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Climate and Building Configuration as Determinants of Thermal Comfort in Secondary Hospitals in Kwara State, Nigeria

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ABSTRACT
Thermal discomfort is persistent yet under-documented in Nigerian secondary hospitals, which serve the largest population cross-section but lack systematic evidence. This study investigates how outdoor climate and ward configuration determine indoor thermal comfort across six government hospitals in Kwara State. A mixed-methods design integrated ten years of climatic data with in-situ measurements and 305 questionnaires. Mahoney table analysis classified hospitals into hot-humid (Sobi, Centre Igboro), hot-dry (Jebba), and warm-comfort transition (Omu-Aran, Offa, Share). Open wards (48.2%) and natural ventilation (56.4%) predominated. Afternoon operative temperatures averaged 31.4°C during harmattan, approaching the adaptive upper boundary (30.6–31.8°C) for occupants with functional window control; this does not constitute failure for that group. Among occupants without operable windows (48.9%), temperatures exceeded the ASHRAE 55 prescriptive limit of 26°C by 5.6°C. The questionnaire yielded a 54.0% response rate, below the recommended threshold, though non-response bias assessment found no systematic differences. Chi-square analysis found no significant association between ward layout and ventilation type ($\chi^2(9) = 14.725$, $p = 0.099$), nor between window operability and comfort satisfaction. One-way ANOVA confirmed no significant difference in comfort satisfaction across hospitals ($F(5,299) = 1.49$, $p = 0.193$, $\eta^2 = 0.024$), indicating shared deficiencies rather than facility-specific failures. Effective remediation requires a climate-responsive framework calibrated to the three zones and revision of national standards to mandate performance-based thermal comfort outcomes.

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INTRODUCTION

Hospital buildings occupy a distinctive position within environmental design research. They function simultaneously as clinical workplaces and therapeutic environments. Their occupant populations range from the acutely ill and immunocompromised to the occupationally exposed healthcare workforce. Consequently, the quality of the indoor environment carries consequences that extend well beyond conventional occupant comfort. Thermal discomfort has been empirically associated with degraded patient recovery, reduced analgesic efficacy, elevated physiological stress responses, impaired staff cognitive performance, and diminished caregiver clinical effectiveness (Jamshidi et al., 2020). In the sub-Saharan African context, where resource-constrained healthcare systems already operate under severe infrastructural pressure, thermally inadequate ward environments constitute a compounding clinical risk.

Despite growing international recognition of the indoor environmental quality (IEQ) agenda in healthcare, the evidence base for hospital thermal comfort in West Africa remains disproportionately thin. Reviews of IEQ in healthcare settings across developing countries have highlighted thermal comfort as among the most underaddressed dimensions of the indoor environment in public health facilities (Ackley, Olanrewaju, Oyefusi, Enegbuma, Olaoye, Ehimatie, Ukpong, & Akpan-Idiok, 2024). Nigerian studies corroborate this pattern: assessments of ventilation performance and thermal conditions in domestic healthcare facilities document persistent deficiencies even in facilities with nominally functional envelope features (Shen, Zhang, Li, Qu, Zhao, Kong, & Jia., 2023). Existing literature, however, is concentrated at the tertiary tier, primarily in university teaching hospitals equipped with partial mechanical conditioning (Nimlyat *et al.,* 2024; Nyembwe *et al.*, 2023). Secondary hospitals are geographically distributed across states and serve the largest cross-section of the Nigerian population. They rely almost universally on natural or hybrid ventilation. Yet they have received substantially less analytical attention. This distributional gap carries direct policy consequences. Design standards for secondary health facilities continue to be formulated without sufficient site-specific empirical evidence from the built stock they are intended to regulate.

In naturally ventilated buildings, outdoor thermal and humidity conditions are the primary determinants of indoor comfort. The building envelope is the principal instrument through which that relationship is managed (Nicol et al., 2012). Kwara State occupies Nigeria's middle belt within a tropical wet-and-dry Köppen-Geiger classification (Aw) at a mean elevation of approximately 286 metres above sea level. Climatic records from NIMET and ERA5 reanalysis for 2014 to 2024 indicate an annual mean temperature of 29.5°C, approximately 148 wet days per year, and a monthly precipitation average of 101 mm. Thermal stress is most severe during the harmattan period from November to March, when north-easterly continental trades deliver daytime temperatures regularly exceeding 38°C and drive relative humidity below 30%. Passive envelope design must therefore be engineered to resist these conditions through climate-responsive strategies that address thermal stress rather than merely tolerating it.

