MATERIALITY, HABITAT AND HEALTH: EVALUATION OF THE HOUSING ENVELOPE IN URBAN CONTEXTS

Eugenia Lyli Moreira-Macías[1],Walter David Cobeña-Loor[2]; Jhon Gabriel Mendoza-Cantos [2], Silvia Gabriela Corrales-Zambrano[2], Jose Fabricio Alcívar-Rodríguez[3], Carmen Rebeca Ramírez-Moreira[3], Nexar Omar Loor-Macías[3]

Abstract

The architectural envelope plays a key role in determining hygrothermal comfort and indoor air quality in urban houses in tropical climates. This PRISMA 2020 systematic review is exploratory and includes 30 articles published between 2000 and 2025 and indexed in Scopus, WoS and Latin American databases. The results show that adaptive models (ASHRAE 55 and Humphreys/Givoni) are more prevalent than static physiological models (ISO 7730), which supports their greater applicability in tropical climates. The most analyzed variables are temperature, relative humidity and natural ventilation, and it is notable that cross ventilation and shade improve thermal habitability. Nevertheless, there is a methodological gap: most studies focus on perceived comfort or energy simulations, ignoring clinical indicators and objective health measurements. Consequently, the impact on environmental health remains underrepresented. It is concluded that it is necessary to incorporate integrative frameworks that link thermal performance with environmental health and occupancy validation.

L'involucro architettonico svolge un ruolo fondamentale nel determinare il comfort igrotermico e la qualità dell'aria interna nelle abitazioni urbane dei climi tropicali. Questa revisione sistematica PRISMA 2020 è di natura esplorativa e include 30 articoli pubblicati tra il 2000 e il 2025 e indicizzati nelle banche dati Scopus, WoS e latinoamericane. I risultati mostrano che i modelli adattivi (ASHRAE 55 e Humphreys/Givoni) sono più diffusi rispetto ai modelli fisiologici statici (ISO 7730), il che ne conferma la maggiore applicabilità nei climi tropicali. Le variabili più analizzate sono la temperatura, l'umidità relativa e la ventilazione naturale, ed è degno di nota il fatto che la ventilazione incrociata e l'ombra migliorano l'abitabilità termica. Tuttavia, esiste una lacuna metodologica: la maggior parte degli studi si concentra sul comfort percepito o sulle simulazioni energetiche, ignorando gli indicatori clinici e le misurazioni oggettive della salute. Di conseguenza, l'impatto sulla salute ambientale rimane sottorappresentato. Si conclude che è necessario incorporare quadri integrativi che colleghino le prestazioni termiche con la salute ambientale e la convalida dell'occupazione.

[1]Universidad Internacional SEK-Ecuador
[2] Universidad Particular San Gregorio de Portoviejo-Ecuador
[3]Independent Researcher
Corresponding author:eugenia.moreira@uisek.edu.ec
DOI: 10.70102/fbxnvh70

Keywords hygrothermal comfort; architectural envelope; urban housing; environmental health; tropical climate. comfort igrotermico; involucro architettonico; edilizia urbana; salute ambientale; clima tropicale

The Housing Envelope in Urban Contexts
In tropical urban environments, the architectural envelope plays a key role in ensuring the physical and psychological well-being of users by acting as a mediator between external climatic conditions and the indoor microclimate (Chen, Austin et al., 2021). The selection of materials, construction system and passive strategies applied to the envelope directly impact thermal performance, comfort and environmental quality, as evidenced in the scientific literature. In particular, material choice is highly relevant to thermal mass and interior thermal stability (Véliz-Párraga & González-Couret, 2019), while the application of bioclimatic strategies such as natural ventilation, shading and adequate building orientation allows thermal stress to be drastically reduced (Freire Navas et al., 2023). Similarly, architectural form and volumetric proportions between built mass and voids influence energy efficiency and occupants' comfort (González Vásquez & Molina-Prieto, 2018).

In Latin America, these dynamics are exacerbated by rapid urbanisation, inadequate housing, the intensive use of unsuitable industrialised materials, and insufficient consideration of environmental health in architectural planning. Various studies urge tropical cities to adopt a transformative, interdisciplinary approach integrating bioclimatic principles, human well-being and ecological sustainability (Molina Molina, 2025; Sotelo Barrios et al., 2025). This shift must involve not only design innovation, but also transformation at the level of training and regulatory models. In today's architecture, there are still gaps in the conception of hygrothermal comfort and healthy habitability as core aspects of the project (Arango Díaz et al., 2022). Recent developments in approaches such as biophilic architecture demonstrate positive results in terms of mental health, social cohesion and energy efficiency. However, their implementation is still limited by a lack of adequate institutional frameworks and technical capacities (Molina Molina et al., 2025).

This systematic exploratory review will analyse architecture, hygrothermal comfort, and occupant health in urban housing in tropical areas, focusing on experiences in Latin American cities. The review will provide insight into dominant theoretical approaches, thermal assessment methodologies, models, metrics and knowledge gaps that foster sustainable architectural design. It is hoped that this will provide a basis for discussion for the development of project and regulatory strategies to improve the urban habitat from an environmentally responsible perspective with a focus on human health.

Materials and methods
A systematic literature review is a secondary study used to identify, evaluate, and interpret all relevant evidence related to a specific research question (Kitchenham, 2004). It stands out for its use of explicit and reproducible methods, which allow for transparency and methodological rigor in synthesizing existing information about a phenomenon of interest (Manterola et al., 2013).
This review adopted the updated PRISMA 2020 statement, which aims to improve transparency in describing the process of identifying, selecting, evaluating, and synthesizing evidence (Page et al., 2021). The research question is: What scientific evidence is there on the impact of the architectural envelope on the hygrothermal comfort and environmental health of users in urban housing in tropical climates, particularly in Latin American urban contexts?
According to this guide, a structured search strategy was formulated using the keywords: "thermal comfort," "building envelope," "health," "urban housing," and "tropical climate" in English and "thermal comfort," "thermal stress," "environmental health," "urban housing," and "warm zones" in Spanish.
The search was conducted in high-impact academic databases (Scopus and Web of Science) and Latin American repositories (SciELO, Redalyc, Dialnet, and Latindex), enabling the identification of literature globally and in territories with tropical climates. According to the PRISMA flow, the selection of records was carried out by removing duplicates, evaluating titles and abstracts, and finally, reading the potentially included texts in full. Only studies directly investigating the association between the architectural envelope, thermal comfort, and environmental health in urban housing in warm or tropical areas in Latin America were considered.
Original articles published from 2000 to 2025 in English or Spanish with full text available were considered, as long as they were developed in similar tropical or subtropical situations and dealt with thermal comfort and its impact on health in urban housing. Studies that were not reproducible or valid in

terms of methodology (e.g., studies without empirical data or with indirect tests), those carried out in cold or temperate climates where the behavior of the envelope cannot be extrapolated, and those focused on non-residential buildings or environmental variables with no impact on human habitability were excluded. Documents with limited, incomplete access or insufficient technical reporting were also denied.
The selection process followed the PRISMA 2020 guidelines (Page et al., 2021). In the identification phase, 104 records were initially collected from the following databases: Dialnet (14), Latindex (18), Redalyc (9), SciELO (16), Scopus (24), and Web of Science (23), as shown in Table 1. These records corresponded to scientific articles related to comfort models, thermal variables, and health indicators in urban housing.

Table 1. Inclusion criteria for systematic review according to database

Database	Search terms	Number of records	Type of documents	Quantity finally chosen	Languages	Quantity
Dialnet	"thermal comfort" / "confort térmica" AND "urban housing"	14	Scientific articles	6	Spanish	6
Latindex	"architectural envelope" AND "environmental health"	18	Scientific articles	7	Spanish	7
Redalyc	"urban housing" AND "warm areas"	9	Scientific articles	3	Spanish	3
SciELO	"building envelope" OR "envolvente" AND "comfort"	16	Scientific articles	5	Spanish	5
Scopus	"building envelope" OR "envolvente" AND "comfort"	24	Indexed articles / conference papers	7	Spanish/ English	5/2
Web of Science	"urban housing" AND "health"	23	Scientific articles	2	English	2
Total	—	104 base records	—	30 studies included	—	30

Subsequently, during the screening process, duplicates, interbases, and documents with insufficient evidence or distant approaches from the thermal-health axis were eliminated. At the eligibility stage, the full texts were examined for methodological relevance, climate type, and applicability to the tropical urban context. In the final stage of the systematic review, a total of 30 studies were selected based on their alignment with the predetermined thematic, geographical, and methodological criteria. These studies constituted the final corpus for analysis (Figure 1).

