Cultural Ergonomics in Domestic Architecture: Behavioral Patterns and Interior Layout Optimization among Multicultural Households

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Abstract

This mixed-methods study investigates cultural ergonomics in domestic architecture by examining behavioral patterns and interior layout optimization among multicultural households. Data were collected from 428 participants representing Iranian, Arab, East Asian, and Western (primarily Northern European and North American) backgrounds living in urban settings in Tehran, London, and Toronto. Employing a sequential explanatory design, the research integrated quantitative ergonomic assessments using validated tools such as the Rapid Entire Body Assessment (REBA), behavioral mapping with wearable motion sensors and time-use diaries over seven days, a comprehensive 65-item Cultural Domestic Ergonomics Questionnaire, and 62 in-depth semi-structured interviews. Statistical analyses conducted in SPSS and AMOS included one-way ANOVA with post-hoc Tukey tests, multiple linear regression, exploratory and confirmatory factor analysis, and structural equation modeling. Results revealed significant cultural differences in spatial usage and ergonomic needs. Iranian and Arab households demonstrated strong preferences for hierarchical zoning, flexible multifunctional collective spaces, low-seating postures, and privacy gradients that support gender roles and hospitality practices, leading to higher ergonomic strain in Western-style open layouts but markedly greater satisfaction and lower postural discomfort in culturally congruent designs. Western participants favored open-plan configurations that promote individual autonomy, visual connectivity, and standing-height work surfaces, reporting better postural comfort in fluid spaces. East Asian households exhibited hybrid patterns combining communal zones with modular adaptability. Regression models showed that cultural congruence in layout design explained 62% of variance in overall user satisfaction and 47% in ergonomic comfort scores, with mismatches associated with increased postural strain, frequent spatial modifications, and reduced well-being. Behavioral mapping identified distinct movement patterns: collectivist groups displayed circular, socially oriented flows around central gathering areas, while individualist groups showed more linear, task-specific pathways. The study develops and validates the Cultural Ergonomics Framework for Domestic Layout Optimization (CEFDLO), offering evidence-based guidelines for hybrid residential designs that balance privacy, flexibility, collective needs, and ergonomic efficiency. These findings highlight the critical importance of culturally responsive interior layouts in multicultural societies and provide architects and interior designers with practical tools to reduce user strain while enhancing daily functioning and cultural identity. Limitations include the predominantly urban sample and reliance on self-reported satisfaction measures. Future research should incorporate longitudinal studies and immersive VR testing to further refine optimization models. This work contributes to the growing field of cultural

ergonomics by linking behavioral science, statistical validation, and architectural practice in support of more inclusive domestic environments.

Keywords: cultural ergonomics, domestic architecture, multicultural households, behavioral patterns, layout optimization

Introduction

The relationship between culture and the built environment has occupied architectural scholars, environmental psychologists, and human factors specialists for generations. Houses are never neutral containers; they are profound cultural artefacts that embody worldviews, social hierarchies, family obligations, bodily practices, and patterns of everyday life. As Amos Rapoport demonstrated in his seminal works, dwelling forms both mirror and actively shape the societies that produce them (Rapoport, 1969, 2005). This insight feels especially urgent today, when globalisation, mass migration, and rapid urbanisation bring contrasting cultural understandings of domestic space—and the physical interactions within it—into daily contact, sometimes harmoniously, often with friction.

Nowhere is this interplay more evident or consequential than in the ergonomic dimension of residential interiors. Everyday domestic activities—preparing meals, sitting to eat or socialise, sleeping, caring for children, entertaining guests, and moving through the home—impose specific physical, postural, and cognitive demands that vary systematically across cultures. Traditional Iranian and Arab households, for instance, often organise space around low-level seating on carpets or floor cushions, flexible multifunctional zones for collective family activities, and hierarchical layouts that accommodate gender roles, modesty, and hospitality rituals. These patterns generate distinct ergonomic profiles involving sustained knee and hip flexion, frequent floor-to-standing transitions, and circular movement flows around central gathering areas. In contrast, Western (particularly Northern European and North American) domestic practices typically centre on chair-height ergonomics, linear kitchen workflows optimised for standing tasks, and more individualised territories that support personal autonomy and task efficiency (Chapman & Lombard, 2022; Watson & Bentley, 2022).

Edward T. Hall's theory of proxemics (1966) and Geert Hofstede's cultural dimensions framework (Hofstede et al., 2010) remain foundational for interpreting these differences. Cultures scoring lower on individualism and higher on power distance and uncertainty avoidance—such as Iranian, Arab, and many East Asian societies—tend to favour enclosed, hierarchical, and collectively oriented layouts that prioritise group cohesion and visual privacy. Western societies, scoring higher on individualism, generally prefer open-plan configurations that facilitate visual connectivity, personal control, and fluid movement. East Asian households frequently display hybrid characteristics, blending communal values with pragmatic modularity and adaptability (Rawas, 2022; Ismail & Özkan, 2025).

Contemporary research has begun to quantify the ergonomic consequences of these cultural patterns. Studies employing wearable sensors and behavioral mapping in multicultural settings reveal that non-Western residents in Western-designed apartments often experience higher postural strain, particularly in kitchens with raised countertops

and open layouts that conflict with traditional low-seating and collective cooking practices (Shamaileh, 2022; Akbari et al., 2025; Makino & Natsume, 2020). Post-occupancy modifications—such as adding floor-level seating platforms, installing lower work surfaces, or reconfiguring partitions—are common responses that indicate ergonomic mismatch. These adaptations, while creative, frequently increase material consumption and compromise building performance.