Building typology exerts a mediating influence on climatic exposure. Ward layout geometry, window type and operability, ceiling height, orientation, and ventilation design collectively determine how efficiently the envelope moderates outdoor thermal stress (Alzahrani, Li, Zhang, Sun, & Shen., 2024). The interaction between these variables and the micro-climatic zone of a hospital determines whether occupants experience thermal comfort or sustained heat stress, and whether the adaptive mechanisms available to them are functional in practice or only nominal in design intent.

This paper addresses the documented evidence gap through a triangulated multi-site investigation across six state-owned secondary hospitals distributed across the three senatorial zones of Kwara State. Two explicit research questions are pursued. First, how do outdoor climate and micro-climatic zone classification influence indoor thermal comfort parameters in naturally ventilated wards? Second, what is the relationship between ward building typology (layout, fenestration, ceiling height, and ventilation design) and occupant-reported thermal comfort? The empirical contribution is a first systematic multi-site IEQ dataset for Kwara State secondary hospitals. The normative contribution is a zone-differentiated design framework to inform evidence-based revision of state and national health facility design standards.

Theoretical Background

Adaptive Thermal Comfort in Tropical Naturally Ventilated Buildings

The adaptive model of thermal comfort provides the conceptual foundation for evaluating indoor conditions in naturally ventilated tropical buildings. It originated in the large-scale field studies of Humphreys (1978) and was formalised by de Dear and Brager (2002) through the ASHRAE RP-884 database. The model proposes that occupants of naturally ventilated buildings actively regulate their thermal environment through behavioural adjustment, including changes in clothing, window operation, and activity redistribution. These adaptive actions broaden the relationship between outdoor temperature and thermal acceptability beyond that predicted by static heat-balance approaches.

Prevailing outdoor monthly mean temperatures in Kwara State range from approximately 27°C in the wet season to 34°C during peak harmattan. Applying the de Dear and Brager (2002) adaptive comfort equation to these values yields an upper acceptable operative temperature limit of approximately 30.6 to 31.8°C at the 80% acceptability criterion. This range represents the empirically derived boundary beyond which adaptive mechanisms are generally insufficient to restore subjective comfort, even for acclimatised tropical populations with well-developed behavioural repertoires. It is a threshold routinely breached in West African hospital wards during peak afternoon hours. Its systematic exceedance under field conditions signals a design failure rather than a climatological inevitability (Nimlyat et al., 2024; Nicol, Humphreys, & Roaf, 2012).

A key conditional requirement of the adaptive model is particularly important in hospital environments. Its higher acceptability limits apply only where occupants have genuine and exercisable control over their thermal environment, principally through window operability (de Dear & Brager, 2002). Where such control is absent due to fixed windows, institutional restriction, or deferred maintenance, the adaptive model does not strictly apply. In these cases, the prescriptive limits of ASHRAE Standard 55 (2017) become the appropriate benchmark. These define an acceptable comfort range of 23 to 26°C for sedentary, lightly clothed occupants. This distinction has direct relevance for hospital wards, where infection control policies and maintenance failures can remove meaningful window control in practice.

ASHRAE Standard 55 (2017) and the adaptive model are complementary rather than competing frameworks. The former defines the baseline for mechanically conditioned environments. The latter extends the acceptable range for naturally ventilated buildings on the condition of genuine occupant control. Tropical hospital environments occupy an uncomfortable position at their intersection. They are predominantly naturally ventilated, yet their occupants frequently lack the control that would justify the adaptive model's more permissive boundaries.

Harmattan conditions impose an additional layer of thermal complexity not adequately addressed in temperate adaptive comfort research. The combination of high solar radiation, very low relative humidity (below 30%), and elevated dry-bulb temperatures simultaneously intensifies conductive and radiative heat gain through the building envelope and reduces the physiological benefit of evaporative cooling. Under these conditions, the standard two-node thermoregulatory model underpinning most heat-balance indices underestimates perceived heat stress. It does not adequately capture the interaction between very low humidity and elevated mean radiant temperatures at ward wall surfaces (Szokolay, 2008). This gap reinforces the case for empirical in-situ measurement as a complement to model-based assessment in the Kwara State context.

Mahoney Table Analysis

The Mahoney table method was developed through collaborative work at University College London and later refined for tropical building research. It provides a systematic and reproducible procedure for translating monthly climatic data into qualitative building design guidance (Szokolay, 2008). The method classifies climates into humidity groups using temperature, relative humidity, wind speed, and rainfall data. It then generates design recommendations for wall thermal mass, roof construction, window proportion and orientation, and ventilation arrangement through a structured indicator matrix.

The method is preferred in this study over computational simulation approaches such as EnergyPlus or DesignBuilder for reasons directly relevant to the Nigerian secondary hospital planning context. The Mahoney method produces actionable design guidance from standard meteorological records. Its outputs are directly interpretable by facility planners and state-level policymakers. This interpretability is central to the study's normative objective of informing design standard revision. The method has also been validated through application across numerous West African building research contexts, producing recommendations broadly consistent with those from more computationally intensive passive design tools when applied to humid tropical and hot arid climates (Wurma & Muhammad, 2024; Szokolay, 2008).