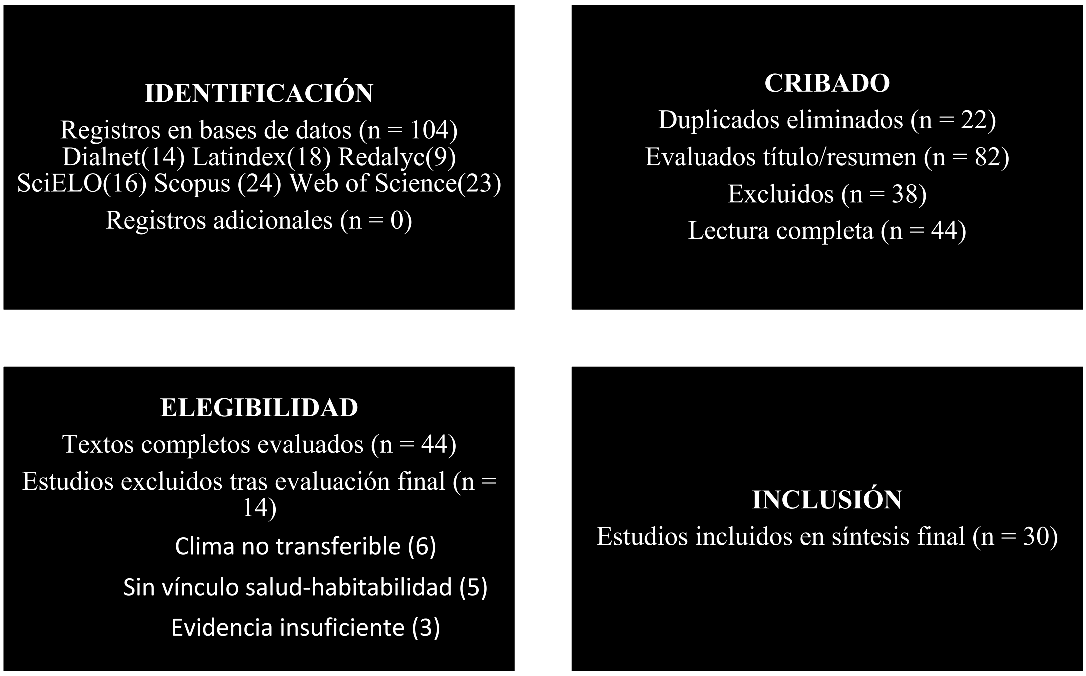

Fig. 1 - Process of Identification, Screening, Eligibility, and Inclusion

Note. The diagram presents the detailed process of identification, screening, eligibility, and inclusion of studies in accordance with the PRISMA 2020 Declaration. The total number of initial registrations (n = 104), progressive exclusions and the final selection of articles included in the qualitative synthesis (n = 30) are evidenced. Adapted from Page et al. (2021).

To organize and systematize the evidence, a matrix was constructed that combines bibliometric and content analysis indicators. In the bibliometric dimension, the year of publication, the country of origin, and the database of each study were recorded. In the content dimension, the central variables linked to the research question were coded, particularly those that describe the impact of the architectural envelope on thermal comfort and its implications on the environmental health of users in urban housing in tropical climates. This dual approach facilitated the identification of thematic trends, methodological approaches, and the degree of scientific transfer to the Latin American context (Table 2).

Table 2. Data Extraction Matrix Format

ID	Author	Year	Country	Database	Type of housing	Comfort model	Thermal variables	Health indicators	Key takeaways

Note. The table presents the format used for the systematic extraction of information from the included studies, considering bibliometric aspects and content variables analyzed.
Source: Own elaboration, 2025.

Furthermore, the Atlas.ti software was employed for qualitative content analysis, through the thematic coding of the thermoenvironmental variables and the indicators associated with health and well-being. This process enabled the integration of empirical evidence with the geographical context of the studies, resulting in the generation of relational visualizations — such as the Sankey-type diagram — that illustrate the correspondence between the countries analyzed and the conceptual categories identified. The use of the aforementioned instrument enabled the comparative interpretation and detection of recurrent patterns in urban contexts characterized by a tropical climate.

Results of the bibliometric analysis

As illustrated in Figure 2, the results indicate a mounting level of interest among the scientific community over the past decade, particularly since 2011. A notable surge in publications occurred between 2021 and 2025, indicating a contemporary trend in research endeavors concerning the comfort model, thermal variables, and health indicators in residential dwellings in urban areas with hot climates.

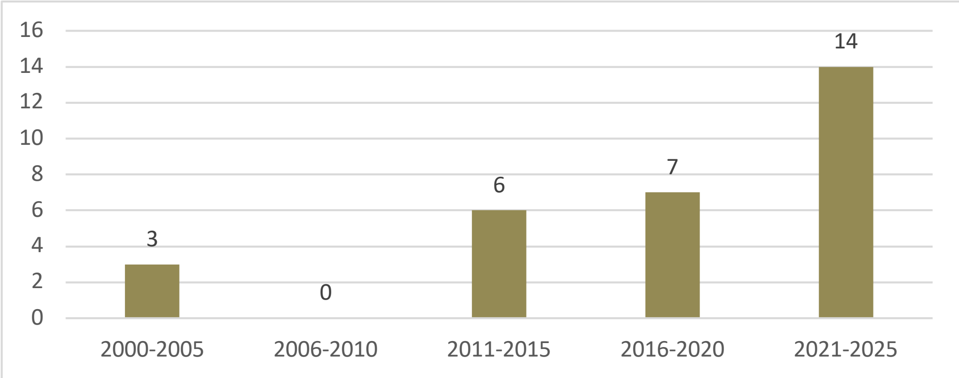

Fig. 2 - Temporal distribution of studies included in the review (2000–2025)
Note. The figure shows the temporal evolution of the studies included in the systematic review. Source: Own elaboration, 2025.

The preponderance of evidence in Ecuador is indicative of the presence of active agendas concerning sustainability and urban habitability in Latin American countries, as evidenced by the scientific production of these nations. Contributions from other countries, including Argentina, Panama, and Chile, are intermittent, while Central America and the Caribbean exhibit a less pronounced presence (Figure 3).

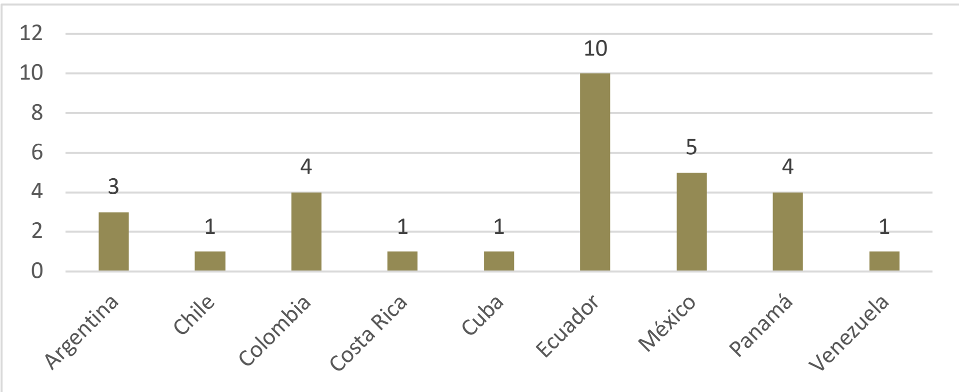

Fig. 3 - Geographical distribution of included studies by country
Note. The figure presents the geographical origin of the 30 studies included in the systematic review. Source: Own elaboration, 2025.

The largest group of studies is Latindex and Scopus, which shows a balance between regional production and high-impact literature. SciELO and Dialnet offer additional coverage of Latin America, while Redalyc and Web of Science have a less significant representation of the region (Figure 4).

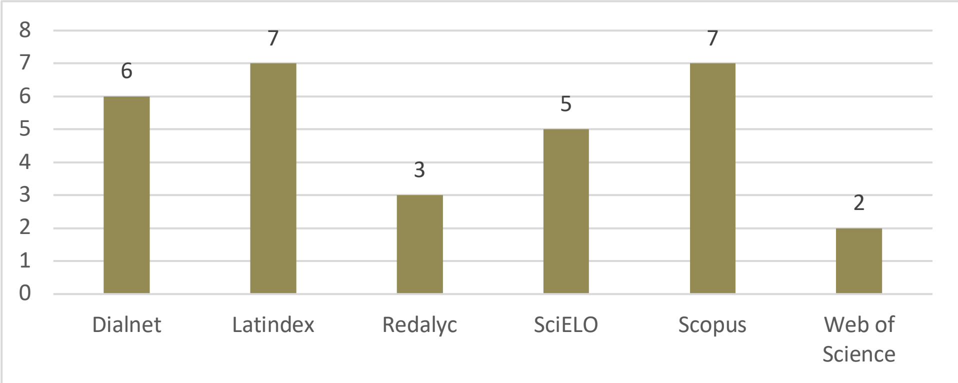

Fig. 4 - Distribution of studies according to database consulted

Content Analysis Results

As indicated by the findings presented in Table 3, there was a clear predominance of adaptive and bioclimatic approaches over static physiological models. This observation signifies a clear preference for the implementation of methodologies that consider the thermal response of users in tropical environments. The most frequently utilized variables encompass air temperature, relative humidity, and natural ventilation. Additionally, measurements pertaining to the performance of the envelope are considered, including solar radiation, thermal transmittance, and hygrothermal behavior. However, the majority of research conducted thus far has focused on assessing perceived comfort without incorporating clinical health indicators. This oversight has led to a dissociation between thermal habitability and the comprehensive evaluation of environmental health. A paucity of studies has been conducted on the relationship between indoor air quality and morbidity, suggesting that research into hygrothermal comfort continues to predominate over the investigation of more direct health indicators.

