Optimal Footrest and Backrest Angles for Young Adults' Functional Recliners: An EEG and Subjective Assessment

Yanfeng Miao,[a,*] Yu Zhang,[a] Xuefei Gao,[a] and Wei Xu,[b]

Functional recliners are increasingly used in urban homes, but their footrest and backrest settings are often adjusted without clear ergonomic guidance. This may reduce postural support, comfort, and ease of use. This study examined suitable footrest and backrest angles for young adults by combining electroencephalography (EEG) measurements with subjective comfort ratings. Twenty participants completed static sitting and reclining tests. The footrest angle was adjusted from 0° to 90°, and the backrest angle was adjusted from 110° to 130°. Alpha-band power was used as a physiological indicator of relaxation, while comfort was assessed using subjective ratings. The results showed that a 60° footrest angle produced the highest alpha-band power and was associated with high comfort ratings. For the backrest, the strongest alpha activity and favorable subjective comfort were observed at 125°. Alpha activity was most prominent in the parietal and occipital regions, particularly at O1, O2, and Pz. Based on the combined EEG and subjective results, a footrest comfort range of 40° to 70° is recommended for seated rest, while the backrest showed a broader and more gradual comfort transition during reclining. These findings provide preliminary physiological and subjective evidence for improving recliner design. Preset positions near the recommended angles may help improve adjustment efficiency and user experience for young adults.

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Keywords: Functional recliners; EEG (Electroencephalography); Comfort evaluation; Footrest angle; Backrest angle

*Contact information: a: College of Furnishings and Industrial Design, Nanjing Forestry University, Nanjing 210037, China; b: Jiangsu Co-Innovation Center of Efficient Processing and Utilization of Forest Resources; *Corresponding author: myf1203@163.com*

INTRODUCTION

Wood has long been an important material in furniture manufacturing, especially for load-bearing seating structures. Wooden frames are valued for their workability, strength, elasticity, and natural tactile qualities (Zhong *et al.* 2024). In modern furniture design, hardwoods such as oak, walnut, and beech are commonly used because of their structural stability and visual appeal (Lin *et al.* 2024). However, as high-quality timber becomes increasingly scarce, reducing wood consumption and extending the service life of furniture have become important goals for sustainable manufacturing and environmental protection (Li *et al.* 2023).

A functional single chair is a single-seat sofa or lounge chair with adjustable features for sitting and reclining. These chairs may be operated manually or electrically, and many current models also include rocking, swivel, massage, storage, or small tabletop functions. As shown in Fig. 1, such features are intended to reduce fatigue during prolonged sitting and improve leisure comfort. However, adding these functions also makes the internal structure more complex. Features such as rocking, swiveling, and massage place higher demands on the design and fabrication of wooden frame components. Therefore, the design and optimization of wooden frames are important for the stability, performance, and material efficiency of functional recliners (Trucillo *et al.* 2025).

With changes in urban lifestyles and housing policies, long-term rental apartments have become increasingly common among young urban residents. According to the 2022 Youth Home Living Trends Insight Report, "diverse convenience" is a key requirement for their living spaces (Beike Research Institute 2022). In this context, functional single chairs are well suited to compact rental homes because they are lightweight, multifunctional, and adaptable to limited space. These characteristics have contributed to their growing popularity among young consumers.

Fig. 1. Functional single chair

The functional single chair market currently shows a mismatch between product design and user needs. Many manufacturers emphasize technical features, which can lead to similar products with limited attention to practical comfort. This problem is reflected in inconsistent design parameters and inefficient angle adjustment. Most products return to a basic sitting position by default, requiring users to spend additional time and effort finding a comfortable reclining position. As a result, the overall user experience may be reduced. Moreover, because the key angle parameters are not yet supported by sufficient ergonomic evidence, manufacturers lack clear reference values for designing adjustment ranges, preset positions, and supporting frame structures. Thus, refining angle adjustment mechanisms and establishing evidence-based comfort-related angle references for relevant use scenarios may help improve product design.

This study aimed to identify comfort-related angle references for functional single chairs. By combining electroencephalography (EEG) with subjective comfort evaluation, it examined how key adjustment parameters affect user comfort and identifies suitable comfort-related angles for two postures: seated rest, governed by the footrest angle, and reclined rest, governed by the backrest angle. These comfort-based angle references can provide human-factors input for wood-based recliner design, including adjustment ranges, preset positions, hinge locations, and support-member layout. This link is consistent with studies showing that user-related parameters and structural loads can affect the design of wooden chair components (Hitka *et al.* 2022). By connecting comfort evaluation with early-stage frame design, this study offers practical ergonomic evidence for improving adjustment efficiency, user experience, and subsequent structural optimization of wood-based recliners.

Seating comfort is influenced by multiple factors. De Looze *et al.* (2003) proposed a theoretical model in which environmental, seating, and human factors jointly affect sitting comfort and discomfort (Zhong *et al.* 2025). Quantitative studies on seat design have mainly examined contact pressure, material properties, and support parameters. For example, Smulders *et al.* (2019) used surface electromyography, video analysis, and visual analog scales to evaluate how head support affects comfort and neck muscle activity when passengers watch in-flight entertainment in reclined positions (Lee and Park 2006). Studies of static seating comfort have also shown that higher-density seat foam, such as 80 kg/m³ foam, and fabric covers that reduce interface temperature are associated with better comfort ratings (Silva *et al.* 2024).

Pressure sensitivity and pressure distribution are also important to seating comfort. Studies of the buttocks and thighs have shown that perceived pressure distribution, rather than mechanically measured pressure alone, plays a key role in comfort and varies considerably among individuals (Hirao *et al.* 2022). To reduce interference during measurement, Yao *et al.* (2021) evaluated perceived comfort using pressure data collected from beneath seat cushions. Lumbar support is another important factor. Finite element modeling suggests that a lumbar support thickness of approximately 10 mm may help reduce intervertebral disc stress and improve pressure distribution (Guo *et al.* 2016). Studies of specific user groups, including older adults and wheelchair users, have also identified sitting postures and support parameters, such as seat height, backrest inclination, and full contact with the seat and backrest, that can improve comfort and delay muscle fatigue by improving body pressure distribution (Huang *et al.* 2024; Lyu *et al.* 2025). Overall, these studies suggest that a subjectively comfortable pressure distribution tends to be relatively uniform within an appropriate range, although it is strongly affected by individual sensitivity and physiological differences (Hu *et al.* 2017; Hirao *et al.* 2022).

Adjustability has also been examined in relation to comfort and task performance. Qing *et al.* (2017) used a hybrid physical–virtual environment with fNIRS and HRV monitoring to compare three types of chairs—non-adjustable, height-adjustable, and auto-adjustable—during cognitive tasks. Their results showed that ergonomic auto-adjustable chairs, such as Cosm, reduced stress by 13% and improved decision-making speed by 17% in the Set-Shift test (Herman Miller and Texas A&M Ergonomics Center 2017), highlighting the value of adjustability. However, the specific angles needed for optimal comfort remain unclear. Although previous studies have examined added functions, such as pneumatic massage pads for older adults (Yu *et al.* 2025), the main adjustment parameters of functional single chairs designed for young users have not been systematically studied.