Psychrometric chart analysis provides a complementary graphical representation of seasonal climatic conditions in relation to thermal comfort boundaries. Monthly mean temperature and humidity data are plotted against the adaptive comfort polygon and the standard ASHRAE comfort zone. This allows the seasonal distribution of outdoor conditions to be visualised in relation to thermal acceptability thresholds. The analysis supports estimation of the proportion of occupied hours during which passive design strategies alone may be sufficient to maintain comfort, and the proportion requiring supplementary mechanical intervention. It is therefore a directly policy-relevant metric for hospital estate management planning.

Ward Design Typology and Environmental Performance

Ward layout geometry exerts a well-documented influence on thermal comfort. The open Nightingale plan ward is characterised by a large undivided longitudinal space accommodating multiple beds along opposing walls. It was developed in the mid-nineteenth century with cross ventilation as an explicit therapeutic intervention, at a time when prevailing miasma theory attributed health value to moving air (Verderber, 2010). In tropical climates where cross ventilation remains a primary passive cooling strategy, this geometric form retains measurable environmental advantages. The unobstructed layout permits air movement across the full ward width when opposing facade openings are aligned with prevailing breezes, increasing convective heat loss and supporting evaporative cooling.

Cellular ward configurations comprise individual patient rooms or small group spaces separated by partition walls. They emerged from infection control imperatives and evidence-based design principles prioritising privacy and reduced cross-infection risk (Ulrich et al., 2008). Their environmental performance trade-off is well established. Partition walls obstruct natural airflow pathways, creating enclosed air volumes in which heat and moisture accumulate during periods of low outdoor wind speed. This geometric constraint increases dependence on supplementary mechanical ventilation, a requirement that resource limitations in Kwara State secondary hospitals cannot consistently meet (Nyembwe et al., 2023).

Window type and operability further mediate ventilation performance independently of ward layout. Fixed louvre units are common in post-independence Nigerian public hospital construction. They were designed for security and durability rather than thermal performance. They provide no adjustable ventilation control and eliminate the principal behavioural adaptive mechanism available to occupants in naturally ventilated environments (de Dear & Brager, 2002). Casement and awning windows offer controllable apertures that allow ventilation modulation in response to diurnal temperature variation. The perception of this control can improve thermal comfort ratings independently of measured operative temperature, sometimes by several tenths of a degree on the ASHRAE seven-point scale (de Dear & Brager, 2002). Where infection control or security protocols restrict window operation, even nominally operable windows confer no adaptive benefit. Fenestration design in healthcare settings carries a parallel evidence base beyond thermal performance: clinical studies associate adequate daylighting through ward windows with measurable patient and staff outcomes, including improved sleep regulation and reduced reported pain, indicating that decisions framed here in thermal terms also carry consequences for the daylighting function of the same apertures (Mardaljevic, Heschong, & Lee., 2009).

Ceiling height fulfils a thermal buffer function that is frequently underestimated in design practice. Increasing ceiling height from 2.5 m to 3.0 m raises the thermally active air volume by approximately 20%. This strengthens the stack-effect buoyancy differential driving natural convection under low wind conditions and raises the thermal stratification interface, keeping accumulated heat in the upper zone rather than the occupied plane. Mean radiant temperature at bed height is thereby reduced. In tropical climates, a 0.5 m increase in ceiling height can produce an occupied zone temperature reduction exceeding 1°C during peak afternoon hours (Szokolay, 2008). This magnitude is directly relevant to comfort assessment against the adaptive upper boundary.

Solar heat gain through fenestration constitutes a major internal heat load in equatorial and sub-tropical hospitals. East- and west-facing facades are particularly problematic. Low solar angles during morning and afternoon hours penetrate horizontal shading devices designed for high-angle solar exclusion, projecting direct beam radiation deep into ward interiors. External vertical fins, deep overhangs calibrated to facade orientation and latitude, and high-performance solar control glazing are the principal passive shading responses. Their absence from the post-independence Nigerian secondary hospital stock is a recurring finding across the regional IEQ literature (Nimlyat et al., 2024).