Table 3. Architectural characteristics and variables analyzed in Latin American studies

Author	Comfort model	Thermal variables	Health indicators
Aguilar-Arriola et al. (2024)	Not reported (no mention of PMV, ASHRAE 55 or adaptive model application)	Temperature, relative humidity, wind speed, natural ventilation, solar incidence	Presence of COVID-19 infections, persistence of symptoms, perception of suitability of the home for isolation, ventilation capacity and exposure to contagion
Araúz et al (2022)	ASHRAE 55 (Adaptive Comfort)	Interior temperature, thermal gains per envelope, heat transfer through walls, ceilings and glazing	Not reported (does not assess perceived health or well-being, or symptoms; indirect thermal comfort only)
Balter and Miranda-Gassull (2024)	Givoni (1998) – adaptive comfort range criteria for arid climates	Indoor temperature, outdoor temperature, natural ventilation, daily thermal amplitude, effects of solar radiation in summer and winter	Perceived comfort according to the ASHRAE scale (-3 to +3) and subjective wind chill
Barragán and Ochoa (2014)	Psychosometric diagram and bioclimatic criteria (non-PMV/PPD; passive approach)	Interior temperature, solar radiation, natural ventilation, natural lighting, orientation and hygrothermal balance	Thermal well-being (climate comfort) and visual comfort; does not assess physical symptoms or air quality
Bravo-Martínez et al. (2023)	Givoni Psychrometric Diagram / Passive Adaptive Approach	Indoor temperature, relative humidity, daily thermal oscillation; with registered natural ventilation	Perceived/hygrothermal comfort (without clinical health measurement); absence of CAI or physical symptoms
Bravo Morales and González Cruz (2003)	Adaptive Model (based on ISO 10551 and comparisons with Humphreys/Nicol/Auliciems)	Indoor Dry Bulb Temperature, Globe Temperature, Relative Humidity, Wind Speed	Perceived comfort/thermal preferences (no clinical health is assessed, only thermal perception)
Calderón Uribe (2019)	ISO 7730 – Fanger/Givoni/Mahoney (combined)	Indoor temperature, outdoor temperature, relative humidity, air velocity, average radiant temperature, WBGT index	Thermal comfort (indirect perception); does not assess indoor air quality or physical symptoms
Carpino et al. (2024)	ASHRAE 55 (Adaptive Comfort – hours of discomfort 80% acceptability)	Indoor temperature, outdoor temperature, natural ventilation, infiltrations, envelope performance (U-values), energy balance and cooling load	Hours of thermal discomfort (perceived comfort according to adaptive standard); does not evaluate physical symptoms or indoor air quality
Chen Austin et al. (2022)	ASHRAE 55 – Adaptive Comfort (80% acceptability)	Interior temperature, heat transferred by envelope, impact of PCM on walls and roofs, energy for cooling	Thermal discomfort (hours out of range) → an indirect indicator of well-being; does not assess environmental health or air quality
Dick Zambrano et	Fanger (comfort zone NEC-2011)	Indoor-outdoor temperature, solar radiation, natural ventilation,	Perceived comfort (thermal habitability), hygrothermal well-being

Author	Comfort model	Thermal variables	Health indicators
al. (2017)		orientation and thermal behaviour of the enclosure	
Dick Zambrano et al. (2016)	Fanger (NEC-2011)	Indoor/outdoor temperature, thermal conductivity in enclosures, natural ventilation, air velocity	Perceived comfort / thermal habitability
De Ignacio et al. (2018)	Adaptive model (passive comfort due to ventilation and climate response of the user; no PMV/PPD used)	Indoor/outdoor temperature, relative humidity, natural ventilation (airflow), shading effect	Indirect perceived comfort (no reported perception), thermal improvement linked to housing well-being; No direct clinical evaluation
Flores Zambonino (2025)	Adaptive Comfort based on ASHRAE Standard 55 (adaptive 80% acceptability)	Dry Bulb Temperature, Black Globe Temperature, Relative Humidity, Outside Temperature, Medium Radiant Temperature, Operating Temperature	Indirect perceived comfort by analysis of hours of discomfort; does not assess CAI, SBS, or clinical symptoms
Freire Navas et al. (2023)	Adaptive Model + Olgyay Bioclimatic Chart + Psychrometric Chart	Air temperature, relative humidity, solar radiation, wind speed (natural ventilation)	Perceived thermal well-being (no CAI or clinical physical symptoms are assessed)
Fuentes Pérez (2014)	Humphreys' (2001) adaptive model, thermal comfort zone by mean temperature	Air temperature, relative humidity (indoor and outdoor measurement), daily and monthly temperature oscillation	Perceived comfort (state of thermal comfort based on adaptive limits); does not apply direct clinical indicators, only thermal well-being
Guevara Fierro et al. (2025)	Standard: ISO 16000-26, ISO 7726, ISO 7730 and ANSI/ASHRAE 55 (regulatory approach to environmental well-being)	Dry bulb temperature, relative humidity, carbon dioxide (CO_2), seasonal temporal variation	Indoor air quality (CO_2) as a risk indicator; Associated morbidity (viral spread, unsanitary conditions)
García Gómez et al. (2011)	Adaptive Comfort (based on ISO 10551)	Dry bulb temperature, black globe temperature, relative humidity, air velocity	Perceived Comfort, Thermal Acceptance, Thermal Tolerance (ISO 10551)
González-Santos et al. (2023)	ASHRAE 55 (80% acceptability, non-comfort hours)	Temperature in walls, ceiling and ceiling, thermal loads, hygrothermal behaviour according to materiality	Direct health indicators are not evaluated; thermal comfort only (hours of non-comfort as an indirect indicator)
Heard & Olivera (2013)	It does not apply a model of human comfort; thermal-energy analysis (DOE2) oriented to thermal loads is used	Heat transfer in walls/ceilings, electricity consumption by air conditioning, effect of thermal insulation on the envelope	It does not evaluate health indicators; thermal efficiency and indirect comfort only through reduced heat load/AC use
Lara-Zamudio et al. (2024)	ANSI/ASHRAE 55-2020 Adaptive Model (80% comfort zone and 90% acceptability)	Interior operating temperature, exterior temperature, solar radiation, natural ventilation, heat transfer on façade and roof (U-value)	Perceived comfort (through surveys), does not evaluate clinical health indicators
Manzaba et al. (2025)	PMV according to ASHRAE 55 + EN 15251 (in digital simulation)	Indoor temperature, relative humidity, solar radiation, accumulated heat stress, passive ventilation	Perceived thermal comfort (non-clinical), habitability associated with thermal conditions (without direct measurement of physical health)
Manzaba Carvajal et al. (2025)	Adaptive Comfort + Passive bioclimatic criteria (no explicit PMV/PPD used)	Interior temperature, cross ventilation, solar radiation, thermal insulation of enclosure	Perceived thermal well-being (hygrothermal comfort)
Martínez (2004)	It does not apply a formal physiological model; Empirical analysis of habitability (perception of comfort)	Interior temperature (summer/winter), orientation, air infiltration, direct solar radiation, location at height	Perceived comfort – living conditions declared by users (no physical symptoms or IAQs)
Martínez et al. (2005)	PMV/PPD does not apply; instrumental evaluation + humidity/dew point-based hygrothermal habitability (ASHRAE/NCh criterion)	Indoor Ambient Temperature, Indoor Surface Temperature, Relative Humidity, and Dew Temperature	Hygrothermal risk (appearance of fungi) and perceived comfort associated with condensation (not direct medical symptoms)
Rodríguez et al. (2019)	PMV/PPD and Adaptive Comfort static model (ASHRAE 55 / CBE Tool)	Air temperature, relative humidity, infiltrations, radiation (implicit via MRT), natural ventilation	Perceived comfort and occupant satisfaction (thermal well-being)
Rodrigo et al. (2012)	Adaptive model (based on Humphreys/Nicol) + comparisons with Bioclimatic Chart	Indoor temperature, outdoor temperature, relative humidity, natural ventilation, thermal transmittance of the enclosure	Perceived comfort (does not include CAI or physical symptom measurements)
Rojas et al. (2022)	Ecuadorian referential regulations (NEC / INEN-ISO 7730 / ASHRAE 55) – interpreted under an adaptive approach	Indoor and outdoor temperature (averages/minimums/maximums), relative humidity (mentioned as taken), thermal behavior according to materiality and altitude	Perceived comfort/habitability (no clinical indicators or CAI; indirect assessment)
Suárez et al. (2020)	PMV/PPD does not apply; Empirical adaptive approach (comparison of case control vs. green façade)	Outdoor and indoor ambient temperature, outdoor and indoor surface temperature, relative humidity	Perceived thermal comfort (thermal reduction); does not include CAI or clinical health symptoms
Varini & Luciani (2015)	Passive/adaptive comfort (PMV/PPD does not apply; based on natural ventilation and observed thermal	Air temperature, radiant temperature, operating temperature, relative humidity, natural ventilation/chimney effect, infiltration	Perceived thermal comfort (improved habitability) and reduced interior discomfort