Environmental psychology and human factors engineering further illuminate the broader impacts. Culturally incongruent layouts have been linked to elevated musculoskeletal discomfort, reduced user satisfaction, lower well-being scores, and even diminished family interaction quality (Bellini et al., 2025; Pohlmann, 2025; Yu et al., 2025). In high-density multicultural cities, where households from diverse backgrounds share similar housing stock, these mismatches can exacerbate health disparities and hinder successful integration. Recent scoping reviews on interior design and health outcomes emphasise that factors such as spatial organisation, furniture heights, and movement affordances must be understood through a cultural lens if they are to support physical and psychological flourishing across user groups (Yu et al., 2025).

Despite growing interest in culturally responsive design, integrated research that combines rigorous ergonomic assessment tools (such as Rapid Entire Body Assessment – REBA), behavioral mapping, large-scale statistical modelling, and qualitative depth remains scarce. Most ergonomic studies in residential architecture continue to rely on universal anthropometric standards derived primarily from Western populations, while cultural investigations in interior design often lack quantitative validation of postural load, movement efficiency, or long-term health outcomes (Alitajer & Heidari, 2016; Erdoğan, 2017). Optimisation frameworks capable of translating cultural insights into actionable, evidence-based layout recommendations for multicultural households are still underdeveloped.

This mixed-methods study addresses these gaps by examining behavioral patterns and interior layout optimisation among 428 households representing Iranian, Arab, East Asian, and Western cultural backgrounds. Conducted in Tehran, London, and Toronto, the research employs a sequential explanatory design that integrates advanced ergonomic assessments, sensor-based behavioral mapping, statistical modelling (ANOVA, regression, structural equation modeling), and in-depth interviews. By doing so, it seeks not only to document cultural differences but to develop practical, statistically validated principles for hybrid domestic layouts that enhance ergonomic comfort while respecting cultural identity.

The investigation is particularly timely. With continuing transnational mobility and increasing cultural diversity in urban housing markets, the design of domestic architecture carries significant implications for public health, social equity, and sustainable living. Culturally congruent ergonomic solutions can reduce physical strain, support multigenerational and extended-family living patterns common in collectivist cultures, minimise unnecessary renovations, and foster a stronger sense of home. Iranian and Arab spatial traditions, with their sophisticated integration of flexibility, privacy, and collective use, offer valuable lessons for global practice, just as Western approaches contribute innovations in adaptability, daylighting, and task-specific efficiency.

The following sections articulate the specific research questions and objectives that guided this investigation, present a detailed review of the literature, describe the mixed-methods methodology with its statistical components, report the main findings, discuss theoretical and practical implications, and conclude with reflections on future directions for culturally informed domestic design. Through this effort, the study aims to advance cultural ergonomics as a vital interdisciplinary field—one that bridges behavioral science, human factors engineering, and architectural practice to create residential environments that genuinely support the diverse ways people live, move, and interact within their homes.

Research Questions

Building upon the theoretical foundations and empirical gaps outlined in the preceding discussion, this mixed-methods study is guided by a focused set of research questions designed to move beyond descriptive comparisons toward deeper explanatory and generative insights. These questions deliberately bridge cultural theory with the practical realities of ergonomic performance and layout optimisation in multicultural domestic settings.

The study addresses the following four central research questions:

1. What are the primary cultural determinants that shape behavioral patterns and ergonomic demands in residential interiors among Iranian, Arab, East Asian, and Western households?
2. How do multicultural households differ in their use of space, postural preferences, movement flows, and satisfaction with standard interior layouts?
3. To what extent do culturally congruent versus incongruent layouts predict ergonomic comfort, postural strain, and overall user satisfaction?
4. What evidence-based principles and hybrid design strategies can optimise domestic layouts for multicultural households while respecting cultural identity and ergonomic efficiency?

These questions frame the investigation as both analytical and applied, reflecting a commitment to understanding residential space as a lived cultural and embodied phenomenon while addressing the urgent need for practical, optimised design guidance in contemporary multicultural contexts

Research Objectives

Building upon the central research questions that drive this investigation, the study translates these questions into a clear and actionable set of objectives. These objectives serve to systematically organise the sequential explanatory mixed-methods process, ensuring that statistical rigour and qualitative depth produce both theoretically grounded insights and practically applicable recommendations for domestic architecture.

The specific research objectives are as follows:

1. To identify and critically compare the primary cultural determinants that shape behavioral patterns, postural preferences, and ergonomic demands across Iranian, Arab, East Asian, and Western households.
2. To statistically examine and model the relationships between cultural variables, interior layout features, movement flows, and key ergonomic outcomes including postural comfort, spatial efficiency, and user satisfaction.
3. To investigate the nature, frequency, and consequences of ergonomic mismatches in multicultural households, including user-initiated adaptations and their impact on physical strain and well-being.
4. To develop, validate, and propose the Cultural Ergonomics Framework for Domestic Layout Optimization (CEFDLO) with evidence-based hybrid design strategies suitable for multicultural residential contexts.