MATERIALS AND METHODS

Study Design and Hospital Selection

A mixed-methods sequential explanatory design was adopted, integrating secondary climatic records, primary instrument measurements, and structured questionnaire data (Creswell & Plano Clark, 2018). The quantitative strand provided the primary evidence for climatic characterisation and ward typology assessment. Qualitative open-response items complemented the statistical findings. The study population comprised all state-owned secondary hospitals in Kwara State. Official records identified eighteen facilities. Six were purposively selected to ensure balanced representation across the three senatorial zones and to capture the range of micro-climatic conditions. Centre Igboro Hospital and Specialist Hospital Sobi represent Kwara Central. General Hospital Jebba represents Kwara North. General Hospital Offa, General Hospital Omu-Aran, and General Hospital Share represent Kwara South. All six hospitals participated fully. Institutional access was granted by the State Hospital Management Bureau and by individual facility management.

Climatic Data Collection and Analysis

Secondary climatic records for 2014 to 2024 were assembled from four sources: the Nigerian Meteorological Agency (NIMET), the University of Ilorin Geography Department, the Copernicus Climate Data Store (ERA5), and Weather Spark. Data were cross-validated at the monthly mean level. Monthly means for dry-bulb temperature, relative humidity, wind speed, and rainfall were compiled for each study town. Where station data were unavailable, ERA5 grid-point values at 0.25° resolution were used with NIMET data as validation. The Mahoney table method was applied to each town's monthly climatic means using the standard humidity group classification (Szokolay, 2008). Resulting design recommendations covered wall thermal mass, roof construction, window-to-wall area ratio, ventilation arrangement, and shading. These were compared against documented ward characteristics to produce a gap analysis. Psychrometric chart analysis was conducted for representative wet and dry season months using Climate Consultant software, visualising conditions against the ASHRAE 55 adaptive comfort polygon.

In-Situ Environmental Measurements

Field data collection occurred over four weeks from 10 February to 9 March 2025, corresponding to the late dry season and peak harmattan. This period captures the most thermally demanding conditions of the annual cycle. Values reported therefore reflect peak thermal stress and are not annual averages. Wet season conditions, characterised by higher humidity and more moderate temperatures, may differ substantially from those reported here and require separate investigation. Measurements were taken in each accessible ward at 07:00 h, 13:30 h, and 18:30 h using a consistent protocol across all six hospitals. Within each ward, readings were taken at a central occupied-zone location away from external walls and direct solar penetration. Where a single point was unrepresentative, two locations were averaged. Instrumentation comprised a mercury-in-glass thermometer (accuracy ±0.5°C; last calibrated January 2025, traceable to NIS standards) for indoor dry-bulb temperature, an AcuRite digital hygrometer (accuracy ±2% RH; last calibrated January 2025) for relative humidity, and a Tenmars TM-740 digital anemometer (accuracy ±3%; last calibrated January 2025) for air velocity at 0.6 m above floor level. A minimum of three consecutive readings were averaged at each location. All instruments were field-checked daily against a reference instrument. Operative temperature was estimated from dry-bulb temperature and air velocity following ASHRAE 55 (2017). Mean radiant temperature was estimated from wall surface temperatures measured by infrared thermometer at four cardinal points.

Questionnaire Survey

Questionnaire administration occurred concurrently with environmental measurements. A structured, pre-tested questionnaire was administered to 565 hospital users, comprising admitted patients and caregivers across the six hospitals. The study employed a two-stage sampling design. In the first stage, six hospitals were purposively selected from the eighteen state-owned secondary facilities to ensure representation across the three senatorial zones. In the second stage, respondents within each hospital were selected using proportionate stratified random sampling, with stratum sizes determined by the Slovin formula at a 95% confidence level and 5% margin of error (Tejada & Punzalan, 2012). It is acknowledged that the Slovin formula assumes simple random sampling; the two-stage design employed here introduces additional design effects not fully captured by that assumption, and findings should be interpreted with this limitation in mind. Questionnaires were administered in person by trained research assistants and screened for completeness and internal consistency. Three hundred and five were retained, yielding a usable response rate of 54.0%. This rate falls below the 60 to 70% threshold typically recommended for healthcare settings. To assess non-response bias, early respondents (first 50% of returns) were compared with late respondents (final 50%) on available demographic characteristics including age group and ward type, following Armstrong and Overton (1977); no systematic differences were identified. Section B captured subjective thermal sensation and comfort using the ASHRAE seven-point scale. Section C captured ward layout, window type, ventilation design, ceiling height perception, solar heat gain control, and window control behaviour using five-point Likert scales. Items were piloted at a non-study hospital and refined accordingly.