Author	Comfort model	Thermal variables	Health indicators
	behavior)		
Velasco Roldan et al. (2019)	Passive adaptive model (no mention of MVP/PPD; focus on in-situ thermal stability)	Indoor and outdoor temperature, relative humidity, ventilation effects and solar radiation on surfaces	Perceived thermal comfort (thermal stability); no symptoms or air quality are evaluated

Note. The table presents the comparative synthesis of comfort models, thermal variables and health indicators reported in the included studies, allowing the identification of methodological patterns and gaps in the health evaluation associated with hygrothermal comfort. Prepared by the author based on documentary analysis.

Figure 5 shows that indoor and outdoor temperature, as well as air/ventilation velocity, are the most considered variables in the evaluation of thermo-ambient comfort. Relative humidity and solar radiation have a moderate presence, while radiant/operating temperature has a more restricted use, which indicates that most of the work is oriented to basic measurements of thermal performance and not to advanced indicators of energy transfer and integral thermal perception.

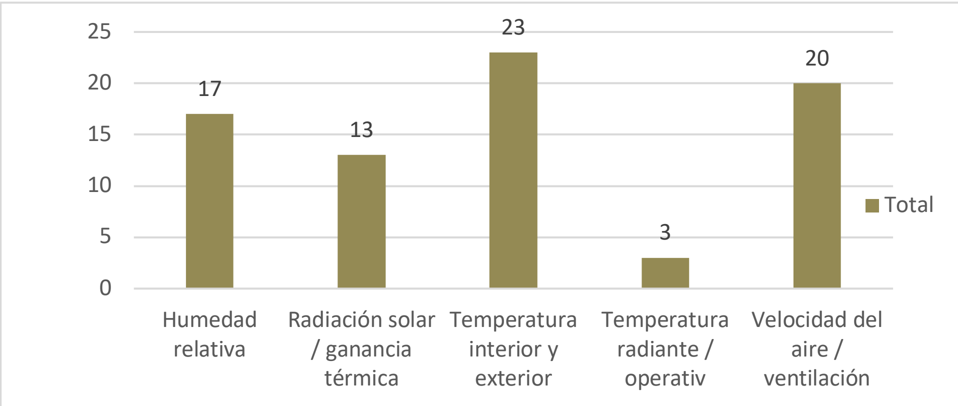

Fig. 5 - Frequency of thermoenvironmental variables analyzed in the included studies

Note. Frequency of occurrence of each thermoenvironmental variable in the 30 included studies. Source: Own elaboration, 2025.

Figure 6 reveals a clear predominance of the ASHRAE 55 adaptive model over static models based on the different versions of ISO 7730. This finding corroborates that in tropical environments and in Latin America, hygrothermal comfort is mainly evaluated through methodologies that take into account the dynamic user-environment relationship, while models based on PMV/PPD (Fanger) provide less than half.

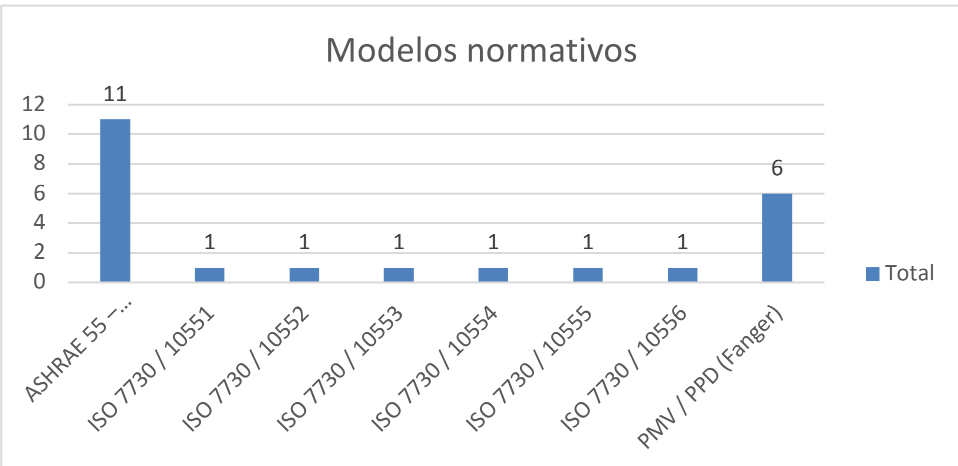

Fig. 6 - Normative models used in the included studies

Note. Frequency of use of the normative models used to evaluate thermal comfort in the included studies.
Source: Own elaboration, 2025.

The review in Table 3 shows a clear predominance of adaptive models (100% based on ASHRAE 55 or the variants derived from Humphreys, Nicol and Givoni), this because they are the most applicable for tropical climates and Latin American contexts. In contrast, the Fanger PMV/PPD model that appears in ISO 7730 has less presence and is limited to some instrumental evaluations or energy simulations. It can also be seen that there are additional contributions from bioclimatic charts (Givoni, Olgyay) and hybrid methods that integrate passive criteria together with operational regulations. These results reveal a methodological inclination towards adaptive methodologies that consider comfort as a phenomenon that arises from the relationship between user, climate and envelope architecture, rather than a purely physiological balance.

Figure 7 illustrates that normative models are the majority in the evaluation of comfort in Mexico, Panama and Venezuela; on the other hand, in Colombia and Ecuador there is a mixed use between standardized approaches, empirical models and bioclimatic models. This indicates that there may be a difference in the degree of methodological institutionalization between countries, more adapted to the climate and context for those that use non-standardized models.

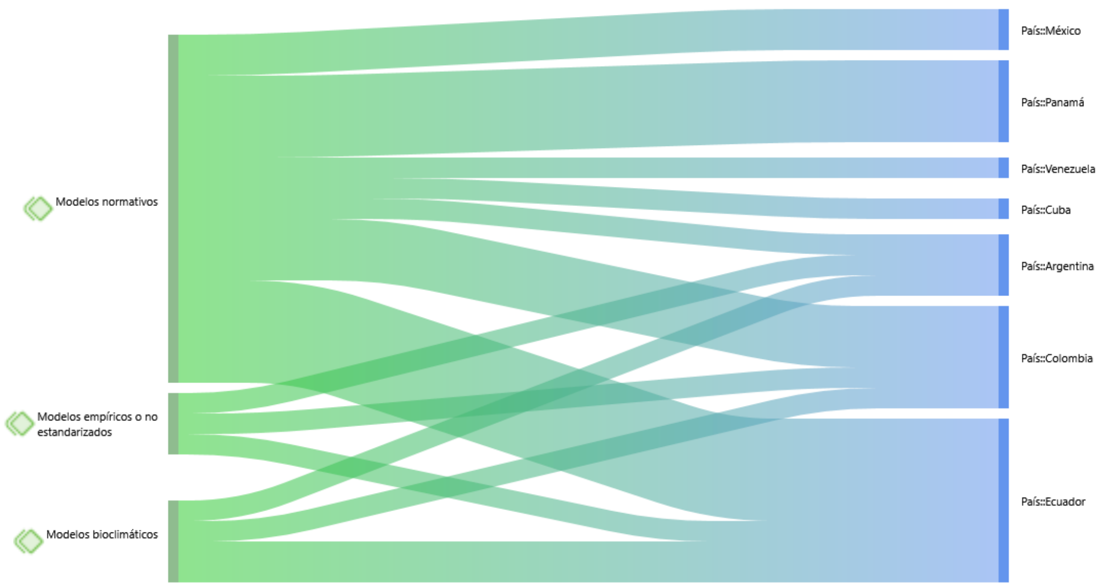

Fig. 7 - Relationship between types of models applied and countries of origin
Note. Link between the types of models used in the studies and the geographical distribution of their application.
Source: Own elaboration, 2025.