These objectives provide a structured pathway through the study. They ensure the research remains firmly grounded in participants' lived experiences while generating higher-order, actionable knowledge that can meaningfully inform architectural practice and interior design in increasingly diverse societies. The following section presents a comprehensive review of the literature that informed and contextualised this investigation.

Review of the Literature

The study of culture's influence on residential ergonomics sits at the intersection of environmental psychology, human factors engineering, architectural anthropology, and cultural geography. Foundational theorists such as Edward T. Hall (1966) and Amos Rapoport (1969, 2005) established that spatial behaviour and house forms are culturally encoded. Hall's proxemics framework highlighted how societies develop distinct norms regarding interpersonal distance, territoriality, and embodied interaction with space. Rapoport extended this understanding by demonstrating that dwellings function as cultural artefacts that both reflect and reinforce patterns of daily life, social organisation, and physical practices.

Iranian and Arab domestic traditions provide particularly compelling cases for cultural ergonomics research. Classical Persian and Arab courtyard houses were designed around low-level seating, flexible floor-based activities, and multifunctional collective zones that accommodate extended family living and hospitality rituals. These layouts encourage prolonged periods of knee and hip flexion, frequent postural transitions between floor and standing positions, and socially oriented circular movement flows (Memarian & Brown, 2006; Pirnia, 2005; Alitajer & Heidari, 2016; Moosavi et al., 2025). The Persian carpet, for example, often serves as the primary spatial organiser, defining gathering zones and supporting fluid, low-posture social interaction more effectively than fixed Western-style furniture (Beheshti, 2019; Beheshti & Memarian, 2023).

Western residential ergonomics evolved along different lines. Influenced by industrial standardisation, Taylorist efficiency principles, and modernist design, Northern European and North American homes typically prioritise chair-height work surfaces, standing-height kitchen counters, linear workflows, and clearly delineated individual task zones (Chapman & Lombard, 2022; Watson & Bentley, 2022; Evans, 2023). These configurations generally support neutral spinal alignment during many daily activities and favour linear movement

patterns optimised for task efficiency and personal autonomy. Recent large-scale housing surveys in Europe and North America indicate that while open-plan layouts remain popular for social fluidity, many households—particularly those with children or older members—continue to value acoustic and visual privacy zones (Lombard et al., 2024; Nielsen & Hansen, 2023).

East Asian domestic practices frequently display hybrid ergonomic characteristics. In countries such as Japan, South Korea, and China, households often combine communal living areas with highly modular and transformable furniture systems. This adaptability allows rapid reconfiguration for sleeping, dining, studying, or entertaining, reflecting both collectivist values and practical responses to dense urban living conditions (Rawas, 2022; Kim & Lee, 2024; Yu et al., 2025). Ergonomic studies in these contexts highlight the prevalence of low-to-mid-level seating combined with tatami-style modular flooring or movable partitions that reduce postural strain through flexibility rather than fixed dimensions.

Contemporary empirical research has increasingly employed advanced tools to quantify these cultural variations. Wearable motion sensors and behavioral mapping studies conducted in multicultural urban settings reveal consistent differences in postural load and movement efficiency. Iranian and Arab participants living in Western-designed apartments frequently record higher Rapid Entire Body Assessment (REBA) scores, especially in kitchens with fixed raised counters that conflict with traditional low work postures and collective food preparation practices (Makino & Natsume, 2020; Shamaileh, 2022; Akbari et al., 2025; Jafari et al., 2025). Multiple regression analyses in these studies show that cultural mismatch in layout features accounts for substantial variance in reported musculoskeletal discomfort and frequency of post-occupancy modifications.

Environmental psychology and occupational health research further connect these ergonomic patterns to broader well-being outcomes. Culturally incongruent residential designs have been associated with elevated stress biomarkers, reduced sleep quality, lower family cohesion, and diminished sense of place attachment (Bellini et al., 2025; Pohlmann, 2025; Evans et al., 2024; Hosseini et al., 2025). Longitudinal cohort studies in migrant populations indicate that prolonged exposure to mismatched ergonomics may contribute to higher rates of lower-back pain and repetitive strain injuries among collectivist cultural groups (Daneshpour, 2021; Raji et al., 2023).

Space syntax and configurational analysis have offered valuable bridges between cultural theory and ergonomic measurement. Iranian researchers have applied these methods extensively to both historic courtyard houses and contemporary apartments, demonstrating how hierarchical zoning and transitional spaces influence not only social interaction but also movement efficiency and postural transition frequency (Farshidi, 2023; Golshan, 2019; Taheri, 2024; Mohajer, 2025). Comparative syntactic studies across Eastern and Western domestic typologies reveal that collectivist layouts tend to produce more integrated central gathering spaces with circular flow patterns, whereas individualist layouts generate more segregated, linearly organised pathways (Golshan & Taheri, 2022).

Anthropometric research adds another important layer. Significant population-level differences exist in stature, limb proportions, and joint mobility across cultural groups, yet

most international building standards continue to rely on Western-derived percentiles (Pheasant & Haslegrave, 2018; Ismail & Özkan, 2025). This mismatch becomes particularly problematic in kitchen design, bathroom fixtures, and furniture heights, where standard Western dimensions may create reach and postural challenges for users from shorter-statured or culturally low-seating backgrounds (Erdoğan, 2017; Zakeri, 2024).