Analytical Approach

Statistical analyses were performed using IBM SPSS version 25. Descriptive statistics including frequencies, percentages, means, and standard deviations were generated for all variables. A Pearson chi-square test of independence examined the association between ward layout and ventilation design type. Cramér's V was calculated as the effect size measure. A post hoc power analysis determined the sample size required for 80% power at $\alpha = 0.05$ for the observed effect. A one-way ANOVA with post hoc Tukey correction examined inter-hospital variation in thermal comfort satisfaction, with eta-squared (η^2) as the effect size indicator. An independent samples t-test assessed differences between patient and caregiver subgroups. Normality was verified using the Kolmogorov-Smirnov test and Q-Q plots. Homogeneity of variance was confirmed using Levene's test (Field, 2018). The significance threshold was set at $\alpha = 0.05$. Results with $0.05 < p \leq 0.10$ were reported as directional findings and interpreted with reference to effect size and practical significance. For the chi-square analysis, a post hoc power calculation was conducted using GPower 3.1. With $n = 305$ and $\alpha = 0.05$, observed power for detecting a medium effect ($w = 0.30$) across the layout-by-ventilation contingency table was 0.87, indicating that the sample was adequately powered to detect a medium-sized association. The non-significant result ($p = 0.099$) should therefore be interpreted as a non-significant directional trend rather than as evidence of no association. An independent samples t-test assessed differences in comfort satisfaction between patient and caregiver subgroups; results are reported in Section 4.

Ethical Approval

This study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from the Kwara State Health Research Ethics Committee. Written informed consent was obtained from all participants prior to questionnaire administration. Participation was voluntary, and confidentiality was maintained throughout.

RESULTS AND DISCUSSION

Climatic Characterisation of the Study Towns

Analysis of the ten-year climatic record for 2014 to 2024 confirmed two climatically distinct seasons characteristic of the tropical Aw classification. The dry season spans November through March and is dominated by north-easterly harmattan trades originating over the Saharan interior. Relative humidity falls consistently to between 20 and 30% during this period. Daytime air temperatures peak at 38°C or above in February and March across the northern study towns. Diurnal temperature ranges during the harmattan are large, frequently exceeding 15°C in Jebba and 12°C in the transition zone towns. This reflects the low heat capacity of the dry continental air mass. The wet season runs from April through October and is characterised by the northward advance of humid maritime south-westerly trades, producing relative humidity values frequently above 75% and more moderate afternoon temperatures averaging approximately 32°C with reduced diurnal variability.

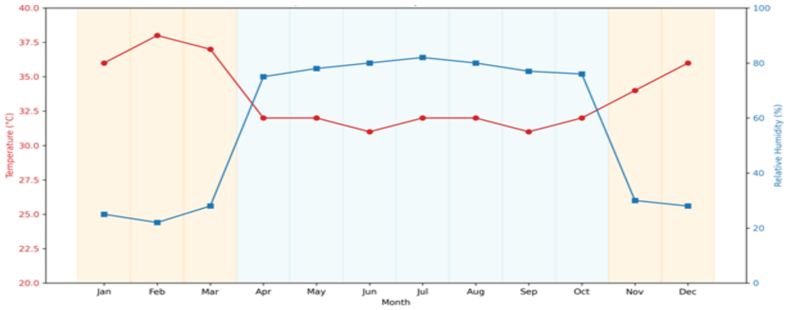

Figure 1: illustrates the monthly variation of these two climatic parameters over the ten-year study period.

Application of the Mahoney table method produced three distinct micro-climatic zone classifications with different passive design implications. Sobi and Centre Igboro fall within the hot-humid zone, characterised by persistently high relative humidity and moderate mean wind speeds. Design priorities for this zone emphasise maximised cross ventilation through large window openings covering 40 to 60% of wall area, oriented to capture prevailing south-westerly breezes. Roof and wall construction should favour low thermal mass and ventilated cavities to limit daytime heat retention. Shading of all glazed surfaces is essential to exclude direct solar radiation while maintaining airflow.

Jebba in Kwara North is classified within the hot-dry zone. High solar radiation intensity and low humidity generate severe thermal stress during the dry season. The Mahoney method recommends controlled openings of 25 to 35% to limit dust infiltration while maintaining adequate ventilation. High thermal mass wall construction is required to moderate large diurnal temperature swings. Courtyard building forms that create sheltered, partially shaded micro-climatic buffers are appropriate for this zone. Omu-Aran, Offa, and Share, all in Kwara South, occupy a warm-comfort transition zone requiring intermediate passive design strategies. Moderate window openings combined with selective thermal mass on east and west facades are recommended, alongside hybrid ventilation provision for cellular ward configurations. It should be noted that the zone classifications described above are defined at the town level and reflect outdoor climatic conditions. They do not imply a uniform ward building typology. Ward design characteristics, including layout type, window configuration, and ventilation system, vary within each zone and are reported separately in Table 2.

