows below 30% were common and found in all but one care home. During occupied hours, the overall mean and median RH were 45.6% and 45.3% respectively, with a lower quartile of 39.7% and upper quartile of 51.0%. This lower quartile indicates that across the whole dataset, more than a quarter of RH readings were below the recommended 40-60% range during occupied hours.

RH in London care homes was 4.8-10.9% lower (mean) than in other regions. Care homes in the South tended to have higher RH, likely due to their coastal proximity: coastal care homes had mean RH 6.6% higher than inland care homes; inland care homes had RH below 40% for a third of occupied hours compared to only 9% of occupied hours for coastal care homes. Only 48% of occupied hours were within the 40-60% recommended RH range in London care homes, with more than half of occupied hours below 40% (Figure 2). In contrast, rooms in care homes across the rest of England had RH between 40 and 60% for 70-80% of occupied hours.

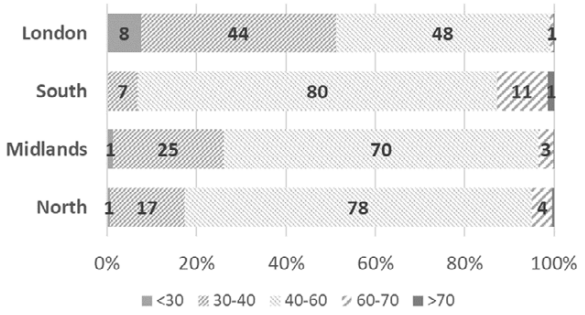

Figure 2 Stacked bar chart showing percentage of occupied hours within the recommended 40-60% RH range, grouped by region.

RH in rural care homes was 3.9-4.8% higher than in urban and suburban localities, and within 40-60% RH for almost 80% of occupied hours compared to 69% (suburban) and 63% (urban). Only 11% of occupied hours were below 40% in rural care homes, compared with 26% (suburban) and 31% (urban). Rural care homes' surroundings (trees, bushes, grass, water etc.) would raise the outdoor RH levels. Pre-1930 care homes had higher RH than those built later. Building size and type made little difference to distributions of RH.

Monitored ground floor rooms had higher RH than those on middle or top floors. More than three quarters of occupied hours in ground floor rooms were in the 40-60% RH range, compared to only 61-63% of occupied hours in middle and top floor rooms. Ground floor rooms were below 40% RH for 17% of occupied hours compared to 31-35% of occupied hours in middle and top floor rooms. Room orientation made no significant difference to RH distribution.

3.3 Overheating

Overheating was investigated for the 33-care homes (149 rooms) sub-set which had monitoring

data covering the full May-Sep 2022 non-heating period. Overheating was endemic during this period, with 95% of rooms failing CIBSE Guide A metric, 62% of rooms failing CIBSE TM52 metric and 99% of rooms failing CIBSE TM59 metric. The binary pass/fail for these overheating metrics did not help identify the severity of overheating. Therefore, analysis also considered how often locations were overheating according to each metric.

CIBSE Guide A found overheating in all 50 monitored locations in London care homes, and in 93-94% of monitored rooms across the rest of England. CIBSE TM52 was much more forgiving: 43-44% of monitored rooms in the Midlands and South overheating compared to 63% in the North and 82% in London (Figure 3). The cooler climate in the north meant lower threshold comfort temperatures and consequently more rooms failing this metric. Whilst London's warmer outdoor temperatures raised threshold comfort temperatures, this was not enough to prevent over 4/5ths of monitored rooms to overheat. Metric TM59 was the least forgiving metric, with all but two monitored locations overheating.

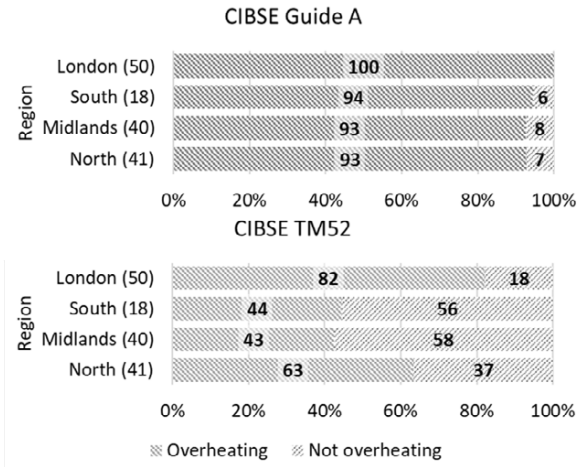

Figure 3 Grouped by region, proportion of monitored locations found to be overheating according to CIBSE Guide A (top) and TM52 (Bottom).