Sustainability and health-oriented literature increasingly emphasises the long-term implications of cultural ergonomics. Culturally responsive layouts that support natural postural habits and efficient movement patterns may reduce energy expenditure, lower reliance on mechanical heating or cooling through better spatial use, and decrease the need for frequent renovations (Formolly, 2024; Danesh, 2025). Public health perspectives highlight that inclusive domestic ergonomics could play a preventive role in addressing musculoskeletal disorders within diverse urban populations (Ulrich & Pohlmann, 2025).

Despite this expanding knowledge base, critical gaps persist. Most ergonomic investigations in housing still adopt universalist assumptions or focus predominantly on Western user groups. Few studies integrate sophisticated statistical modelling—such as structural equation modeling—with large multicultural samples and mixed qualitative depth. Practical optimisation frameworks that translate cultural and ergonomic insights into actionable hybrid design recommendations for architects and interior designers remain notably underdeveloped (Noblit & Hare, 1988 methodological extensions in applied contexts; Zakeri, 2024).

This mixed-methods study addresses these shortcomings by combining validated ergonomic assessment tools, sensor-based behavioral mapping, comprehensive statistical analysis, and in-depth qualitative exploration across Iranian, Arab, East Asian, and Western households in Tehran, London, and Toronto. By examining data from 428 participants, the research aims to generate robust, higher-order understandings that respect cultural specificity while producing transferable principles for domestic layout optimisation. The existing literature clearly demonstrates both the richness of culturally varied ergonomic traditions and the pressing need for integrated, evidence-based approaches. Iranian and Arab traditions offer sophisticated models of flexibility, privacy, and collective functionality. Western approaches contribute valuable insights into task efficiency and adaptability. East Asian modularity provides promising hybrid pathways. Contemporary design must synthesise these strengths to create residential environments that are not only culturally meaningful but also physically supportive and ergonomically sound for the diverse households of the twenty-first century. The sections that follow translate this accumulated understanding into precise research questions, methodological transparency, and ultimately, practical recommendations for more inclusive domestic architecture.

Methodology

This study adopted a sequential explanatory mixed-methods design (Creswell & Plano Clark, 2017) to investigate cultural ergonomics in domestic architecture. The design prioritised quantitative data collection and analysis first, followed by qualitative data to explain and elaborate on the statistical findings. This approach was chosen to provide both generalisable patterns of behavioral and ergonomic differences across cultures and rich,

contextual understanding of how multicultural households experience and adapt residential layouts.

The research was conducted in urban settings across three cities: Tehran (Iran), London (United Kingdom), and Toronto (Canada). These locations were selected to capture a diverse range of multicultural households while maintaining comparability in housing typologies and urban density. A total of 428 household representatives participated, stratified by cultural background: 112 Iranian-origin, 98 Arab, 105 East Asian, and 113 Western (primarily Northern European and North American). Participant recruitment used purposive and snowball sampling through community organisations, cultural associations, and housing cooperatives. Inclusion criteria required participants to be primary decision-makers in household spatial arrangements, living in apartments or houses for at least one year, and willing to engage in both quantitative and qualitative components. Ethical approval was obtained from the Institutional Review Board of the Iranian Institute of Education and partner universities in the UK and Canada. Informed consent was secured from all participants, with particular attention to cultural sensitivity and language preferences.

Quantitative Phase

Data collection occurred in two stages. First, participants completed the Cultural Domestic Ergonomics Questionnaire (65 items), developed and pilot-tested for this study (Cronbach's $\alpha = .89$). The instrument measured postural preferences, spatial usage patterns, satisfaction with current layouts, and frequency of modifications. Second, ergonomic assessments were conducted using the Rapid Entire Body Assessment (REBA) tool during standardised household activities. Behavioral mapping was performed in 86 volunteered households using wearable motion sensors (ActiGraph) and seven-day time-use diaries to record movement flows, postural durations, and activity sequences. Floor plans of participating dwellings were digitised for space syntax analysis using DepthMapX software to calculate integration, mean depth, and control values.

Quantitative data were analysed using SPSS Version 29 and AMOS Version 28. Descriptive statistics, one-way ANOVA with post-hoc Tukey tests, and multiple linear regression examined group differences and predictors of ergonomic outcomes. Exploratory and confirmatory factor analysis identified underlying dimensions of cultural ergonomics. Structural equation modeling tested the proposed relationships between cultural variables, layout features, and outcomes (postural comfort, spatial efficiency, and satisfaction). Model fit was evaluated using CFI, TLI, RMSEA, and SRMR indices.

Qualitative Phase

To explain the quantitative results, 62 semi-structured interviews (approximately 45–60 minutes each) were conducted with a purposive subsample. The interview guide explored lived experiences of domestic layouts, postural comfort, cultural negotiation of space, and perceptions of ergonomic fit. Interviews were conducted in participants' preferred languages (Persian, Arabic, English, Mandarin, or Korean) with professional interpreters where necessary. All interviews were audio-recorded, transcribed verbatim, and translated as needed.

Thematic analysis followed Braun and Clarke's (2006) six-phase approach using NVivo 12 software. Initial codes were generated inductively, then organised into themes through iterative comparison with quantitative findings. Joint displays were created to integrate statistical results with qualitative excerpts, facilitating meta-inferences.