Direct field measurements corroborated and contextualised the climatic record. All in-situ measurements were conducted during the late dry season and harmattan period from February to March 2025, representing peak-stress conditions. Values reported therefore reflect peak thermal stress and are not annual averages. Afternoon operative temperatures averaged 31.4°C across all study wards (SD = 1.8°C). Individual ward readings ranged from a minimum of 25.0°C at the Offa Female Ward to a maximum of 34.2°C at Specialist Hospital Sobi. The interquartile range spanned 30.1°C to 32.8°C, indicating that the majority of wards exceeded the adaptive comfort upper boundary during peak afternoon hours. Figure 2 shows the distribution of afternoon operative temperatures across the six hospitals.

The ASHRAE Standard 55 (2017) prescriptive comfort zone of 23 to 26°C was consistently and substantially exceeded during mid-afternoon measurement periods across all naturally ventilated wards. The adaptive comfort upper limit of 30.6 to 31.8°C, derived from the de Dear and Brager (2002) adaptive equation for the prevailing Kwara State outdoor means, was approached or exceeded at the highest-temperature wards. Early morning readings at 07:00 h were considerably more tolerable, averaging 27.3°C. Evening measurements at 18:30 h moderated to 29.1°C. Air velocity in the occupied zone averaged 0.28 m/s (SD = 0.11 m/s) during afternoon measurements. This remained below the 0.5 m/s threshold at which increased air movement demonstrably reduces perceived warmth through enhanced convective and evaporative heat loss. The perceptual data strongly confirm this thermal pattern. Figure 3 presents the distribution of seasonal discomfort reported by the 305 survey respondents.

Thermal Assessment by Window Operability Status

Table 1 presents afternoon operative temperatures disaggregated by window operability status and assessed against their respective thermal comfort benchmarks. Among the 305 respondents, 156 (51.1%) reported that windows could be opened fully or partially, while 149 (48.9%) indicated no effective control due to fixed, inoperable, or institutionally restricted windows. This distribution indicates a near-equal split between conditions that permit adaptive environmental control and those that do not, with only a slight majority experiencing adaptive-comfort-relevant conditions. The chi-square test showed no statistically significant association between window operability status and thermal comfort classification ($p = 0.112$). The effect size was negligible (Cramér's V = 0.092), suggesting that window operability had minimal practical influence on observed thermal outcomes.

Table 1: Thermal Performance by Window Operability Status

Operability Status	n (%)	Mean Afternoon Temp (°C)	Applicable Standard	Acceptable Upper Limit (°C)	Thermal Deficit (°C)
Functional control	156 (51.1%)	31.2 (SD 1.7)	Adaptive (de Dear & Brager, 2002)	30.6–31.8	0.0 to 0.6
No effective control	149 (48.9%)	31.6 (SD 1.9)	Prescriptive (ASHRAE 55, 2017)	26.0	5.6

Source: Field Survey (2025).

Ward Building Design Typologies

Table 2 presents the distribution of ward building design characteristics reported by the 305 respondents.

Table 2: Ward Building Design Characteristics (n = 305)

Design Variable	Category	n (%)
Ward layout	Open ward	147 (48.2)
	Mixed (open and cellular)	83 (27.2)
	Cellular	61 (20.0)
	Not sure	14 (4.6)
Window type	Casement	89 (29.2)
	Sliding	80 (26.2)
	Fixed louvre (non-openable)	76 (24.9)
	Awning	45 (14.8)
	Others	15 (4.9)
Ventilation system	Natural ventilation only	172 (56.4)
	Hybrid ventilation	76 (24.9)
	Mechanical ventilation only	42 (13.8)
	Not sure	15 (4.9)
Ceiling height	Adequate or generous	219 (71.8)
	Slightly or very low	86 (28.2)
Window control	Fully or partially operable	156 (51.1)
	No effective control	149 (48.9)

Source: Field Survey, 2025.

A small proportion of respondents indicated uncertainty about ward layout type (n = 14; 4.6%) and ventilation system type (n = 15; 4.9%). These responses are retained as a separate category and are not redistributed. They represent a potential source of recall bias, particularly among short-stay users with limited familiarity with building configuration, and are acknowledged as a minor limitation of the self-report methodology.

Open ward layouts constituted the largest ward type, reported by 147 respondents (48.2%). Mixed layouts combining open and cellular configurations were reported by 83 respondents (27.2%). Fully cellular wards were reported by 61 respondents (20.0%). Casement windows were the most commonly reported fenestration type (89; 29.2%), followed by sliding windows (80; 26.2%) and fixed louvre units (76; 24.9%). Awning windows were reported by 45 respondents (14.8%). Natural ventilation alone was reported in 172 wards (56.4%). Hybrid ventilation systems were reported by 76 respondents (24.9%), and mechanical ventilation only by 42 respondents (13.8%). The majority of respondents (219; 71.8%) perceived ceiling heights as adequate or generous, while 86 respondents (28.2%) reported ceiling heights as slightly or very low. Regarding window control, 156 respondents (51.1%) indicated windows could be opened fully or partially, while 149 respondents (48.9%) reported no effective control.