For each overheating metric/criterion, the proportion of monitored occupied hours when the temperature threshold was exceeded has been considered. For CIBSE Guide A, bedrooms were more likely to fail than lounges and offices due to the lower temperature threshold (Figure 4). London bedrooms, lounges and offices exceeded temperature thresholds much more than those in other regions. The three criteria for TM52 produced quite different results, but with similar trends. London bedrooms failed Criterion 1 far more often than bedrooms in other regions. Criterion 2 (daily weighted exceedance) was failed far less often in north and midlands care homes than those in the south and London. Criterion 3 (temperatures <4 °C above $T_{threshold}$) was rarely failed and only for a very small percent of occupied hours.

Whilst most rooms failed CIBSE Guide A, the few that did not fail were in either the oldest Pre-1930 care homes or the newest ones built post-2002. The oldest care homes were more likely to have rooms fail CIBSE TM52 compared to care homes built after 1930. There was little to distinguish between building age groups in terms of how often they exceeded temperature thresholds. More recently built care homes, particularly those purpose built since 2002, were not overheating much more or less than those built in the decades or even centuries before.

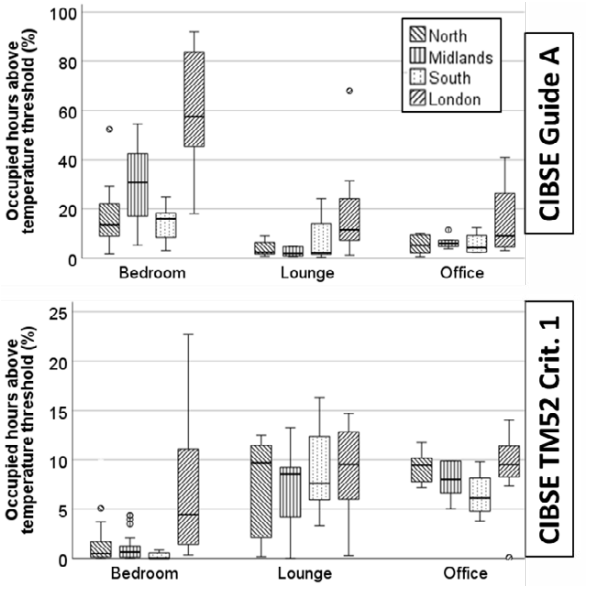

Figure 4 Clustered by region and grouped by room type, proportion of occupied hours above temperature threshold according to CIBSE Guide A (26 ℃ bedrooms, 28 ℃ lounges and offices) and CIBSE TM52, Criterion 1.

Rooms in both purpose-built and converted/ extended care homes were almost equally likely to fail CIBSE Guide A. CIBSE TM52 was failed in a higher proportion of rooms in converted/extended care homes than from rooms in purpose-built care homes. There was very little to distinguish between the two build-type groups when considering CIBSE Guide A in more detail. There was very little to differentiate between lounges and offices in purpose-built and converted/extended care homes for any of the three TM52 criteria. There was little to distinguish between bedrooms in converted/extended and purpose-built care homes with regards to TM59 criterion 2. In summary, the differences between rooms in converted/extended and purpose-built care homes were minimal, with only very subtle differences found for specific criteria.

All seven of the monitored locations to pass CIBSE Guide A were located on the ground floor. Ground and middle floor rooms were significantly more likely

to pass CIBSE TM52 compared to rooms on the top floors (41-42% pass compared to only 26% pass respectively). Both rooms which passed TM59 were both located on the ground floor. Bedrooms on the ground floors exceeded 26 °C much less often than those on middle or top floors. Ground floor bedrooms that exceeded the temperature threshold defined by CIBSE TM52 Criterion 1 did so far less often than bedrooms on middle or top floors. In summary, ground floor rooms – particularly bedrooms – exceeded the temperature thresholds less often than rooms on middle or top floors of the care homes. Although there were subtle differences, rooms on middle and top floors tended to have similar temperatures and overheating results as one another. This contradicts findings of other studies suggesting that top-floor rooms/flats may be more at risk (e.g.[16, 17], although these studies tend to have investigated high-rise apartment blocks rather than buildings such as care homes and hotels with only a few floors and larger footprints).

Despite the southerly orientated rooms experiencing significantly more solar gains than those facing in a northerly direction, the temperature distributions and overheating characteristics of the two groups were remarkably similar. The differences between easterly and westerly rooms were much more significant than differences between northerly and southerly rooms. Bedrooms and lounges that were orientated westerly exceeded the overheating temperature thresholds less often those orientated easterly. Whilst both orientations should in theory receive similar levels of solar gains over the course of a day, easterly rooms will receive these in the mornings. The resulting higher temperatures would remain throughout the day. Westerly orientated rooms would not receive solar gains until later in the day, with the opportunity to purge some of this heat overnight coming much sooner.