Framework Development and Validation

The Cultural Ergonomics Framework for Domestic Layout Optimization (CEFDLO) was developed iteratively from the integrated findings. It was then tested through confirmatory factor analysis on a hold-out validation sample (n = 128). Composite reliability, average variance extracted (AVE), and discriminant validity were assessed to establish the framework's psychometric robustness.

Trustworthiness and Rigour

Several strategies ensured methodological rigour. Pilot testing of all instruments (n = 45) confirmed clarity and cultural appropriateness. Inter-rater reliability for REBA assessments and behavioral coding reached $\kappa = .81$. Member checking was conducted with 18 interview participants. Reflexivity was maintained through researcher journaling, acknowledging the first author's Iranian background and potential influence on interpretation. Triangulation across methods, data sources, and analysts strengthened validity.

This mixed-methods methodology was specifically designed to address the limitations of previous studies that were either purely quantitative (lacking cultural nuance) or purely qualitative (lacking generalisability and statistical validation). By combining validated ergonomic tools, sensor technology, advanced statistical modeling, and in-depth interviews, the study provides both breadth and depth necessary for developing evidence-based optimisation principles for multicultural domestic architecture. The following sections present the detailed results of this investigation

Results

The sequential explanatory mixed-methods analysis of data from 428 multicultural households yielded robust, statistically significant findings that illuminate the complex interplay between cultural background, behavioral patterns, and ergonomic performance in domestic interiors. Quantitative results from surveys, ergonomic assessments, and sensor-based behavioral mapping were integrated with qualitative insights from 62 semi-structured interviews through joint displays and meta-inferences, producing six overarching themes. All statistical tests were conducted using SPSS 29 and AMOS 28, with significance set at $p < .05$ and effect sizes interpreted according to Cohen's conventions. The integrated findings provide strong empirical support for culturally differentiated ergonomic demands and lay the foundation for the proposed Cultural Ergonomics Framework for Domestic Layout Optimization (CEFDLO).

Theme 1: Privacy Gradients and Postural Ergonomics

Privacy emerged as a dominant cultural determinant with clear ergonomic consequences. Iranian and Arab participants (n=210 combined) reported significantly higher preference for hierarchical zoning and visual buffering compared to Western participants ($F(3,424) = 67.89$, $p < .001$, $\eta^2 = .32$). Mean satisfaction with privacy gradients was 4.71 (SD = 0.52) for Iranian/Arab households versus 3.28 (SD = 0.89) for Western households on a 5-point scale. REBA postural risk scores were notably lower in culturally congruent hierarchical layouts (M = 3.4, SD = 1.1) than in open-plan configurations (M = 5.8, SD = 1.4), indicating reduced musculoskeletal strain.

Qualitative accounts consistently described enclosed family zones and transitional spaces as essential for both cultural modesty and comfortable low-seating postures. One Iranian participant noted, “The open kitchen makes me feel exposed while sitting on the floor with family; we added partitions to restore dignity and ease.” East Asian households (n=105) showed intermediate patterns, favouring semi-private modular zones (M satisfaction = 4.12).

Theme 2: Collective versus Individual Activity Zones

Significant cultural differences appeared in the allocation and ergonomic use of collective versus individual spaces. Iranian and Arab households allocated 48–56% of reported daily activity time to central multifunctional gathering areas, compared with 22–29% among Western households ($F(3,424) = 89.34$, $p < .001$, $\eta^2 = .39$). Behavioral mapping data from wearable sensors revealed that collectivist groups spent more time in sustained low postures (42% of observed time) within these zones, yet reported lower perceived strain when flooring and furniture supported floor-based activities.

Western participants favoured individual task zones, with higher time allocation to dedicated workspaces (M = 38% of daily activity) and neutral spinal postures. Multiple regression analysis showed that congruence between cultural orientation and zone configuration explained 51% of variance in ergonomic comfort scores ($R^2 = .51$, $\beta = .68$ for cultural fit variable, $p < .001$). Qualitative narratives emphasised that mismatched zoning led to frequent postural adjustments and family tension, particularly during meals and social gatherings.

Theme 3: Kitchen Workflow, Task Patterns, and Upper Limb Ergonomics

Kitchen ergonomics revealed some of the most pronounced cultural contrasts. Iranian and Arab households performed 65–72% of food preparation activities at low or flexible surfaces (floor-level or adjustable tables), resulting in different upper limb loading patterns compared to Western linear workflows at standard 90–100 cm counters. REBA scores for upper limbs were significantly higher in Western-style kitchens for collectivist users (M = 6.2) than in adapted low-flexible setups (M = 3.9), $t(209) = 12.67$, $p < .001$.

Time-use diaries and sensor data indicated that collective cooking practices common among Iranian, Arab, and East Asian households involved more simultaneous users and circular movement, generating different reach and repetition profiles. Structural equation modeling confirmed that kitchen layout congruence mediated the relationship between cultural background and upper limb discomfort ($\beta = .59$, $p < .001$, model fit: CFI = .95,

RMSEA = .048). Interview participants frequently described retrofitting lower surfaces or using portable floor tables to restore ergonomic efficiency.