Previous studies on seating comfort have mainly focused on traditional seat components, such as seat tilt, lumbar support, and headrests. In contrast, less quantitative research has examined the key adjustable parts of functional single chairs, especially the footrest support angle and backrest tilt angle. The footrest is an important feature that distinguishes functional recliners from conventional chairs, but its effect on comfort has not been fully investigated. Similarly, existing studies on backrest angle have rarely provided specific angle references for single-user leisure settings. In current products, footrests and backrests often allow wide-range adjustment, such as from 0° to 90°. Although this provides flexibility, users often need repeated trial and error to find a comfortable position, which reduces adjustment efficiency and user experience. Therefore, defining suitable comfort ranges for both the footrest and backrest angles is important for improving functional recliner design and supporting a better user experience.

EXPERIMENTAL

This study quantitatively investigated the footrest and backrest angles of functional single chairs. Building upon established applications of EEG technology in seat comfort evaluation (Wang 2024; Zhou *et al.* 2022), a combined subjective-objective methodology was adopted, integrating EEG physiological signals with subjective comfort questionnaires. The correlation between user comfort and functional angles was examined under two conditions: seated (footrest angle adjustment only) and reclined (backrest angle adjustment only). A five-point Likert scale was used to evaluate subjective comfort, with scores ranging from 1 = very uncomfortable to 5 = very comfortable. Both overall comfort and localized comfort were assessed, and the full rating items are described in the Subjective Questionnaire subsection. This approach provides scientific data to inform the design of functional single chairs.

Functional Angle Definitions

The footrest support angle (α) is defined as the angle between the chair's extendable lower surface and the vertical plane, while the backrest support angle (β) denotes the angle between the backrest surface and the horizontal plane during reclining, as illustrated in Fig. 2. In this study, β is defined as a horizontal-reference angle for experimental calibration and control. Because the test chair maintained a constant 3° seat tilt, the corresponding seat-to-backrest included angle equals β minus 3°. Thus, the tested β range of 110° to 130° corresponds to a conventional seat-to-backrest angle range of approximately 107° to 127°. Two primary usage scenarios were evaluated. The seated leisure scenario, intended for brief rest or activities like using a phone, involves increasing the footrest angle (α) from 0° to 90° while the backrest angle (β) remains fixed at 110°. The reclining leisure scenario, suited for extended rest, fixes the footrest angle (α) at 90° for full leg support and adjusts the backrest angle (β) from 110° to 130° to facilitate a transition from sitting to reclining. This adjustment sequence was fixed for the experiment.

Fig. 2. Functional angle definitions

EEG

Electroencephalogram (EEG) signals are classified into five primary rhythmic bands based on frequency: Delta (1 to 3 Hz), Theta (4 to 7 Hz), Alpha (8 to 13 Hz), Beta (14 to 30 Hz), and Gamma (>31 Hz) (Lin 2022). The characteristic features and classifications of these EEG frequency bands are summarized in Table 1.

Table 1. EEG Frequency Band Classification and Characteristics

Name	Classification	Frequency	Amplitude	Regions	Characteristics
δ (Delta) wave	Slow wave	0.5 to 4 Hz	20 to 200 μV	Frontal lobe, Occipital lobe	Typically appears only during deep sleep stages, associated with deep relaxation and restorative sleep processes.
θ (Theta) wave	Slow wave	4 to 8 Hz	100 to 150 μV	Occipital lobe, Parietal lobe, Temporal lobe	Most prominent during light sleep stages; also appears in deep relaxation or near-sleep states.
α (Alpha) wave	Intermediate wave	8 to 13 Hz	20 to 200 μV	Any region (strongest in Occipital/Parietal lobes)	Appears in relaxed and comfortable states, indicating brain rest or meditation.
β (Beta) wave	Fast wave	13 to 30 Hz	<30 μV	Frontal lobe, Parietal lobe	Emerges during focused attention, excitement, or tension; induced by cognitive activities and external stimuli.
γ (Gamma) wave	Fast wave	30 to 50 Hz	<30 μV	Frontal lobe, Central region	Closely related to high-level cognitive activities (*e.g.*, learning, memory, decision-making); positively correlated with neuronal excitability.

In human factors research, alpha-wave activity is commonly used to assess changes in brain state. It has been applied in several comfort-related studies, including evaluations of abdominal-shaping garments for middle-aged and older women, pajama fabric effects on sleep comfort (Sugita *et al.* 2002), disposable diaper comfort (Mori *et al.* 2010), and clothing pressure comfort. Previous research has shown that alpha waves are more prominent during relaxed or comfortable states and tend to decrease under tension or anxiety (Liu 2016). Alpha activity in the parietal region is also related to body-position perception because this region processes sensory information from the spine and limbs. For this reason, alpha power was selected in this study as a potential physiological indicator of postural relaxation and was used as the main EEG measure for evaluating comfort in the functional single chair.

Subjective Questionnaire

Subjective comfort was evaluated using a five-point Likert scale: 1 = very uncomfortable, 2 = uncomfortable, 3 = neutral, 4 = comfortable, and 5 = very comfortable. For the footrest test, the rating items included overall comfort, calf comfort, knee comfort, thigh comfort, hip comfort, and lumbar comfort. For the backrest test, the rating items included overall comfort, buttock comfort, lumbar comfort, back comfort, shoulder-neck comfort, and arm comfort.

Experiment

The experimental procedure comprised three key phases: (1) anthropometric measurement of participant height, weight, and limb dimensions using intelligent instrumentation; (2) acquisition of real-time electroencephalography (EEG) data; and (3) collection of subjective comfort ratings based on the five-point Likert scale described above. The study evaluated 10 seated conditions with footrest angles (α) ranging from 0° to 90° in 10° increments, and 5 reclined postures with backrest angles (β) varying from 110° to 130° in 5° increments. During each session, participants maintained a static posture for 5 min to simulate relaxed rest, with back contact against the backrest and forearms positioned flat on armrests to minimize postural variability. EEG recording began after postural stabilization, and all postures were documented digitally. All data were collected under static conditions to minimize substantial body movement during measurements. Therefore, the EEG and subjective ratings in this study reflect short-term static comfort responses after brief postural stabilization, and may partly represent young users' immediate comfort perception under seated and reclining leisure postures.

Subjects

Twenty graduate students, including 12 women and 8 men, participated in this study. Their physical characteristics were consistent with the target users of functional single chairs. All participants had similar educational backgrounds and reported no history of neurological or psychiatric disorders, chronic back or leg conditions, or spinal disorders. Their key anthropometric characteristics are summarized in Table 2.

Test chair

A functional single chair was used in the experiment, as shown in Fig. 3. The chair was adjusted remotely and featured a seat tilt of 3°, an initial backrest angle of 110°, a maximum backrest angle of 130°, and a footrest adjustable from 0° to 90°. The 3° seat tilt remained constant during all backrest-angle tests. The angle adjustment procedure and two usage scenarios followed the description in the "Functional Angle Definitions" subsection of the Experiment section. Principal dimensions of the chair are provided in Table 3.