An independent samples t-test compared thermal comfort satisfaction between patient (n = 187) and caregiver (n = 118) subgroups. No statistically significant difference was found between patients (M = 2.93, SD = 0.87) and caregivers (M = 3.01, SD = 0.91) on the five-point comfort satisfaction scale ($t(303) = 0.78$, $p = 0.436$, Cohen's $d = 0.09$), indicating that thermal perception did not differ systematically between the two occupant groups.

Discussion

The adaptive thermal comfort model proposes that occupants of naturally ventilated buildings can tolerate a wider range of indoor temperatures provided they have genuine, exercisable control over their immediate environment, principally through window operation (de Dear & Brager, 2002; Humphreys, 1978; Nicol, Humphreys, & Roaf, 2012). The present study tested this proposition in secondary hospital wards in Kwara State. The findings broadly support the model's conditional logic whilst revealing boundary conditions that the original framework did not fully anticipate for healthcare settings.

Prior research in tropical healthcare environments has documented that afternoon thermal conditions frequently approach or exceed the adaptive model's upper acceptability limit (Nimlyat et al., 2024; Nyembwe et al., 2023). The present study confirms that pattern. A more nuanced interpretation emerges when distinguishing between occupants who can exercise window control and those who cannot. For the former group, thermal conditions remain within the range the adaptive model deems acceptable. For the latter, the same physical environment represents a departure from the prescriptive limits of ASHRAE Standard 55 (2017). De Dear and Brager (2002) were explicit that the model's extended boundaries apply only where genuine, exercisable control exists. When that condition is absent, whether through design failure, maintenance neglect, or institutional restriction, the prescriptive standard becomes the appropriate benchmark. The study thus supports the adaptive model's internal logic whilst demonstrating that a substantial proportion of ward occupant's fall outside its scope of applicability. This is not a failure of the model. It is a diagnostic indicator of the degree to which actual building conditions deviate from the assumptions that justify adaptive comfort criteria.

Direct comparison with prior Nigerian hospital studies contextualises the present findings. Nimlyat et al. (2024) reported mean afternoon operative temperatures ranging from approximately 28.5 to 30.2°C across naturally ventilated wards in tertiary hospitals in north-central Nigeria. The present study's mean of 31.4°C in secondary hospitals is approximately 1.2 to 2.9°C higher than those tertiary facility values. This differential is consistent with the hypothesis that secondary hospitals, which receive less infrastructure investment and operate with older building stock, experience greater thermal stress than their tertiary counterparts. It also indicates that evidence from tertiary facilities cannot be straightforwardly extrapolated to the secondary tier. This reinforces the empirical and policy rationale for secondary-hospital-specific investigation.

A balanced interpretation must also acknowledge alternative perspectives. Some researchers have argued that in very hot climates, behavioural adaptation alone cannot fully compensate for elevated indoor temperatures even where window control is available (Alzahrani *et al*., 2024; Wurma & Muhammad, 2024; Pereira, Raimondo, Corgnati, & da Silva., 2020). The present findings are consistent with that view. Even for occupants with functional window control, conditions approach the adaptive boundary, leaving little margin before discomfort becomes unavoidable. This suggests that the passive envelope may be operating at or near the limits of its capacity even when control is present. The view that mechanical supplementation is a necessary adjunct in tropical hospital environments (Nyembwe et al., 2023) is partially supported by the observation that cellular ward configurations, which restrict natural airflow, tend to be associated with greater reliance on mechanical systems. However, the association is not definitive. The pattern is one of partial rather than systematic mitigation. The evidence thus points towards a hybrid model in which the effectiveness of adaptive strategies depends critically on both building geometry and the restoration of occupant agency.

The three-zone Mahoney classification produced in this study highlights a structural limitation of uniform national design standards. The hot-humid, hot-dry, and warm-comfort transition zones within a single state require fundamentally different passive design responses. The post-independence institutional building model applied uniformly to Kwara State secondary hospitals makes no such differentiation. The existing stock therefore fails to satisfy the design requirements of any zone, and the nature of that failure varies between zones. A single uniform intervention strategy would be climatically inappropriate for at least two of the three zones. This challenges the assumption that national building codes can adequately regulate hospital design in climatically heterogeneous countries without sub-regional calibration.