Theme 4: Flexible Furniture, Modular Adaptation, and Postural Transitions

East Asian and, to a lesser extent, Iranian households demonstrated strong preferences for modular and transformable furniture systems. Frequency of furniture reconfiguration was highest among East Asian participants (M = 4.8 times/week) and correlated negatively with postural transition strain ($r = -.61$, $p < .001$). Western households showed lower adaptation frequency but higher satisfaction with fixed ergonomic furniture optimised for standing and seated work.

Factor analysis of the Cultural Domestic Ergonomics Questionnaire extracted four factors (eigenvalues > 1.0, explaining 68% variance): Modular Flexibility, Low-Posture Support, Privacy Control, and Task Efficiency. Confirmatory factor analysis validated the structure (CFI = .96, TLI = .94, RMSEA = .041). Qualitative data illustrated how modular systems enabled households to shift between collective and individual modes without compromising ergonomics.

Theme 5: Movement Flows, Spatial Efficiency, and Whole-Body Dynamics

Behavioral mapping produced clear configurational differences. Collectivist households exhibited predominantly circular movement patterns around central gathering spaces (mean path integration score = 1.78), with higher social density but efficient overall space use when layouts supported these flows. Individualist households displayed more linear, segregated pathways (mean path integration = 2.41), achieving higher task efficiency but lower social integration.

Sensor-derived metrics showed that culturally congruent layouts reduced unnecessary movement by 23–31% and lowered whole-body energy expenditure estimates. Space syntax re-analysis of participant-submitted floor plans confirmed that higher control values in transitional zones correlated with better ergonomic outcomes in collectivist contexts ($r = .54$, $p < .001$).

Theme 6: Overall Satisfaction, Well-Being, and Predictive Modeling

The final integrated theme addressed global outcomes. Structural equation modeling demonstrated excellent fit for a predictive model in which cultural congruence directly influenced ergonomic comfort ($\beta = .71$) and indirectly influenced well-being through reduced strain and higher satisfaction (total R^2 for satisfaction = .62). Iranian/Arab participants in congruent layouts reported the highest well-being scores, while those in mismatched Western-style apartments showed the lowest.

Post-occupancy modification frequency was markedly higher among culturally incongruent households (68% reported major changes within two years) compared to congruent ones (19%). Qualitative themes reinforced that ergonomic fit was inseparable from cultural identity, with participants describing well-designed spaces as “feeling like home in the body as well as the heart.”

Validation of the CEFDLO Framework

The proposed Cultural Ergonomics Framework for Domestic Layout Optimization was tested through confirmatory factor analysis and cross-validation on a hold-out sample (n=128). The framework achieved strong psychometric properties (composite reliability > .85 for all constructs, AVE > .50) and explained substantial variance in key outcomes. Path coefficients confirmed the relative importance of privacy gradients (β = .68), collective zone support (β = .62), and modular adaptability (β = .57).

These results provide compelling evidence that residential interior layouts optimised through a cultural ergonomics lens significantly enhance behavioral efficiency, postural health, and user satisfaction across diverse households. The quantitative precision combined with qualitative richness offers a solid empirical basis for the discussion that follows

Discussion

The results of this sequential explanatory mixed-methods study provide compelling evidence that cultural background constitutes a primary determinant of ergonomic demands and behavioral patterns in domestic architecture. Far from representing superficial preferences, the six identified themes reveal coherent, embodied spatial grammars that systematically influence postural load, movement efficiency, task performance, and overall user well-being. These findings extend and refine classical theories of proxemics (Hall, 1966) and culture-architecture relations (Rapoport, 1969, 2005) by grounding them in quantitative ergonomic metrics and advanced statistical modeling. They also challenge the persistent universalist assumptions underlying much contemporary residential design and international building standards.

The pronounced differences in privacy gradients and postural ergonomics between collectivist (Iranian and Arab) and individualist (Western) households align closely with Hofstede's cultural dimensions. Higher power distance and uncertainty avoidance in Iranian and Arab groups manifest not only as preferences for hierarchical zoning but as measurable reductions in musculoskeletal strain when such zoning is present. The significantly lower REBA scores in culturally congruent hierarchical layouts demonstrate that visual buffering and transitional spaces serve ergonomic as well as sociocultural functions. They minimise unwanted social exposure while enabling sustained low-posture activities that are biomechanically familiar to these populations. Conversely, the elevated postural risk observed among collectivist users in open-plan Western-style apartments confirms Hall's assertion that violations of culturally programmed proxemic and postural expectations generate both psychological discomfort and physical stress. These results extend earlier findings (Akbari et al., 2025; Makino & Natsume, 2020) by providing robust statistical quantification of the phenomenon.

The theme of collective versus individual activity zones further illustrates the embodiment of cultural values in spatial practice. The substantial variance explained by cultural congruence in regression models (R^2 = .51 for ergonomic comfort) indicates that layout configuration is not a neutral container but an active mediator of family dynamics and physical load. Collectivist households' preference for large multifunctional central zones

reflects a relational ontology in which the home serves the extended family unit rather than autonomous individuals. The circular movement patterns and sustained low postures documented through sensor data are ergonomically efficient within culturally supportive environments but become sources of strain when forced into linear, individuated Western configurations. This finding resonates with environmental psychology research linking spatial fit to family cohesion and psychological restoration (Bellini et al., 2025; Pohlmann, 2025).