Table 2. Participant Characteristics (n=20)

Items	Female Subjects (n=12)					Male Subjects (n=8)				
	Age (years)	Height (cm)	Weight (kg)	BMI (kg·m⁻²)	Lower-limb length (cm)	Age (years)	Height (cm)	Weight (kg)	BMI (kg·m⁻²)	Lower-limb length (cm)
Mean	24.55	164.00	53.18	19.80	86.29	25.00	175.13	64.13	21.99	93.74
Standard deviation	0.52	3.10	3.49	1.27	2.15	0.76	4.94	9.88	1.94	3.13
Max	25.00	169.00	60.00	22.04	89.70	26.00	185.00	80.00	23.51	99.20
Min	24.00	158.00	49.00	18.14	82.30	24.00	168.00	49.00	17.36	88.40

Fig. 3. Test chair

Table 3. Key Dimensions of the Experimental Chair

Items	Width	Length	Height	Seat width	Seat depth	Seat height	Armrest height	Backrest height
Dimensions (mm)	720	730	1140	540	470	500	140	585

Assisting tools

The footrest adjustment range (0° to 90°) was subdivided into 9 gradients at 10° intervals (10° to 90°), while the backrest tilt range (110° to 130°) was divided into 5 gradients at 5° intervals (110° to 130°).

Preliminary tests indicated that direct angle adjustment using an electronic protractor required repeated calibration, resulting in low operational efficiency. To address this, a standardized "angle-to-height conversion" marking system was developed. During calibration, each target angle was precisely set using an electronic protractor and T-square. Reference points on the footrest and backrest (Figs. 6 and 8) were used to mark corresponding heights on a transparent rigid acrylic plate. This process was repeated until all marks for the same angle achieved consistent alignment, ensuring accuracy.

During experiments, the acrylic plate was vertically mounted in a dedicated fixture (Fig. 4). Each angle adjustment was performed by aligning the reference points with the pre-marked height indicators, enabling rapid and precise positioning. The transparency of the plate allowed visual verification of alignment, while its rigidity minimized deformation-related errors, thereby ensuring adjustment precision throughout testing.

Fig. 4. Assisting tools

Operational Procedures

Prior to testing, participants were required to wash their hair one day before the experiment and refrain from using any hair products. They were also instructed to maintain normal sleep and emotional stability. On the test day, participants received a detailed explanation of the experimental procedures and precautions to reduce anxiety and minimize errors. This study was approved by the Ethics Committee of the College of Furnishings and Industrial Design, Nanjing Forestry University (Approval No. 2025027) and conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained prior to the experiment, and participants were familiarized with the subjective rating scale. During testing, subjects wore short-sleeved shirts and shorts to reduce clothing interference, and the experiment was conducted at a controlled room temperature of 25 °C.

Height and weight measurement

For anthropometric measurements, participants removed their shoes and heavy outer clothing. They stood upright at the center of a standard scale, gazing forward with heels together and arms hanging naturally. Height (cm) and weight (kg) were recorded simultaneously by researchers, with two repeated measurements taken to obtain an average value for accuracy. Lower and upper leg lengths were measured with participants seated on a backless chair, maintaining an upright posture with legs hanging naturally and feet flat on the floor.

EEG equipment setup

An electrode cap matching the participant's head circumference was selected and positioned. Electrodes were adjusted to ensure optimal scalp contact and secure fit. Conductivity was enhanced using saline solution to reduce impedance. System parameters were calibrated, and electrode impedance was monitored and maintained below 5 kΩ. EEG data acquisition commenced only after all signal quality criteria were satisfied, with continuous monitoring of waveform stability and baseline signals throughout the experiment.

Seated comfort testing

After the participant was seated, the functional single chair was adjusted to its initial seated position. Following a one-minute stabilization period, EEG recording was initiated. For each angle condition, the participant maintained a static seated posture for 5 min while the Ergolab platform synchronously recorded EEG signals and video. Subjective comfort ratings for the specific angle were collected immediately after each static test. The chair was then adjusted to the subsequent angle, repeating this procedure sequentially until the footrest reached 90°.

Reclining comfort test

Following participant seating, the functional single chair was adjusted to the initial reclining position (footrest at 90°, backrest at 110°). For each backrest angle condition, participants maintained a static reclining posture for 5 min while the Ergolab platform synchronously recorded EEG signals and video. Subjective comfort ratings were collected immediately after each posture maintenance period. This procedure was repeated sequentially for each subsequent backrest angle until the experiment concluded at a backrest angle of 130°.

Post-test procedure

After the testing was completed, the EEG electrode cap was removed. Participants were invited to provide feedback on their experimental experience, and all experimental data were backed up to the cloud platform.

Data Acquisition and Processing

The experiment utilized an ErgoLAB EEG portable hydrogel electrode system (Fig. 5), configured with 16 high-sensitivity electrodes arranged according to the international 10–20 system, as shown in Fig. 6. EEG signals were recorded at a sampling rate of 2048 Hz with 24-bit resolution. During acquisition, the system-default reference and ground channels integrated in the electrode cap were used, and no additional offline re-referencing was performed. The system provided high signal-to-noise ratio and low impedance characteristics, making it suitable for high-quality data acquisition.

Fig. 5. ErgoLAB EEG Portable Electroencephalography Device

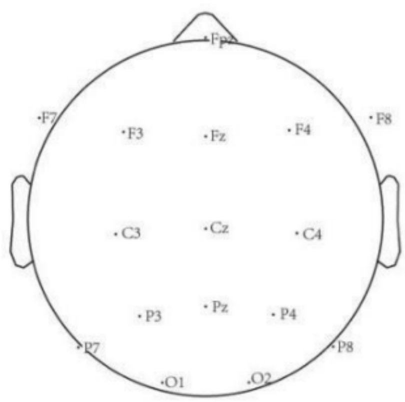


Fig. 6. Electrode distribution

EEG data were preprocessed using established methods on the Ergolab cloud platform. During EEG recording, participants remained awake with their eyes open, kept silent, and were instructed to minimize unnecessary eye and body movements. The signal processing chain included: a 5 Hz high-pass filter to eliminate low-frequency drift; a 500 Hz low-pass filter to suppress high-frequency noise; and a 50 Hz band-reject filter to remove power-line interference. Independent Component Analysis (ICA) was applied to identify and remove artifacts, including ocular artifacts (from electrooculography, EOG) and muscular artifacts (from electromyography, EMG). ICA components were rejected when their time-course, frequency characteristics, and spatial distribution were consistent with ocular or muscle artifacts. Data segments exceeding three standard deviations from the mean for over 2 consecutive seconds were discarded. The retained valid-data proportion was checked for each angle condition, and all conditions retained at least 90% of valid data.

For each 5-min static EEG recording under specific angle conditions, the initial 1-min adaptation period was excluded from analysis. This initial period was excluded as an adaptation period rather than used for baseline normalization, and no additional baseline correction was applied. Power Spectral Density (PSD) was calculated from the subsequent 4-min stable segment using Fast Fourier Transform (FFT) with a 2-second window, 50% overlap, and Hann window smoothing. The resulting alpha band (8 to 13 Hz) power values served as the primary physiological metric. Alpha-band power values were analyzed in their original PSD units and were not log-transformed. All statistical analyses were performed using specialized software. The entire preprocessing workflow was standardized and automated on the ErgoLAB platform, ensuring consistent application of the filtering parameters and artifact removal procedures described above.

Fig. 7. Synchronized EEG-video acquisition

As shown in Fig. 7, the ErgoLAB platform synchronized the activation of webcams and EEG acquisition devices. EEG-triggered pulse verification ensured temporal alignment of all data streams, enabling integrated multimodal analysis.

Data Analysis

Internal consistency of the subjective questionnaire was evaluated using Cronbach's Alpha coefficient. As shown in Table 4, all dimension-level Cronbach's Alpha values exceeded 0.80, and the overall alpha coefficients were 0.968 for the footrest questionnaire and 0.965 for the backrest questionnaire, indicating good internal consistency.