The results in Figure 8 show that most of the studies evaluate the effect of the architectural envelope on perceived thermal well-being and that indicators related to heat stress or respiratory risks are reported less frequently. This shows that discipline continues to privilege the subjective perception of comfort, over direct measurements in environmental health, which confirms the existing distance between thermal habitability and comprehensive health evaluation.

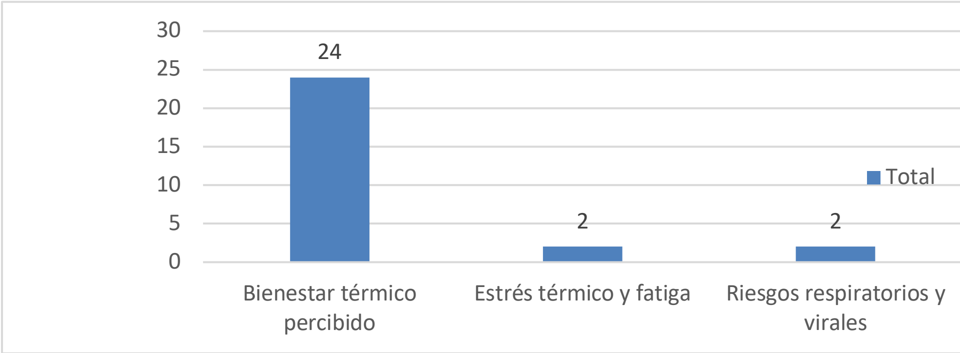

Fig. 8 – Environmental health and well-being indicators identified in the studies

Note. Frequency of environmental health and well-being indicators reported in the 30 included studies.
Source: Own elaboration, 2025.
Figure 9 shows that the strongest articulation between thermoenvironmental variables and environmental health is now within the reach of studies developed in Ecuador and Mexico, where the evaluation of hygrothermal comfort is more linked to aspects of real living conditions. In other countries, the relationship is more dispersed or isolated, thus confirming differences in the degree of consolidation of applied research in hot climates typical of Latin America.

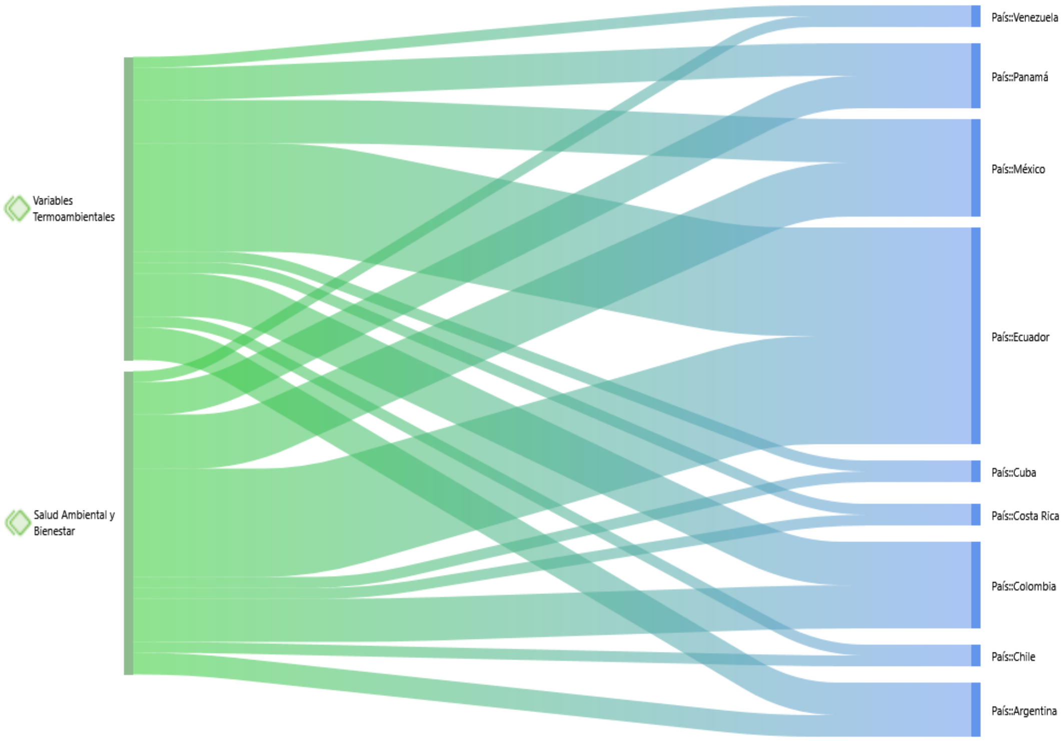

Fig. 9 - Relationship between thermoenvironmental variables, environmental health and countries of origin.

Note. Correspondence between categories of analysis (thermoenvironmental variables and environmental health) and geographical origin of the included studies.

Source: Own elaboration, 2025.

In Table 4, most studies confirm that the architectural envelope directly influences interior thermal comfort (Aguilar-Arriola et al., 2024; Araúz et al., 2022; De Ignacio et al., 2018; Dick Zambrano et al., 2017; González-Santos et al., 2023). Likewise, several studies show that cross ventilation and shading improve thermal habitability in tropical urban homes (Freire Navas et al., 2023; Suárez et al., 2020; Varini & Luciani, 2015).
Various studies show that traditional or low thermal inertia materials have sustained overheating (Bravo Martínez et al., 2023; Martínez, 2004; Rodrigo et al., 2012). Others highlight the improvement of

comfort through biomaterials or passive strategies (Flores Zambonino, 2025; Velasco Roldan et al., 2019; Manzaba et al., 2025).

Direct evidence is identified that links microclimatic conditions with environmental health risk (Guevara Fierro et al., 2025; Aguilar-Arriola et al., 2024). A small number explore adaptive comfort in a sociocultural key (García Gómez et al., 2011; Bravo Morales and González Cruz, 2003).

They also highlight the limitations. It was found that the reliance on simulations without verification in real occupation (Barragán & Ochoa, 2014; Carpino et al., 2024; Chen Austin et al., 2022). There are small samples or single cases, which reduces generalization (Lara-Zamudio et al., 2024; Calderón Uribe, 2019; Fuentes Pérez, 2014). Most do not include clinical or health indicators associated with comfort (Araúz et al., 2022; De Ignacio et al., 2018; Manzaba Carvajal et al., 2025). Few studies incorporate user perception or prolonged post-occupational assessment (Dick Zambrano et al., 2016; Rojas et al., 2022). Climate analysis is usually seasonal and not annual, limiting temporal validity (Martínez et al., 2005; Heard & Villarroel, 2013; Rodrigo et al., 2012). In several urban contexts, there is a low correlation between comfort and environmental health impact (Bravo-Martínez et al., 2023; González-Santos et al., 2023).

Studies show clear effects of the envelope on thermal comfort. However, its impact on environmental health is still small. The evidence is focused on thermal efficiency and ventilation and does not refer to environmental health indicators. The most frequent methodological gap consists of not carrying out sustained monitoring and triangulation between physical measurement, user perception and health data.

Table 4. Analysis of results and limitations stated in the studies analyzed

Author	Main results	Stated limitations
Aguilar-Arriola et al. (2024)	Social interest housing had higher rates of COVID-19 infection associated with less ventilation and higher indoor temperatures compared to residential housing.	Exploratory study in a single urban sector, based on perception and specific measurements; it does not include a standardized comfort model or prolonged monitoring; Possible bias for self-reporting in surveys
Araúz et al. (2022)	Envelope configurations with high insulation on roofs and walls significantly reduce thermal gains and hours of discomfort in humid tropical climates.	The analysis is based on numerical simulation (not on-site measurement), study of a single housing case, results that cannot be generalized to the entire residential stock, does not include occupant perception, or health assessment
Balter and Miranda-Gassull (2024)	Light houses have good thermal performance in winter but significant overheating in summer, with differences according to the thermal inertia of the construction system.	Studio limited to 6 homes; limited measurement periods; it does not include validation with simulation models; social factors (use, occupancy and opening of windows) influence results; a single climatic and urban context.
Barragán and Ochoa (2014)	The designed house maintains stable interior temperatures within comfort ranges throughout the year through passive strategies of orientation and solar capture.	Validation only by simulation (not measurement with occupants), study of a single prototype, without post-occupational monitoring or direct evaluation of health or user perception
Bravo-Martínez et al. (2023)	None of the evaluated dwellings remains within the range of thermal comfort and isolated strategies (insulation or ventilation) are insufficient to mitigate overheating in hot-humid climates.	Evaluation in two unique cases; short measurement period; without user perception; without direct health indicators; High ambient humidity as an uncontrolled variable
Bravo Morales and González Cruz (2003)	The temperatures of the balloon were higher than those of the indoor air, affecting the thermal perception and evidencing the adaptation of the occupants to warm conditions in naturally ventilated homes.	Non-probabilistic sample, limited to a specific sector, without direct analysis of air quality or health, and restricted to specific months of the year.
Calderón Uribe (2019)	The incorporation of sustainable materials on the roof increased the interior temperature to 6°C and improved the heat balance in cold nighttime periods.	Study of a single case; measurement limited to a short period; no post-occupational evaluation; it does not correlate comfort with health; cold-Andean climate (not tropical); No long-term ventilation analysis
Carpino et al. (2024)	The size of the photovoltaic system, the use of air conditioning (schedule/set-point) and the transmittance of the floor are the measures with the greatest impact on the reduction of energy consumption and hours of discomfort in tropical climates.	Simulated study (not on-site measurement), single case, without post-occupational validation, without direct indicators of environmental health and without energy storage
Chen Austin et al. (2022)	Configurations with PCM on deck have a greater reduction in energy consumption and thermal discomfort in humid tropical climates than configurations with PCM on walls.	Based on simulation (not experimental verification in real occupancy), analysis in a single climate and architectural model, with no direct correlation with health
Dick Zambrano et	The use of insulating materials and bioclimatic	It does not assess the user's real perception or occupational