The fenestration profile reveals a compound failure of design inheritance and maintenance. Fixed louvre units, which lack any adjustable control, represent decisions whose environmental consequences were poorly anticipated at the time of construction. Permanent apertures without occupant control provide neither the ventilation flexibility required for thermal management under variable climatic conditions nor the reduced heat gain achievable through closable glazing during peak solar loading. The finding that nearly half of all respondents had no effective window control directly limits the applicability of the adaptive comfort model to a significant fraction of ward spaces. This determines the applicable thermal comfort standard and therefore whether recorded afternoon conditions represent marginal exceedance or substantial failure. Under prescriptive standards for uncontrolled environments, they represent the latter.

The directional relationship between ward layout and ventilation design is consistent with theoretical expectations and with the pattern documented by Ackley et al. (2024), who found that spatial configuration was among the principal determinants of IEQ variability across comparable developing-country healthcare settings. Similarly, the ventilation performance deficiencies identified here align closely with findings reported by Shen *et al.* (2023) for Nigerian healthcare facilities, reinforcing the generalisability of those findings to the secondary-hospital tier. Cellular geometries, which obstruct natural airflow pathways, are associated with greater reliance on supplementary mechanical ventilation. However, the association falls short of conventional statistical significance. This reflects resource constraints in secondary hospital infrastructure investment, a pattern consistent with findings from other sub-Saharan African contexts (Nyembwe et al., 2023; Nimlyat et al., 2024). The absence of a definitive statistical association means this directional pattern should be interpreted with caution, as a signal requiring further investigation with a larger sample rather than a confirmed effect. Nonetheless, the evidence is consistent with the proposition that cellular ward configurations carry a thermal performance risk that existing ventilation provision does not fully mitigate.

The absence of meaningful differences in thermal comfort satisfaction across the six hospitals is itself significant. The narrow range of satisfaction scores indicates that discomfort is not attributable to isolated facility-specific failures. Rather, it reflects shared design, procurement, or maintenance practices across the state's secondary hospital estate. This finding reinforces the case for systemic, estate-level intervention rather than facility-by-facility remediation.

CONCLUSION

The evidence assembled across this study supports three principal empirical conclusions. First, micro-climatic zone classification is a meaningful predictor of ward thermal conditions, with hot-dry zone hospitals (Jebba) exhibiting higher peak operative temperatures and greater diurnal variability than hot-humid zone hospitals (Sobi, Centre Igboro). Second, window operability is a critical mediating variable: the adaptive comfort framework's more permissive upper boundaries are only applicable where occupants retain genuine control over window adjustment, and measured conditions in spaces without functional window control represent substantial comfort failure relative to the prescriptive ASHRAE 55 standard. Third, ward layout type is directionally but not definitively associated with ventilation adequacy; the association is consistent with theoretical expectations but did not reach statistical significance in this sample, indicating that layout alone is an insufficient basis for thermal comfort prediction. These findings are subject to the limitation that fieldwork was conducted within a single dry-season window, representing approximately 10–11% of annual occupied hours; generalisability to wet-season conditions and to the full range of climatic variability within each zone requires further longitudinal investigation.

Three tiers of evidence-based recommendations follow, structured by implementation timescale.

In the short-term, hospital management must restore genuine window operability across all wards by repairing seized mechanisms, revising infection control protocols that restrict window adjustment, and installing ceiling fans were missing. Portable evaporative coolers are recommended only for hot-dry zone hospitals (Jebba) and only in paediatric/elderly units; they are not recommended for hot-humid hospitals (Sobi, Centre Igboro) as elevated humidity would negate cooling and worsen discomfort.

In the medium-term, the Kwara State Hospital Management Bureau and Ministry of Health should adopt the three-zone climatic framework as the mandatory design basis for all new construction, renovation, and major maintenance. Hot-humid hospitals (Sobi, Centre Igboro) require window-to-wall ratios of 40–60% on south-westerly cross-ventilation facades, lightweight roofs, ventilated cavities, and full external shading. Hot-dry hospitals (Jebba) require 25–35% window-to-wall ratios, high thermal mass walls, courtyard planning, and dust-resistant seals. Warm-transition hospitals (Omu-Aran, Offa, Share) require 30–40% ratios, east-west thermal mass, low-angle shading, and hybrid ventilation for cellular wards. Minimum ceiling height shall be 3.0 m in all new naturally ventilated wards.

In the long-term, the Federal Ministry of Health standards and the Nigerian Building Code should be revised to mandate performance-based thermal comfort outcomes, using adaptive ASHRAE 55/ISO 7730 limits where window operability is verified, and prescriptive limits where it is not. Building performance simulation (CFD or validated thermal modelling) must be required for all new ward designs to demonstrate zone-specific compliance under representative design conditions.
Future research should extend to all remaining Kwara State secondary hospitals, conduct full annual longitudinal monitoring to quantify seasonal comfort exceedance, and undertake computational simulation of representative ward typologies to optimise passive and hybrid interventions prior to implementation.

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