Table 4. Reliability Analysis of the Subjective Comfort Questionnaire

Test condition	Questionnaire dimension	Cronbach's Alpha	Overall Cronbach's Alpha
Footrest test	Overall comfort	0.824	0.968
	Calf comfort	0.805	
	Knee comfort	0.889	
	Thigh comfort	0.862	
	Hip comfort	0.855	
	Lumbar comfort	0.852	
Backrest test	Overall comfort	0.808	0.965
	Buttock comfort	0.852	
	Lumbar comfort	0.825	
	Back comfort	0.802	
	Shoulder-neck comfort	0.810	
	Arm comfort	0.866	

Content validity was evaluated by three ergonomics experts with experience in human factors and seating comfort evaluation. Each expert independently rated the relevance of each questionnaire item to the measurement objective using a 4-point scale: 1 = not relevant, 2 = relevant only after major revision, 3 = relevant but requiring minor revision, and 4 = highly relevant. The item-level content validity index (I-CVI) was calculated as the proportion of experts assigning a rating of 3 or 4 to each item. Because three experts were involved, full agreement among all experts was required for I-CVI = 1.0. Items with I-CVI < 1.0 were revised or removed before the final questionnaire was retained. The calculated I-CVI and S-CVI values were both 1.0, indicating acceptable content validity and all questionnaire items were retained.

For the subjective comfort ratings, the effect of footrest angle on overall comfort was analyzed using the Friedman test, because the same participants evaluated all angle conditions and the ratings were based on a five-point Likert scale. When appropriate, planned post-hoc comparisons were performed using Wilcoxon signed-rank tests with Holm correction.

For the EEG alpha-band PSD results, one-way ANOVA and Duncan's post hoc grouping were retained as exploratory condition-level comparisons of mean PSD values across angle conditions. The final interpretation of the recommended angles was based primarily on the convergence between alpha-band PSD trends and subjective comfort ratings.

The average power spectral density of EEG signals was used as the primary metric to assess participants' relaxation states and dynamic changes in neural activity. Alpha wave power spectra, recorded across various footrest and backrest angles, were analyzed with SPSS software using one-way ANOVA and post-hoc multiple comparisons. The analysis revealed statistically significant differences in alpha wave power spectral density among different footrest angles ($P < 0.05$) and backrest angles ($P < 0.05$). Although standard errors were relatively large compared to mean values in both experimental setups—reflecting considerable inter-individual variability—the overall trends across samples remained consistent.

RESULTS AND DISCUSSION

The effects of two primary design factors—footrest support angle and backrest angle—on subjective and physiological comfort are reported here. Ten seating conditions were evaluated. The following sections describe the influence of these angle variations on participant comfort. In the present study, the optimal angle was defined by a combined subjective–physiological criterion, with alpha-band power spectral density serving as the primary physiological indicator of relaxation and 5-point comfort ratings representing perceived comfort. An angle was regarded as optimal when alpha-band power reached the highest or near-highest level and subjective comfort ratings remained highest or consistently high across overall and localized comfort dimensions, with final interpretation based on the convergence of both indicators when minor discrepancies occurred. The following results were interpreted according to this combined subjective–physiological criterion.

Effects of Footrest Angle Adjustment on Comfort

Subjective questionnaire findings

Comfort ratings from 20 participants (Fig. 8) showed that comfort decreased across all body regions except the calves when the footrest angle increased from 0° to 10°, due to enhanced calf support. As the angle increased, the scores fluctuated upward, peaking at 60° (mean 4.6) and reaching a secondary peak at 70° (mean 4.4). At 90°, the body assumed a kyphotic hunched posture, with excessive knee extension in the lower legs and inadequate support for the lumbar spine, shoulders, and neck. This led to a noticeable overall drop in comfort to the lowest level (mean 3.2).

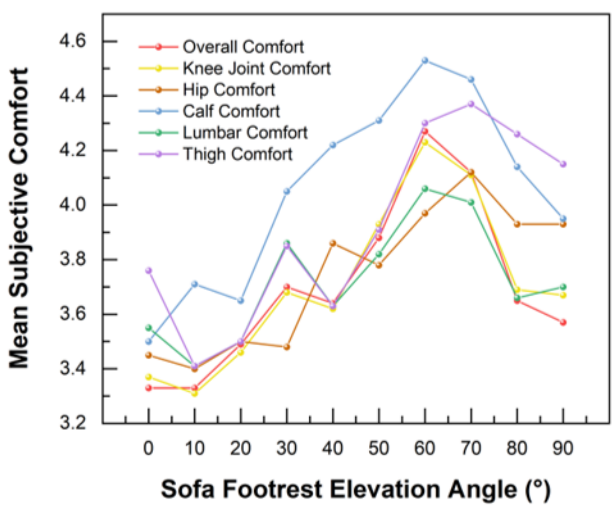


Fig. 8. Mean subjective comfort score in the footrest test

In the footrest experiment, the multidimensional subjective ratings showed an overall pattern of an initial decline, followed by fluctuating increases and a gradual decrease after the favorable range. Specifically, when the footrest was raised from its initial position to 10°, comfort levels decreased to varying degrees across all body parts except the lower legs. This indicates that slight footrest elevation at the initial stage negatively affected seated comfort. For the calves, comfort increased compared with the unsupported state because of the additional support provided by the footrest. The Friedman test showed a significant effect of footrest angle on overall subjective comfort, $\chi^2(9) = 30.591$, p <

0.001, Kendall's W = 0.170. Planned post-hoc comparisons indicated that the difference between 60° and 70° was not significant. Therefore, 60° and 70° were interpreted as neighboring favorable footrest angles in terms of subjective comfort. These two angles were associated with the highest or near-highest comfort levels across the subjective ratings. Comfort levels declined to varying degrees after this favorable range. This decline was likely caused by an excessive footrest angle while the backrest angle remained unchanged. Similar to the extreme case at 90° described earlier, under this configuration, the body tended to adopt an unnatural kyphotic hunched posture. This led to overstretching of body parts such as the calves and knees, as well as insufficient support for the back, shoulders, and neck.

Trends in alpha wave changes

Alpha wave power spectral density showed angle-related changes with footrest support angle (Table 5, Fig. 9). Values are presented as mean ± SD. Lowercase letters indicate Duncan's post-hoc grouping at $p < 0.05$; angle conditions sharing the same letter are not significantly different. As the angle increased from 0°, alpha intensity initially showed suppression at 10°. Then it gradually rose from 20° onward, reaching a peak at 60°, before declining with further increases (60° to 90°). Exploratory condition-level comparisons indicated differences in mean alpha-band PSD among footrest-angle conditions. Duncan grouping further suggested differences between several angle intervals (*e.g.*, 10° *vs*. 40° and 40° *vs*. 60°), supporting the observed trend of increasing alpha activity toward 60° followed by a subsequent decline. Statistically significant differences were observed between angle groups on the same side of the peak, whereas those on opposite sides did not differ significantly. Given the established role of alpha waves as a biomarker of relaxation, and considering that subjective comfort remained high at 60° and did not differ significantly from 70°, the convergence of physiological and subjective evidence indicates that the 60° footrest angle provided the most favorable comfort condition under the seated leisure posture. Beyond this angle, comfort decreased while tension and discomfort rose, corresponding to the observed suppression of alpha activity.