4 Discussion

This paper has gathered and analysed temperature and RH data gathered from 41 care homes (195 rooms) from Jun-Aug 2022, and overheating in a subset of 33 care homes (149 rooms) from May-Sep 2022, with a focus on identifying significant differences in these data streams depending on the characteristics of the care homes or rooms. Regarding the overheating metrics, 95% of monitored rooms failed CIBSE Guide A, 99% failed CIBSE TM59, but only 62% failed CIBSE TM52.It is worth considering that since most residents spend most/all of their time indoors, outdoor temperatures may not have much influence on their comfort temperatures, particularly compared to staff who come and go from the building much more often. Furthermore, the ability of elderly residents to adapt physiologically to their local environmental conditions may be reduced, particularly those with underlying health concerns. Key findings can be grouped according to care home locations, care home buildings and individual room characteristics.

With regards to location, rooms in London care homes were around 2 °C warmer than rooms in other regions. Consequently, they were much more likely to fail overheating metrics, particularly TM52, and to exceed the temperature thresholds of these metrics for much greater proportions of occupied hours. Rooms in rural locations were around 1 °C cooler than rooms in suburban and urban locations. Rural rooms were less likely to fail CIBSE Guide A and much less likely to fail TM52. Rural bedrooms exceeded the overheating temperature thresholds less often than bedrooms in suburban and urban care homes. Coastal care homes were around 1 °C cooler than in inland care homes. Consequently, coastal rooms were less likely to fail CIBSE Guide A and TM52, and when they did fail, coastal rooms exceeding overheating temperature thresholds less often than those inland.
With regards to the care home buildings, the oldest age group of care home (Pre-1930) had slightly lower temperatures than care homes built since 1930. However, the relationship between build age and overheating performance was difficult to define: Monitored rooms in Pre-1930 and Post-2002 care homes exceeded CIBSE Guide A temperature thresholds less often than monitored rooms in care homes built in between. This distinction was not seen when measured against TM52. Large care homes experienced less extreme temperatures than small and medium care homes, but their overall temperature distributions were very similar. Differences in how often overheating metrics were failed were only marginal.

With regards to individual rooms, rooms located on ground floors were almost 1 °C cooler than those on middle and top floors. There was little difference between rooms on middle or top floors. There was surprisingly little to distinguish between rooms orientated to the north and rooms orientated to the south. However, rooms orientated to the west were around 0.5 °C cooler and exceeded overheating thresholds less often than those orientated east.

The findings from this study should provide useful insights for those involved in the design of new care homes or the refurbishment of existing care homes. Characteristics that make buildings or individual rooms more vulnerable to overheating should be considered and, where possible, measures taken to mitigate these risks. To minimise installation and running costs, as well as carbon emissions, passive solutions (shading, enhanced natural ventilation, use of thermal mass) should be prioritised over active cooling measures (air conditioning).

5 Conclusion

This study has provided useful insights into which typologies/groupings have the most significant differences in indoor environment/overheating. Clearly, each location has a unique combination of characteristics. The use of CIBSE overheating metrics (Guide A, TM52 and TM59) revealed endemic overheating across the care homes. Peak temperatures exceeded 40°C within three care homes and 35°C within 14 care homes. London care homes were nearly 2°C warmer than those elsewhere. Upper-floor rooms were significantly warmer than ground floor rooms, urban/suburban care homes significantly warmer than rural care homes, and inland care homes significantly warmer than coastal care homes. Other characteristics (building age, size, room orientation) showed much less significant differences in temperature distributions between groups. Identifying precisely which occupancy and building characteristics have the most influence room-by-room with regards to overheating is a complex statistical challenge.

Care homes present several distinctive challenges to designers. The reliability and performance of equipment is paramount since the provision of a comfortable environment is a critical part of providing effective care [11]. However, care home residents tend to find cool air-conditioned air unacceptably cold and draughty. Adaptive behaviours (changing clothing, changing food and drink intake, and opening windows) provide low tech and low-cost alternatives and are more feasible to implement.

One important practical constraint to any potential retrofit measures is the fact that care home buildings are in constant use [18]: even a light-touch retrofit could cause significant disturbance to the frail and sensitive residents. Careful planning could allow some quick-to-deploy retrofit measures to be taken in conjunction with scheduled redecoration/ refurbishment. However, this often occurs piecemeal as and when rooms become available 'between residents', making it difficult to integrate retrofit measures that require physical materials and labour which would be much more efficiently deployed in one go. Another constraint specific to care home settings is that safety regulations mean window openings are limited to a maximum 10 cm, both for security against outsiders coming in and to prevent residents – particularly those with dementia – from climbing out [12].

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