Author	Main results	Stated limitations
al. (2017)	strategies reduces the interior temperature to levels close to the comfort zone in critical hot hours.	health; results based solely on simulation; there is no on-site validation; climate modeled in a single seasonal scenario.
Dick Zambrano et al. (2016)	The houses have higher interior temperatures than the exterior temperatures due to low ventilation, minimal solar protection and high thermal conductivity of the envelope.	Reduced sample (only two dwellings), measurements in a single climatic period, absence of direct perception of the user, partial validation with simulation.
De Ignacio et al. (2018)	Passive envelope optimization through cross ventilation and shading improves interior thermal stability and reduces overheating in social housing in tropical climates.	It does not include direct measurement of thermal perception of the occupants, reduced sample, without seasonal longitudinal evaluation or explicit health indicators.
Flores Zambonino (2025)	The bamboo house registered fewer hours of thermal discomfort than the block house due to its lower thermal inertia and greater dissipation of accumulated heat.	Short monitoring period (10 days), small sample (two households), no direct subjective measurement of occupants, no seasonal assessment and no explicit health indicators
Freire Navas et al. (2023)	The study identified that cross ventilation, overhangs, vegetation and strategic orientation improve indoor thermal comfort in homes located in a tropical mega-thermal semi-humid climate.	No built housing is evaluated (theoretical proposal), absence of measurement in real users, without prolonged empirical validation or evaluation of indoor air quality.
Fuentes Pérez (2014)	The traditional house maintained more stable indoor temperatures than the outside, but presented a constant accumulation of high relative humidity.	Single case; absence of comparative sampling; lack of direct health indicators; only two monitored variables; dependence on the warm-humid urban microclimate
Guevara Fierro et al. (2025)	Temperature, humidity and CO_2 values were kept outside the optimal comfort ranges in most homes, showing a direct relationship between poor habitability and risk to environmental health.	Studio limited to 6 homes; no prolonged post-occupational measurement; without control of behavioral variables; hot-dry climate (not humid tropical); generalization restricted to a specific urban context
García Gómez et al. (2011)	Residents of self-produced housing exhibit greater thermal tolerance and higher ranges of adaptive comfort than occupants of economic housing in hot humid climates.	Other physiological variables were not included; only temperature and not radiation or other parameters were evaluated; absence of differentiation by age or sex; analysis restricted to the warm period; limited to two types of housing in a single city.
González-Santos et al. (2023)	Enclosures with bamboo biocomposites significantly reduce interior thermal gain and eliminate hours of non-comfort in the warmer months compared to conventional materials.	Study based on simulation (without on-site measurement), a single case, does not include user perception or health variables; Analysis restricted to two climatic months
Heard and Villarroel (2013)	Thermal insulation in walls and ceilings reduces energy consumption in tropical climates and improves the hygrothermal performance of the envelope in social housing.	No perception or data of occupants is collected; there is no measurement of indoor comfort or health; simulation-based analysis; extrapolation limited to typical cases; No real typological variation
Lara-Zamudio et al. (2024)	The combination of blinds plus wall and roof insulation reduces the interior temperature by up to 5.7°C and improves thermal comfort compared to the baseline.	Small sample in surveys (n=11), a single case study, without post-occupation measurements, does not include environmental health indicators, and is based on simulations rather than on prolonged instrumental data.
Manzaba Carvajal et al. (2025)	The house located in the Sierra region requires greater thermal inertia to conserve heat, while the one located in the Coast requires thermal dissipation and shading strategies due to solar gain.	Simulation limited to the equinox (not annual cycle), absence of empirical data in real users, occupancy habits or induced ventilation are not considered, and costs and socioeconomic evaluation are not included.
Manzaba et al. (2025)	The progressive housing model achieved up to 6°C of thermal improvement and an average energy efficiency of more than 20% through passive bioclimatic strategies and the use of recyclable materials.	Unique geographic context (Mount Sinai), absence of evaluation in other climates, limited temporal validation, and untested performance in extreme conditions.
Martínez (2004)	58% of the dwellings are uncomfortable in summer and 75% in winter, a condition associated with orientation, infiltrations and position in height within the building.	Qualitative evaluation (surveys); absence of prolonged instrumental measurement; mixed subtropical climate and not strictly tropical; no clinical health indicators; Analysis in a single urban context
Martínez et al. (2005)	The study identified that surface condensation is caused by high rates of indoor relative humidity combined with low surface temperatures in the social housing envelope.	A small sample (6 households), a single seasonal period (winter), absence of evaluation in other climatic zones, clinical health indicators and deep qualitative perception are not included.
Rodríguez et al. (2019)	Passive intervention on the envelope (interior insulation and additional sealing/windows) increased the interior temperature and reduced occupant thermal dissatisfaction compared to the original condition.	Short monitoring period, absence of long-term evaluation, still high relative humidity, budget restriction, impossibility of modifying original windows due to building regulations.
Rodrigo et al. (2012)	The houses studied presented interior thermal conditions that exceed the ranges of adaptive comfort during the summer due to low thermal inertia and little passive control over the envelope.	Study limited to a single type of construction, without annual longitudinal measurement, without detailed post-occupancy evaluation, and without direct health indicators.
Rojas et al. (2022)	The two rural dwellings studied remained below the recommended normative range of comfort, evidencing that the traditional materiality used does not guarantee thermal	No prolonged seasonal measurement, direct health indicators not included, reduced sample (2 cases), analysis focused only on temperature (no ventilation or full IAQ), no comparative simulation.

Author	Main results	Stated limitations
	habitability in cold Andean climates.	
Suárez et al. (2020)	The traditional green facades reduced the interior ambient temperature to 3.2 °C and the exterior surface temperature to 26.5 °C in the east orientation, improving the thermal behavior with respect to the control houses.	Short monitoring period (15 days per case), no annual longitudinal measurement, results dependent on the type of plant species and specific orientation, no direct perception of occupants or air quality was evaluated.
Varini and Luciani (2015)	The passively ventilated wooden housing model significantly reduces the interior temperature compared to the exterior, maintaining daily thermal stability without mechanical equipment.	It does not include direct perception of users, absence of physiological or health measurements, single case modeled by simulation, without long-term on-site validation.
Velasco Roldan et al. (2019)	The prototype with natural insulation, ventilated façade and green roof maintains stable interior temperatures within the comfort zone without mechanical air conditioning.	Unique prototype, specific climatic context, does not include user perception measurements or direct health indicators, absence of replicability in real inhabited homes

Note. The table presents the comparative synthesis of the results and methodological limitations declared in the 30 studies analyzed, allowing to evidence recurrent patterns and structural gaps in the evaluation of hygrothermal comfort and its relationship with environmental health.
Source: Own elaboration based on documentary analysis.
The results show a consensus regarding the role of the envelope in the interior thermal modulation. However, the available evidence remains focused on energy efficiency and perceived comfort. The health issue is treated in a marginal or tangential way. Most studies do not combine environmental data with verifiable health indicators. There is no long-term follow-up in real occupancy either. This gap evidences a methodological gap between habitability and environmental health. Therefore, it is necessary to move towards integrative analysis models that relate thermal performance with well-being and health risk. This paper focuses on responding to this gap in literature.