The footrest angle was associated with noticeable changes in alpha wave intensity. More pronounced fluctuations in alpha activity were observed when the footrest was adjusted within the 40° to 70° range and during the transition from 80° to 90°. This suggests that participants' perceived comfort varied more markedly across these angle intervals compared to other stages. In contrast, backrest angle adjustments elicited relatively gradual changes in alpha wave dynamics, indicating a more steady shift in comfort perception during reclining.

Table 5. Influence of Footrest Angle on Alpha-Band Power Spectral Density

Footrest angle	N	Alpha-band PSD	F-value	Significance
0°	20	8.076±2.367d	4.464	0.001
10°	20	8.023±2.57d		
20°	20	8.162±2.808d		
30°	20	8.896±2.934d		
40°	20	9.477±2.844d		
50°	20	11.061±3.011ab		
60°	20	12.115±3.2a		
70°	20	10.636±3.462abc		
80°	20	10.311±3.402abc		
90°	20	8.891±3.082cd		

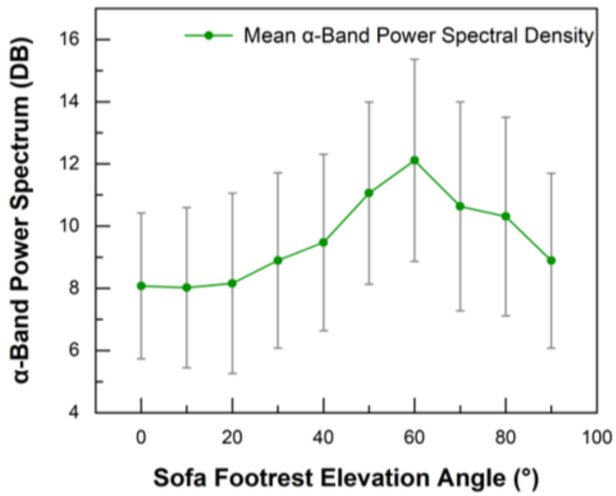


Fig. 9. Alpha-band power as a function of footrest angle

Effects of Backrest Angle Adjustment on Comfort

Subjective questionnaire results

Multidimensional comfort data exhibited an overall trend of fluctuating increase followed by a decline. With the exception of shoulder-neck comfort, which peaked at 120°, optimal comfort for all other body regions was achieved at a backrest angle of 125°. As the backrest tilt increased, the posture transitioned from an initial “arched” position to a more extended state, contributing to enhanced overall comfort. This postural change expanded the pressure-bearing contact area of the buttocks, leading to a gradual improvement in seating comfort. Concurrently, the backward shift in the body’s center of gravity and the lowering of the posture provided effective support to previously suspended regions such as the shoulders, neck, and arms, thereby increasing their comfort.

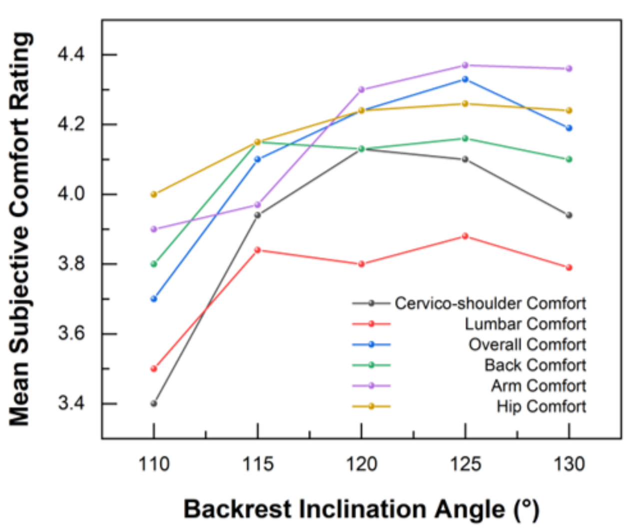


Fig. 10. Mean subjective score of backrest test comfort

As shown in Fig. 10, in which the backrest angle follows the definition given in Fig. 2, the comfort trends for the lumbar and back regions were similar; however, lumbar comfort was consistently rated lower than back comfort, indicating insufficient lumbar support. Beyond 125°, comfort declined across all body regions except the arms. Participant feedback suggested that at angles exceeding 125°, the recline was insufficient for lying down to sleep. In an awake state, excessive backward tilt of the head forced an upward gaze, elevating pressure on the neck and shoulders and hindering common leisure activities. Simultaneously, the lumbar curve shifted rearward, leaving the lower back inadequately supported and transferring load to the upper back and buttocks, which increased pressure in these areas.

Alpha wave trend

Alpha wave intensity increased progressively as the backrest angle was raised from 110°, reaching a peak at 125° before declining with further inclination. Duncan's post-hoc test confirmed differences between adjacent 5° angle intervals (*e.g.*, 110° *vs.* 120°). Consistent with the recognized role of alpha activity as an indicator of relaxation, and considering the subjective questionnaire results in which overall comfort and most localized comfort ratings were also highest or relatively high at 125°, this trend supports the identification of 125° as the recommended optimal backrest angle under the reclining leisure posture. Beyond this angle, the decline in alpha activity suggests a reduction in physiological relaxation, which is generally consistent with the decrease in subjective comfort. Specific data are shown in Table 6 and Fig. 11.

Table 6. Analysis of the Influence of Backrest Angle on Alpha-band Power Spectral Density

Backrest angle	N	Alpha-band PSD (mean ± SD)	F-value	Significance
110°	20	8.742±3.594c	4.262	0.003
115°	20	9.807±3.465bc		
120°	20	11.836±5.037ab		
125°	20	13.042±3.608a		
130°	20	12.195±3.382ab		