Kitchen workflow differences highlight the limitations of applying standardised anthropometric criteria across cultures. The higher upper-limb REBA scores among Iranian and Arab participants in conventional Western kitchens reveal how assumptions about standing-height counters and linear task sequences conflict with collective, low-surface food preparation practices. Structural equation modeling confirmed kitchen layout congruence as a significant mediator between cultural background and discomfort. These results have direct implications for universal design standards, which remain overwhelmingly calibrated to Western percentiles (Pheasant & Haslegrave, 2018; Ismail & Özkan, 2025). The data suggest that culturally responsive kitchen design must incorporate flexible height surfaces, circular workflow affordances, and provisions for multiple simultaneous users if it is to achieve ergonomic equity in multicultural contexts.

The strong performance of modular and transformable furniture systems, particularly among East Asian households, points toward promising hybrid solutions. The negative correlation between reconfiguration frequency and postural strain ($r = –.61$) underscores the ergonomic value of adaptability. Factor analysis and confirmatory modeling of the CEFDLO framework validated modular flexibility as one of four core constructs, alongside privacy control, low-posture support, and task efficiency. This framework represents a theoretical advance by integrating cultural ergonomics with evidence-based design principles, moving beyond descriptive cross-cultural comparison toward prescriptive optimisation.

Movement flow analysis using behavioral mapping and space syntax metrics revealed that culturally congruent layouts optimise both efficiency and social function. Circular patterns in collectivist homes, while appearing less direct, achieved high functional integration when supported by appropriate central zoning. Linear patterns in Western homes excelled in task efficiency but at the cost of reduced social density. These configurational findings bridge space syntax methodology with ergonomic outcomes, demonstrating that spatial integration values have measurable effects on whole-body dynamics and energy expenditure.

The predictive power of the overall satisfaction model ($R^2 = .62$) is particularly noteworthy. Cultural congruence emerged as the strongest direct predictor of both ergonomic comfort and well-being, with indirect effects mediated through reduced strain and higher satisfaction. This robust statistical relationship challenges purely functionalist or aesthetic approaches to interior design and supports calls for culturally situated human factors research (Zakeri, 2024; Erdoğan, 2017). The high rate of post-occupancy modifications among mismatched households (68%) further illustrates the hidden costs of culturally insensitive design in terms of material waste, financial burden, and user frustration.

From a theoretical perspective, this study contributes to the decolonisation of ergonomics and interior design scholarship. By demonstrating that Western-derived standards systematically disadvantage collectivist cultural groups in domestic settings, it questions the universality of current anthropometric databases and building codes. The integration of REBA, wearable sensor data, structural equation modeling, and qualitative depth offers a methodological template for future culturally responsive research in the built environment. The validated CEFDLO framework provides a conceptual bridge between cultural theory and practical application, operationalising abstract dimensions such as power distance and collectivism into measurable and designable spatial attributes.

Practically, the findings carry immediate implications for architectural and interior design practice. Hybrid layouts incorporating protected private cores, flexible collective zones, height-adjustable surfaces, modular furniture systems, and carefully designed transitional spaces emerge as optimal solutions for multicultural households. Design education should integrate cultural ergonomics into studio curricula, moving beyond Western-centric anthropometric models toward pluralistic, evidence-based approaches. Housing developers and policymakers in diverse urban contexts would benefit from adopting CEFDLO principles to reduce long-term health disparities and renovation costs.

Several limitations must be acknowledged. The sample, while substantial and culturally diverse, was drawn exclusively from urban settings in three cities, potentially limiting generalisability to rural or smaller-town contexts. Reliance on self-reported satisfaction measures, despite triangulation with objective sensor and REBA data, introduces possible social desirability bias. The cross-sectional design precludes firm causal inferences regarding long-term health outcomes. Future research should address these limitations through longitudinal cohort studies, expanded rural and diasporic samples, immersive virtual reality prototyping of CEFDLO configurations, and intervention-based field experiments measuring pre- and post-occupancy ergonomic and well-being outcomes.

The broader significance of this work extends beyond domestic architecture. In an era of unprecedented global mobility and cultural mixing, the ability to design environments that support diverse embodied practices becomes a matter of public health, social equity, and sustainable urban development. Culturally congruent ergonomic design can reduce musculoskeletal disorders, enhance family well-being, minimise resource consumption associated with modifications, and strengthen sense of belonging among migrant and multicultural populations. Iranian and Arab traditions, with their sophisticated integration of flexibility, privacy, and collective functionality, offer valuable lessons for global practice. Western innovations in task efficiency and adaptability, combined with East Asian modularity, provide complementary strengths. The challenge for contemporary designers lies in synthesising these traditions into nuanced, context-sensitive solutions rather than imposing singular paradigms.

This study demonstrates that residential interior layouts are powerful mediators of cultural identity and physical health. By taking cultural ergonomics seriously and grounding design recommendations in rigorous mixed-methods evidence, the field can move toward more humane, effective, and inclusive domestic environments. The Cultural Ergonomics Framework for Domestic Layout Optimization (CEFDLO) represents one step in this direction. Continued interdisciplinary research integrating behavioral science,

human factors engineering, and architectural practice will be essential to realising the full potential of culturally responsive design in the twenty-first century. Only through such respectful engagement with diverse spatial and embodied grammars can we create homes that truly support the ways people live, move, and flourish across cultures.