Convergences with existing evidence
The findings are consistent with contemporary research, as they demonstrate the immediate effect of the thermal envelope on interior habitability. This finding aligns with the findings of other studies that have identified natural ventilation and shading as the primary strategies for tropical climates (Aguilar-Arriola et al., 2024; Suárez et al., 2020). Furthermore, the findings underscore the significance of adaptive models over static ones, a notion that is particularly salient in Latin American cities, where high daily thermal variability persists (Freire Navas et al., 2023; Varini & Luciani, 2015). Consequently, it has been determined that the concept of hygrothermal comfort is predominantly assessed from the perspective of the user, rather than considering its ramifications for environmental health. This finding aligns with previous research employing analogous methodologies (Guevara-Fierro et al., 2025; González-Santos et al., 2023). Therefore, the evidence that has been reviewed lends support to the link between envelope performance and thermal comfort. Furthermore, the evidence justifies the manner in which attention is focused.

Methodological divergences and gaps
While the extant literature acknowledges the pertinence of thermal comfort, there is a paucity of studies that employ verifiable health metrics. The majority of comfort studies evaluate the subjective sensation of well-being, neglecting to establish a correlation with its potential physiological or environmental ramifications. A segregated approach is maintained between health risk and thermal performance. This discrepancy complicates the assessment of the actual impact on users. Furthermore, the majority of the measurements are seasonal in nature and do not correspond to annual thermal cycles. This phenomenon compromises the comparative validity of critical heat times. A persistent challenge pertains to the limited triangulation between instrumental data and user perception. In a series of studies, the actual occupation appears to be simulated or represented in an indirect manner. This limitation restricts the scope of the analysis and hinders the comprehensive evaluation of the comfort context. Additionally, the typological diversity of housing is limited. The emphasis remains on instances where cities are not included in inter-neighborhood analysis. This restriction, however, has the effect of diminishing the scalability of the conclusions. Finally, environmental health is regarded as a theoretical implication rather than an empirical variable.

Structural causes of divergences

The observed discrepancies can be attributed to methodological and structural factors inherent to the field. The initial facet pertains to the dynamic orientation of architectural research. A number of studies have been conducted that prioritize thermal efficiency over health impact. This approach effectively relegates the environmental dimension to a secondary status. A secondary rationale pertains to the absence of regulatory frameworks that incorporate health considerations into the assessment of comfort. Habitability policies continue to prioritize physical performance as an indicator of total well-being. The third aspect pertains to the limited availability of health data associated with housing. However, research in this field rarely utilizes epidemiological records. The absence of longitudinal measurement in real occupancy also has an impact on the model. Absent the implementation of continuous monitoring, the repercussions on health are frequently underestimated. The prevailing field of study demonstrates a preference for international normative models devoid of a robust socio-cultural contextualization. This results in a limitation of the connection between technical knowledge and the user's life experience.

Theoretical and practical implications

The findings suggest that incorporating environmental health into comfort analysis is a beneficial practice. This phenomenon is further compounded by additional factors that extend beyond the realm of mere energy. In principle, the envelope is dematerialized as a physical barrier and constituted as an ecosystem mediator. The house is regarded as a thermal interface between climate and body. This finding serves to bolster adaptive models in tropical climates. Evidence suggests that culturally situated passive strategies are endorsed at the practical level. Cross ventilation in conjunction with shading continues to be a highly effective solution. However, the effectiveness of these interventions necessitates further validation through rigorous health assessments. It is imperative that housing policies encompass a broader scope, encompassing environmental health indicators beyond mere thermal considerations. This objective would be to establish a unification between the domain of architecture and that of verifiable well-being. Subsequent studies must include the articulation of permanent monitoring and exposure measurements. This facilitates the enhancement of the bidirectional relationship between comfort and urban health.

Projection of the field and future lines of research

The findings suggest a methodological evolution for the field. Consequently, research will transition towards the development of comprehensive models that integrate comfort, environmental health, and real occupation. A transition from descriptive thermal studies to those applied in eco-physiology would be necessary. This necessitates a comprehensive evaluation of heat stress and its correlation with health load. Concurrent measurements of microclimate, material, and body response are imperative to ensure the validity of the findings. Greater sophistication is also planned in the evaluation of the envelope. A transition from thermal efficiency to habitable thermal resilience is imminent. Future studies should include comparative longitudinal follow-up. The objective of this study is to examine the cumulative impact on health and well-being. The incorporation of epidemiological data will serve to bolster the causal evidence. In conclusion, there is an imperative for regulatory frameworks that are commensurate with the climate and cultural particularities of the countryside. The outcome of this process will be architecture that is both climatically situated and verifiably sanitary.

Conclusions

The review confirmed an increasing focus of studies over the past decade, with most tropical climate reports originating from Latin American countries. The preponderance of the evidence is oriented towards the analysis of the thermal performance of the building envelope rather than towards the assessment of indoor environmental quality.

Adaptive models demonstrated greater efficacy in their ability to predict climate-related outcomes when compared to static physiological models. ASHRAE 55 has been recognized as the prevailing standard in the field, a distinction attributable to its demonstrable practicality. In contrast, ISO 7730 is less frequently cited and transferred.

The most frequently investigated variables were temperature, humidity, and ventilation. However, a paucity of research has been dedicated to the assessment of indoor air quality or cumulative thermal stress.

The relationship is addressed in an indirect or marginal manner. The emphasis on thermal perception is notable, yet there is a conspicuous absence of integration with verifiable health-related metrics. This

finding underscores a methodological gap in the comprehensive evaluation of urban well-being.
The designs are predominantly simulation-based, there is an absence of actual occupancy, and the measurements are of a short-term nature. A paucity of evidence exists to substantiate the occurrence of a correlation between physical data, perception, and health.

Conflict of Interest Statement

The authors declare that they have no conflict of interest.

References

1. Aguilar-Arriola, E. J., Rosales-Rivera, B. A., & Aguilar-Arriola, A. J. (2024). Análisis de temperatura, ventilación y materiales constructivos que promueven contagio de Covid-19 en viviendas sociales. *Revista Arquitectura +*, *9*(18), 136–162. https://doi.org/10.5377/arquitectura.v9i18.19080
2. Arango Díaz, L., Herreño Tellez, E., & Murillo Galvis, M. (2022). Cambio climático y bienestar humano. Retos de la arquitectura en Latinoamérica. *Módulo Arquitectura - CUC*, *29*, 135–152. https://doi.org/10.17981/mod.arq.cuc.29.1.2022.06
3. Araúz, J., Mora, D., & Chen Austin, M. (2022). Assessment of different envelope configurations via optimization analysis and thermal performance indicators: A case study in a tropical climate. *Sustainability*, *14*(4), 2013. https://doi.org/10.3390/su14042013
4. ASHRAE. (2020). *Thermal environmental conditions for human occupancy. ASHRAE Standard 55-2020*. American Society of Heating, Refrigerating and Air-Conditioning Engineers.
5. Balter, J., & Miranda Gassull, V. P. (2024). Tecnologías de envolvente liviana en la producción de vivienda social pública: estudio de calidad térmica y confort en Mendoza, Argentina. *AUS - Arquitectura / Urbanismo / Sustentabilidad*, (36), 55-63. http://dx.doi.org/10.4206/aus.2024.n36-08
6. Barragán, A., & Ochoa, P. (2014). Design of low-cost environmental housing: Case study for Cuenca, Ecuador. *Maskana*, *5*(1), 81–98. https://doi.org/10.18537/mskn.05.01.06
7. Bravo Morales, G., & González Cruz, E. (2003). Confort térmico en el trópico húmedo: experiencias de campo en viviendas naturalmente ventiladas. *Ambiente Construído*, *3*(2), 47-55.
8. Bravo-Martínez, D., Torres-Quezada, J., & Panchana, R. A. (2023). Análisis del confort térmico en viviendas sociales con diferentes sistemas constructivos en el clima cálido-húmedo de Ecuador. *Green World Journal*, *6*(2), 1-12. https://doi.org/10.53313/gwj62078
9. Calderon Uribe, F. (2019). Evaluación del mejoramiento del confort térmico con la incorporación de materiales sostenibles en viviendas en autoconstrucción en Bosa, Bogotá. *Revista Hábitat Sustentable*, *9*(2), 30-41. http://dx.doi.org/10.22320/07190700.2019.09.02.03
10. Carpino, C., Chen Austin, M., Mora, D., & Arcuri, N. (2024). Retrofit measures for achieving NZE single-family houses in a tropical climate via multi-objective optimization. *Buildings*, *14*(3), 566. https://doi.org/10.3390/buildings14030566
11. Chen Austin, M., Araúz, J., & Mora, D. (2022). Numerical assessment of different phase change materials as a passive strategy to reduce energy consumption in buildings under tropical climates. *Buildings*, *12*(7), 906. https://doi.org/10.3390/buildings12070906
12. Chen Austin, M., Castillo, M., Carrizo, K., de Mendes Da Silva, Á., & Mora, D. (2021). Evaluación del rendimiento térmico y estrategias bioclimáticas de un edificio universitario en clima tropical húmedo. *Revista De Iniciación Científica*, *7*(1), 16-23. https://doi.org/10.33412/rev-ric.v7.1.3048