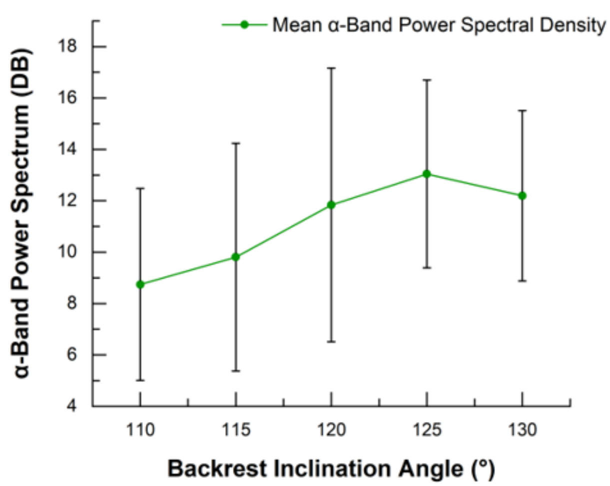


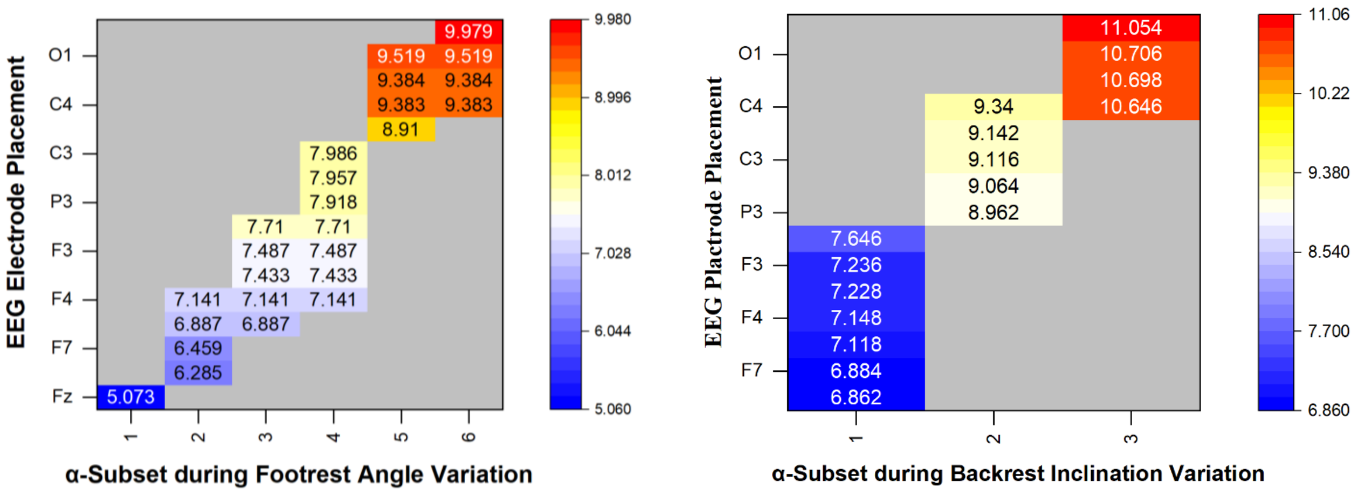
Fig. 11. Alpha-band power as a function of backrest angle

Effect of Different EEG Electrode Positions on Alpha Wave Power Indicators

An exploratory one-way ANOVA was conducted to compare mean alpha-band PSD values across the 16 EEG electrode sites. The results indicated a non-uniform spatial distribution of alpha-band activity ($P < 0.05$), with relatively higher PSD values mainly observed over the occipital, parietal, and central regions, as detailed in Table 7.

Table 7. Effect of EEG Electrode Position on Alpha-Band Power Spectral Density

	Type III Sum of Squares	df	Mean Square	F-value	Significance
Footrest	27.303	15	18.020	21.936	0.001
Backrest	176.621	15	11.775	12.585	0.001



(a) (b)

Fig. 12. EEG alpha wave power subset lead attribution heatmap

Duncan grouping was used to summarize possible electrode-site clustering patterns. For the footrest test, the 16 electrode locations were clustered into 6 subsets, with half of the electrodes belonging to multiple subsets due to the absence of significant between-group differences. In the backrest test, the same 16 electrode positions were grouped into 3 non-overlapping subsets: (Pz, Cz, C4, Fz); (O1, O2, C3, P4, P3); and (Fpz, P8, F3, F8, P7, F7, F4). Within each subset, the mean alpha-wave power spectral density values remained similar across the five backrest angles. To visualize these grouping patterns, heatmaps were generated to display the subset affiliations of electrode positions for both tests (Fig. 12). In the heatmaps, the mean alpha-wave power spectral density decreased progressively as the color shifted from warm to cool tones. Overall, alpha activity was more prominent over posterior and central regions, especially occipital, parietal, and central areas.

Based on the subset clustering and corresponding heatmap color gradients (Fig. 13), varying shades of red reflect different levels of alpha-wave intensity. The figure illustrates the spatial distribution of brain regions activated by somatosensory stimuli induced through footrest and backrest adjustments. Darker colors correspond to higher average alpha-wave power spectral density at the respective electrode sites, indicating greater spectral energy. Although the subset compositions differed between the two test conditions, alpha activity was consistently strongest over the occipital, parietal, and central regions, and weaker in the frontal and temporal lobes. This spatial pattern aligns with established functional neuroanatomy, wherein alpha rhythms are typically most prominent in posterior regions, and somatosensory processing primarily engages parietal, occipital, and central cortices.

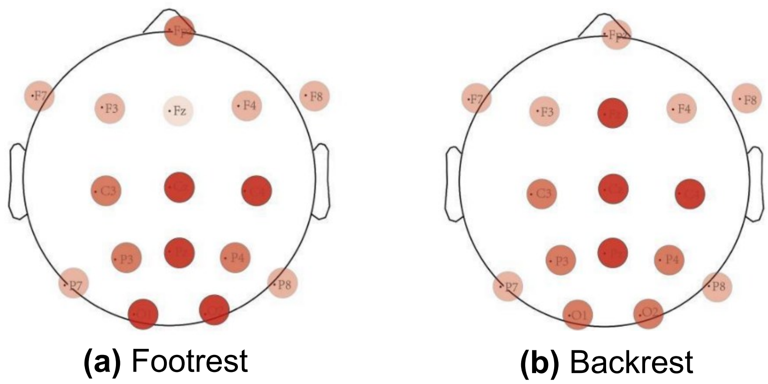


Fig. 13. Alpha wave intensity distribution

Association between Wave Spectrum Energy and Subjective Comfort Ratings

Pearson correlation was used as an exploratory trend analysis to examine the consistency between angle-level mean subjective comfort ratings and angle-level mean alpha-band PSD values at each electrode site. The analysis compared mean subjective comfort scores across footrest and backrest angles with the average alpha-wave power spectral density recorded at each of the 16 electrode positions. As shown in Fig. 14, while alpha activity at a minority of electrodes showed no significant correlation with subjective ratings, most electrode sites exhibited a clear positive trend: the lowest comfort ratings coincided with the lowest alpha-wave intensity, and the highest comfort ratings corresponded to peak alpha-wave intensity.

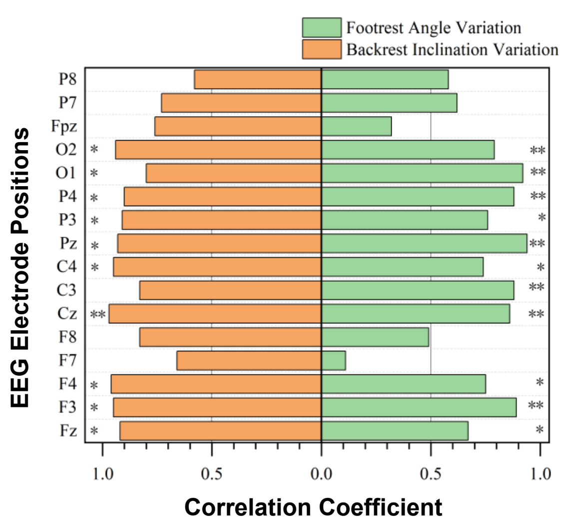


Fig. 14. The relationship between subjective comfort and alpha-wave intensity. Correlations significant at the 0.05 and 0.01 levels are denoted by * and **, respectively

This finding corroborates the earlier analyses and confirms a link between subjective comfort and alpha-wave spectral energy, and the results can be interpreted as exploratory evidence. Footrest adjustment demonstrated a stronger association with subjective comfort than backrest adjustment. Correlations during backrest changes were predominantly significant at the 0.05 level, whereas footrest changes more frequently reached the 0.01 significance level. Electrodes showing significant correlations—notably O1, O2, Pz, P3, P4, Cz, and C4—were concentrated primarily over the occipital, parietal, and central regions.

Main Findings and Underlying Mechanisms

This study identified two recommended optimal angles for young adult users of functional single chairs—a footrest angle of 60° and a backrest angle of 125° (corresponding to approximately 122° when expressed as the conventional seat-to-backrest included angle)—based on the predefined combined subjective–physiological criterion. These findings were supported by the peak alpha-wave power spectral density recorded in the parieto-occipital leads (O1, O2, Pz) and by high subjective comfort ratings. Furthermore, the footrest angle range of 40° to 70° was identified as a comfort-sensitive zone, within which perceived comfort changed markedly, whereas backrest adjustment elicited a more gradual transition in comfort.