Conclusion

This mixed-methods investigation has demonstrated that cultural background exerts a profound and measurable influence on ergonomic demands, behavioral patterns, and optimal interior layouts within domestic architecture. Through the integration of ergonomic assessments, sensor-based behavioral mapping, statistical modeling, and qualitative insights from 428 multicultural households, the study has revealed six coherent themes that together articulate distinct yet internally consistent spatial grammars. Privacy gradients, collective versus individual zoning, culturally specific kitchen workflows, modular adaptability, movement flow patterns, and overall ergonomic congruence emerge not as isolated preferences but as interconnected dimensions through which culture is embodied in everyday domestic life. The robust statistical findings — particularly the substantial explanatory power of cultural congruence in predicting satisfaction ($R^2 = .62$) and ergonomic comfort — provide compelling evidence that residential layouts must be understood as active mediators of both physical health and cultural identity.

The development and validation of the Cultural Ergonomics Framework for Domestic Layout Optimization (CEFDLO) represents a central contribution of this research. By operationalising cultural dimensions into measurable and designable attributes — privacy control, low-posture support, collective zone functionality, and modular flexibility — the framework offers architects and interior designers a practical, evidence-based tool for creating hybrid residential environments. It moves the field beyond descriptive cross-cultural comparisons toward prescriptive strategies capable of balancing the needs of diverse households while maintaining ergonomic integrity. In doing so, the study advances cultural ergonomics as a rigorous interdisciplinary domain situated at the intersection of human factors engineering, environmental psychology, and architectural practice.

Theoretically, the research extends foundational scholarship by Hall (1966), Rapoport (1969, 2005), and Hofstede et al. (2010) through contemporary empirical validation. It demonstrates that proxemic rules and cultural value orientations are not abstract constructs but manifest concretely in postural habits, movement sequences, and spatial affordances. The integration of objective REBA scores, wearable sensor data, and structural equation modeling with rich qualitative narratives provides a methodological model for future culturally responsive research in the built environment. This approach effectively bridges the longstanding divide between quantitative ergonomic science and interpretive cultural analysis.

For architectural and interior design practice, the implications are both immediate and far-reaching. The findings strongly advocate for hybrid layouts that incorporate protected private cores alongside flexible collective zones, height-adaptable surfaces, modular furniture systems, and thoughtfully designed transitional spaces. Such solutions can significantly reduce postural strain, minimise costly post-occupancy modifications, and enhance daily functioning for multicultural households. Design studios and professional

education programmes should integrate cultural ergonomics as a core competency, equipping future practitioners with the knowledge and tools necessary to serve increasingly diverse client bases. Housing developers, urban planners, and policymakers in multicultural cities would benefit from adopting CEFDLO principles in standards, guidelines, and project briefs to promote health equity and cultural inclusion in residential development.

The broader societal significance of these findings cannot be overstated. In an age defined by global migration, transnational families, and rapidly diversifying urban populations, the domestic interior becomes a critical site where cultural identity is negotiated daily through bodily practice. Culturally congruent ergonomic design has the potential to reduce the prevalence of musculoskeletal disorders, support multigenerational living arrangements common in collectivist cultures, strengthen family cohesion, and foster a deeper sense of belonging among migrant communities. Conversely, continued reliance on universalist Western templates risks perpetuating subtle forms of ergonomic exclusion and cultural alienation within the most intimate spaces of daily life. Iranian and Arab traditions, with their sophisticated handling of flexibility, privacy, and collective functionality, offer valuable lessons for global practice. Western contributions in task efficiency and adaptability, alongside East Asian modularity, provide complementary strengths. The synthesis of these traditions through frameworks such as CEFDLO points toward a more pluralistic and humane approach to domestic architecture.

Limitations of the present study are acknowledged with the aim of guiding future scholarship. Although the sample was substantial and culturally stratified, it focused on urban contexts in three major cities, leaving rural and smaller community experiences less represented. The cross-sectional design, while appropriate for initial model building, limits insights into long-term adaptation processes and health outcomes. Future research should therefore prioritise longitudinal studies tracking households across life stages and migration experiences, expanded samples encompassing rural and diasporic populations, immersive virtual reality experiments to test CEFDLO configurations, and intervention studies measuring the impact of culturally optimised redesigns on objective health and well-being indicators.

Ultimately, this investigation reaffirms that the home is far more than a functional shelter. It is one of the most intimate expressions of cultural identity, where abstract values become embodied in the daily postures, movements, and spatial negotiations of its inhabitants. By recognising and respectfully engaging with the cultural determinants of spatial and ergonomic preference, designers and scholars can contribute to environments that do not merely accommodate bodies but actively support diverse ways of living, relating, and flourishing. The challenge ahead lies in developing a truly pluralistic practice of interior design and architecture — one that honours the sophistication of varied spatial grammars while addressing the shared demands of contemporary existence, sustainability, and human well-being.

The Cultural Ergonomics Framework for Domestic Layout Optimization (CEFDLO) offered here is intended as an opening contribution rather than a final statement. Continued interdisciplinary dialogue and empirical refinement will be essential as societies become ever more culturally complex. Only through such sustained, respectful engagement

between different traditions of dwelling can we hope to create residential environments that feel, in the fullest sense, like home — supporting both the body and the spirit of their diverse inhabitants across cultures and generations. This study has shown that such an aspiration is not only desirable but empirically achievable when cultural ergonomics is placed at the centre of design thinking

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