13. De Ignacio Vivens, G., Soutullo Castro, S., López-Zaldivar, O., Lozano-Diez, R. V., & Verdú Vázquez, A. (2018). Sobre inercia térmica y aislamiento de viviendas en clima cálido-húmedo. *Anales De Edificación*, *4*(1), 14-26. https://doi.org/10.20868/ade.2018.3730
14. Dick Zambrano, S., González, V., & Palacios, C. (2016). Estudio de las condiciones de confort higrotérmico y habitabilidad en dos viviendas del programa Socio Vivienda 1, Guayaquil. *Revista Universidad de Guayaquil*, *123*(2), 33-48. https://doi.org/10.53591/rug.v123i2.408
15. Dick Zambrano, S. R., Coque Arias, J., & Oviedo Machuca, C. (2017). Propuesta de vivienda con criterios bioclimáticos y bajo costo. *Revista Universidad de Guayaquil*, *124*(1), 90-109. https://doi.org/10.53591/rug.v124i1.648
16. Flores Zambonio, S. (2025). Análisis del confort térmico entre viviendas de bambú y bloque. *Esprint Investigación*, *4*(1), 420-433. https://doi.org/10.61347/ei.v4i1.120
17. Freire Navas, J. C., Romo Zamudio, C. E., & Trajano Javier, G. R. (2023). Incorporation of passive strategies in the design of a dwelling for tropical mega thermal semi-humid climate, located in Durán province of Guayas. *Ciencia Digital*, *7*(3), 147-170. https://doi.org/10.33262/cienciadigital.v7i3.2631
18. Fuentes Pérez, C. A. (2014). Adaptabilidad higrotérmica de la vivienda tradicional en Tampico, México. *Contexto. Revista de la Facultad de Arquitectura de la Universidad Autónoma de Nuevo León*, *8*(9), 77-97.
19. García Gómez, C., Bojórquez Morales, G., & Ruiz Torres, P. (2011). Sensación térmica percibida en vivienda económica y autoproducida, en período cálido, para clima cálido húmedo. *Ambiente Construído*, *11*(4), 99–111. https://doi.org/10.1590/S1678-86212011000400008
20. González-Santos, C., Delgado, N., Madrid-Vásquez, E., Guevara-Sinisterra, P., Villarreal-Scott, W., & Chen Austin, M. (2023). Evaluación del rendimiento energético de los cerramientos a base de bambú bajo el clima tropical de la Ciudad de Panamá. *I+D Tecnológico*, *19*(1), 72-83. https://doi.org/10.33412/idt.v19.1.3779
21. González-Vásquez, M. R., & Molina-Prieto, L. F. (2018). Envolvente arquitectónica: un espacio para la sostenibilidad. *Arkitekturax Visión FUA*, *1*(1), 49-61. https://doi.org/10.29097/26191709.201
22. Guevara Fierro, P. M., Bojórquez Morales, G., & Martínez Valenzuela, M. C. (2025). Factores de habitabilidad y salud, monitoreados en vivienda vertical de clima cálido seco. *Ciencia Latina Revista Científica Multidisciplinar*, *9*(2), 270-289. https://doi.org/10.371311/cl_rcm.v9i2.16820
23. Heard, C. L., & Olivera Villarroel, S. M. (2013). Evaluación económica de la resistencia térmica de la vivienda de interés social en las ciudades tropicales de México. *Acta Universitaria*, *23*(4), 17–29. https://doi.org/10.15174/au.2013.458
24. INEN-ISO 7730. (2014). *Norma Técnica Ecuatoriana [NTE] - Servicio Ecuatoriano de Normalización [INEN], sobre ISO 7730: Ergonomía del entorno térmico*.
25. Kitchenham, B. (2004). *Procedures for performing systematic reviews*. Keele University.
26. Lara-Zamudio, B. S., Rodriguez, C. M., & Coronado-Cabrera, M. C. (2024). Estudio comparativo de estrategias pasivas para favorecer el confort térmico en viviendas multifamiliares en climas cálidos: Ricaurte, Colombia. *AUS - Arquitectura / Urbanismo / Sustentabilidad*, (35), 108–120. https://doi.org/10.4206/aus.2024.n35-12
27. Manterola, C., Astudillo, P., Arias, E., Claros, N., & MINCIR, G. (2013). Revisiones sistemáticas de la literatura. Qué se debe saber acerca de ellas. *Cirugía Española*, *91*(3), 149-155. https://doi.org/10.1016/j.ciresp.2011.07.009
28. Manzaba Carvajal, G. R., Valencia Robles, R. A., & Romero Jara, M. I. (2025). Impacto ambiental y térmico de materiales en viviendas sociales según región climática en Ecuador. *Revista Digital Novasinergia*, *8*(2), 178-202. https://doi.org/10.37135/ns.01.16.10

29. Manzaba, G., Valencia, R., Balladares, D., & Neira, W. (2025). Hábitats en transformación: vivienda progresiva con materiales reciclados y eficiencia energética. *Revista Digital Novasinergia*, *8*(2), 154-177. https://doi.org/10.37135/ns.01.16.09
30. Martínez, C. F. (2004). Evaluación cualitativa de condiciones ambientales de viviendas del IPV en SM de Tucumán. *Avances en Energías Renovables y Medio Ambiente*, *8*(1).
31. Martínez, P., Sarmiento, P., & Urquieta, W. (2005). Evaluación de la humedad por condensación al interior de viviendas sociales. *Revista INVI*, *20*(55), 154-165.
32. Molina Molina, J. P. (2025). Arquitectura: el papel de la arquitectura biofílica en la planificación de ciudades inteligentes y sostenibles. *Código Científico Revista De Investigación*, *6*(1), 389–407. https://doi.org/10.55813/gaea/ccri/v6/n1/897
33. Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., ... & Alonso-Fernández, S. (2021). Declaración PRISMA 2020: una guía actualizada para la publicación de revisiones sistemáticas. *Revista Española de Cardiología*, *74*(9), 790-799. https://doi.org/10.1016/j.recesp.2021.06.016
34. Rodrigo, B. G., Sanabria, J. C., Marchamalo, M., & Umana, M. (2012). Análisis del confort y el comportamiento higrotérmico de sistemas constructivos tradicionales y actuales en viviendas de Santa Ana-Ciudad Colón (Costa Rica). *Informes de la Construcción*, *64*(525), 75-84. https://doi.org/10.3989/ic.10.047
35. Rodríguez, C. M., Medina, J. M., Pinzón, A., & García, A. (2019). A post-occupancy strategy to improve thermal comfort in social housing in a tropical highland climate: A case study in Bogotá, Colombia. *Informes de la Construcción*, *71*(555), e305. https://doi.org/10.3989/ic.61006
36. Rojas, A. M., Fernández, L., Zambrano, L., & Paredes, A. (2022). Análisis de la vivienda rural utilizando el confort térmico como medida de habitabilidad. *CienciAmérica*, *11*(2), 124-138. https://doi.org/10.33210/ca.v11i2.399
37. Sotelo Barrios, M. E., Monsalve Jaimes, S. J., & Valencia, J. D. R. (2024). Desarrollo urbano sostenible: integración del ecodiseño, la arquitectura bioclimática y la ingeniería ambiental para ciudades resilientes. *FACE: Revista de la Facultad de Ciencias Económicas y Empresariales*, *24*(3), 130-137. https://doi.org/10.24054/face.v24i3.3307
38. Suárez, P., Cantón, M. A., & Correa, É. (2020). Efecto térmico de fachadas verdes tradicionales en envolventes de viviendas unifamiliares con orientación este: análisis de casos en el Área Metropolitana de Mendoza. *Arquitecno*, (15), 7–16. https://doi.org/10.30972/arc.0154375
39. Varini, C., & Luciani, S. (2015). Calidad de vida en la vivienda social de San Andrés, Colombia, mediante la gestión bioclimática de flujos de aire. *Revista Nodo*, *9*(19), 101-110.
40. Velasco Roldán, L., Abatta Jácome, L., & Hevia Antuña, A. (2019). Prototipos de vivienda de madera de baja huella ecológica y alta eficiencia energética para su aplicación en modelos edificatorios en América Latina. *Estudios del Hábitat*, *17*(1), 1–15. https://doi.org/10.24215/24226483e066
41. Véliz-Párraga, J., & González-Couret, D. (2019). Vivienda de interés social en Portoviejo. Ambiente térmico interior. *AUS - Arquitectura / Urbanismo / Sustentabilidad*, (26), 35–41. https://doi.org/10.4206/aus.2019.n26-07