The mechanisms underlying these results could be interpreted from physiological-adaptive and neurocognitive perspectives. Ergonomically, the 125° backrest angle aligned well with the natural spinal curvature of young adults, promoting even pressure distribution across the back and buttocks while reducing lumbar suspension. This explained the synchronous, yet consistently lower, improvement in lumbar comfort relative to back comfort at this angle—a discrepancy indicating that the standard backrest design does not fully accommodate the lumbar lordosis typical in younger users. The optimal 60° footrest angle effectively balances calf support with knee joint stress. It provided sufficient elevation to prevent calf fatigue associated with lower angles (0° to 40°), while avoiding the excessive knee extension and full-body "bow" deformation observed at 90°, thereby matching the physiological adaptability linked to the average calf length of the study population.

From a neurophysiological perspective, alpha waves (8 to 13 Hz) are commonly used as an indicator of relaxation. Their peak activity in the parieto-occipital cortex—a key region for somatosensory integration—suggests that optimal postural support reduces muscle tension and discomfort. This decrease in disruptive somatic input likely lowers the cognitive load for sensory processing, thereby enhancing alpha-wave activity. This interpretation is consistent with the observed positive correlation between alpha-wave intensity and subjective comfort, suggesting consistency between physiological and perceptual measures of relaxation.

Innovation of the Study and Connection with Existing Evidence

This study addressed two major gaps in research on functional single chairs. First, to our knowledge, few studies have quantified comfort-related footrest and backrest angles specifically for young adults in leisure contexts, as previous research has mainly focused on office chairs, elderly populations, or isolated chair parameters. Second, it combined EEG alpha-wave metrics with multi-dimensional subjective ratings, providing convergent "physiological-subjective" evidence for defining comfort angles and mitigating bias inherent in single-method approaches (Körmendi *et al.* 2021).

In the broader ergonomic literature, these findings complement and extend existing knowledge. Whereas previous investigations have examined support parameters such as pressure distribution and muscle activity, the present research quantified footrest and backrest angles, which are core adjustable features of functional recliners. Similarly, while headrest support has been shown to alleviate neck fatigue in other seating contexts, this study proposes a targeted “125° backrest + adjustable headrest” configuration to address shoulder-neck strain in young users during leisure. Furthermore, in contrast to studies that emphasize age-friendly angles for older adults, the current results highlight distinct optima for younger users, underscoring a “population-specific” design logic.

The footrest-angle results showed a more consistent subjective–physiological pattern than the backrest-angle results in the present angle-level analysis. This may relate to young users’ greater responsiveness to lower-limb support during leisure activities, which may be associated with greater daily activity levels and faster accumulation of lower-limb muscle fatigue. This insight offers a new rationale for prioritizing footrest design in functional chairs for this demographic. Further studies incorporating biomechanical or pressure-distribution measurements are needed to verify the role of lower-limb support in functional chair comfort.

Limitations and Directions for Future Research

Several limitations should be noted. First, the sample was limited to 20 young graduate students, with insufficient diversity in body type and occupational background, which may restrict the generalizability of the findings. Second, the fixed-height headrest of the test chair was not fully optimized, and insufficient head support may have affected the evaluation of backrest angles. Third, the protocol simulated only static rest and did not include common leisure activities, which may limit ecological validity. Fourth, the angle conditions were tested in a fixed increasing order rather than in a randomized or counterbalanced sequence; therefore, potential order-related effects, including adaptation, fatigue, expectation, and cumulative time-on-task, could not be excluded. In addition, the EEG PSD and correlation analyses were mainly based on condition-level mean values, with limited angle-level observations, especially for the backrest condition. Therefore, the correlation results should be interpreted as supportive evidence for the consistency between subjective and physiological indicators. Future studies should use randomized or counterbalanced angle sequences and analyze participant-level data using repeated-measures ANOVA or linear mixed-effects models with appropriate multiple-comparison correction.

Each angle condition was evaluated during a relatively short static period. This design helped reduce participant fatigue and motion artifacts during EEG recording, but comfort during longer recliner use may change with postural adaptation, pressure accumulation, or time-on-task effects. In addition, this study examined awake leisure rest in a recliner rather than horizontal sleep or clear napping. Social expectations related to daytime recliner use may also affect posture preference and subjective comfort ratings. Future research should include larger and more diverse samples, longer test periods, and comparisons between initial and later comfort responses during extended reclining or nap-like conditions. Future studies should also use chairs with adjustable headrests and lumbar support to better separate the effects of footrest and backrest angles. More realistic protocols could include task-based scenarios and combine EEG with eye-tracking to examine how visual activity, posture, and comfort interact.

Implications for Practice and Industry

The findings may inform practical strategies for optimizing the design of functional single chairs. Implementing one-touch preset positions for the 60° footrest and 125° horizontal-reference backrest could help reduce the inefficiency of full-range manual adjustment, aligning with young users' demand for convenience. Concurrently, enhancing lumbar support and pairing the 125° backrest with a height-adjustable headrest would mitigate lumbar suspension and shoulder-neck strain caused by head tilt.

This study provides initial physiological and subjective comfort data that may inform future product iteration, prototype refinement, and further human-factors evaluation. The conclusions may also be relevant to settings with concentrated young populations, such as co-living apartments and leisure spaces, offering guidance for furniture specification. It should be emphasized that the observed comfort-related patterns require further validation through product iteration, larger-sample testing, and market feedback before being translated into broad practical recommendations. As this study did not include economic analysis, it does not support direct inferences regarding product pricing or cost-benefit outcomes.

CONCLUSIONS

1. The results suggest that a 60° footrest angle and a 125° horizontal-reference backrest angle, the latter corresponding to approximately 122° when expressed as the conventional seat-to-backrest included angle, can be regarded as recommended comfort-related angles for young adult users under short-term static leisure postures. This interpretation is supported by the convergence between alpha-band activity trends and subjective comfort ratings.
2. A contribution of this research is its focus on young adults in leisure contexts, thereby addressing a gap in the quantitative comfort assessment of functional recliners. It provides preliminary evidence related to young users' needs for convenience and comfort, proposing practical preset-angle design strategies and supporting a shift in product development from a technology-centric to a human-centric approach. For wood-based recliner design, these findings can serve as preliminary human-factors input for future frame layout and support-structure optimization; however, direct implications for structural simplification, material saving, timber conservation, or life-cycle performance require further validation through structural analysis, prototype testing, and material-use assessment.
3. Despite limitations in sample diversity and scenario realism, this study provides preliminary evidence for human-factors optimization in functional furniture. It also offers a methodological example of integrating population-specific physiological responses with subjective comfort evaluation to support data-informed design.

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Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Use of Generative AI

The authors confirm that no generative AI tools were used in the preparation of the text, data analysis, or reference collation for this study.

REFERENCES CITED

Beike Research Institute. (2022). "2022 Youth Home Living Trends Insight Report," Beike Research Institute, (https://research.ke.com/130/ArticleDetail?id=523), Accessed 27 May 2026.

De Looze, M. P., Kuijt-Evers, L. F., and van Dieën, J. (2003). "Sitting comfort and discomfort and the relationships with objective measures," *Ergonomics* 46(10), 985-997. https://doi.org/10.1080/0014013031000121977

Guo, L.-X., Dong, R.-C., and Zhang, M. (2016). "Effect of lumbar support on seating comfort predicted by a whole human body-seat model," *International Journal of Industrial Ergonomics* 53, 319-327. https://doi.org/10.1016/j.ergon.2016.03.004

Herman Miller and Texas A&M Ergonomics Center (2017). "Can a comfortable chair help you fight office stress?" (https://www.hermanmiller.com/research/categories/white-papers/can-chair-lower-office-stress), accessed 8 April 2025.

Hirao, A., Naito, S., and Yamazaki, N. (2022). "Pressure sensitivity of buttock and thigh as a key factor for understanding of sitting comfort," *Applied Sciences* 12, article 7363. https://doi.org/10.3390/app12157363

Hitka, M., Naď, M., Gejdoš, M., Joščák, P., Jurek, A., and Balážová, Ž. (2022). "The effect of body mass on designing the structural elements of wooden chairs," *BioResources* 17(2), 3378-3397. https://doi.org/10.15376/biores.17.2.3378-3397

Hu, H., Yao, Y., Luo, L., Ran, L., Zhao, C., Zhang, X., and Wang, R. (2017). "Research on pressure comfort of sofa based on body pressure distribution and subjective experience," in: *Digital Human Modeling. Applications in Health, Safety, Ergonomics, and Risk Management: Ergonomics and Design* (DHM 2017), V. Duffy (ed.), Lecture Notes in Computer Science, Vol. 10286, Springer, Cham, Switzerland, pp. 26-38. https://doi.org/10.1007/978-3-319-58463-8_3

Huang, Z., Cui, J., Wang, Y., and Yu, S. (2024). "Improving wheelchair user sitting posture to alleviate lumbar fatigue: A study utilizing sEMG and pressure sensors," *Frontiers in Neuroscience* 18, article 1380150. https://doi.org/10.3389/fnins.2024.1380150

Körmendi, J., Ferentzi, E., and Köteles, F. (2021). "Expectation predicts performance in the mental heartbeat tracking task," *Biological Psychology* 164, article 108170. https://doi.org/10.1016/j.biopsycho.2021.108170

Lee, H., and Park, S. (2006). "Quantitative effects of mattress types (comfortable *vs.* uncomfortable) on sleep quality through polysomnography and skin temperature," *International Journal of Industrial Ergonomics* 36(11), 943-949. https://doi.org/10.1016/j.ergon.2006.07.007

Li, Y., Xiong, X., and Qu, M. (2023). "Research on the whole life cycle of a furniture design and development system based on sustainable design theory," *Sustainability* 15, article 13928. https://doi.org/10.3390/su151813928

Lin, X., Li, X., and Chen, Y. (2024). "Affective response difference to the viewing of different styles of solid wood furniture based on Kansei engineering," *BioResources* 19(1), 805-822. https://doi.org/10.15376/biores.19.1.805-822

Lin, Y. (2022). *Study on Comprehensive Comfort of High-speed Train Passengers Based on EEG Signals*, Master's Thesis, Central South University, Changsha, China. https://doi.org/10.27661/d.cnki.gzhnu.2022.004685

Liu, Y. (2016). *Fundamental Study on Evaluation Method of Clothing Pressure Comfort Based on EEG Technology*, Ph.D. Dissertation, Jiangnan University, Wuxi, China.

Lyu, J., Chen, S., Xia, S., Zhong, Q., Chang, D., Lin, Y., Wang, H., and Chen, M. (2025). "Effects of seat height and backrest inclination on body pressure distribution and subjective comfort in seat design for the elderly," *Applied Sciences* 15, article 11224. https://doi.org/10.3390/app152011224

Mori, Y., Ikami, K., Sugita, A., and Kioka, E. (2010). "Clothing comfort of the material (RAFUMA-mixed cotton) of pajamas from the point of biological reactions," *Journal of Home Economics of Japan* 56, 233-240. https://doi.org/10.11428/jhej1987.56.233

Qing, T., Jinsheng, K., Wen-lei, S., Shou-dong, W., and Zhao-bo, L. (2017). "Analysis of the sitting posture comfort based on motion capture system and JACK software," in: *Proceedings of the 23rd International Conference on Automation and Computing* (ICAC 2017), Huddersfield, UK, pp. 1-7. https://doi.org/10.23919/IConAC.2017.8081987

Silva, P., Ribeiro, D., Postolache, O., Seabra, E., and Mendes, J. (2024). "Static factors in sitting comfort: Seat foam properties, temperature, and contact pressure," *Applied Sciences* 14(17), article 7753. https://doi.org/10.3390/app14177753

Smulders, M., Naddeo, A., Cappetti, N., van Grondelle, E. D., Schultheis, U., and Vink, P. (2019). "Neck posture and muscle activity in a reclined business class aircraft seat watching IFE with and without head support," *Applied Ergonomics* 79, 25-37. https://doi.org/10.1016/j.apergo.2018.12.014

Sugita, A., Okabe, K., and Kioka, E. (2002). "Effects of girdles on comfort of aged women—Results from early responses of a heart rate, a skin temperature and an electroencephalograph," *Sen'i Seihin Shohi Kagaku* 43(6), 365-376. https://doi.org/10.11419/senshoshi1960.43.6_365

Trucillo, P., Chaouali, F., and Portioli, F. P. A. (2025). "Sustainable material selection for interior design furniture: A simple procedure based on environmental analysis and structural optimization," *Materials* 18, article 2023. https://doi.org/10.3390/ma18092023

Wang, H. (2024). *Research on Humanized Work Chair Design Based on User Experience and Health Needs*, Master's Thesis, Shandong Jianzhu University, Jinan, China. https://doi.org/10.27273/d.cnki.gsajc.2024.000329

Yao, X., He, Y., Hessenberger, N., Song, Y., and Vink, P. (2021). "Use pressure data below seat cushions to evaluate comfort," in: Comfort Congress 2021, N. Mansfield (ed.), 3rd International Comfort Congress 2021, Nottingham, UK, 2 September 2021. (https://publications.ergonomics.org.uk/publications/use-pressure-data-below-seat-cushions-to-evaluate-comfort.html)

Yu, C., Liu, W., Fei, Y. N., Chen, J., and Hu, Z. (2025). "Research on the design elements of air pressure massage cushion for expanding the elderly-friendly functions of furniture," *BioResources* 20(3), 5988–6018. https://doi.org/10.15376/biores.20.3.5988-6018

Zhong, X., Xi, J., Rassas, B., Figuracion, C., Alawneh, O., Faieghi, M., and Xi, F. (2025). "A study of upper-body postural parameters for measures of human-seat interaction," *International Journal of Industrial Ergonomics* 105, 103683. https://doi.org/10.1016/j.ergon.2024.103683

Zhong, Y., Ren, Y., Zhang, J., and Zhang, Z. (2024). "Wooden sandwich panels with auxetic core for furniture – Experimental and numerical analysis," *Journal of Sandwich Structures & Materials* 26(1), 56-72. https://doi.org/10.1177/10996362231201880

Zhou, C., Huang, T., Zhang, Z., Wu, Z., Ye, Y., and Cao, Z. (2022). "Determination of age-friendly sofa backrest angle by integrating EEG and EMG signal analysis," *Journal of Forestry Engineering* 7(6), 202-210. https://doi.org/10.13360/j.issn.2096-1359.202206015

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