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INTEGRATED ERGONOMIC APPROACH FOR RESIDENTIAL CHAIR DESIGN: A VALIDATION BASED ON MALAYSIAN ANTHROPOMETRY, RULA, AND EMG

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Abstract

This study presents the design and evaluation of an ergonomic chair developed for Malaysian residential users through the integration of anthropometric data, ergonomic assessment, and experimental validation. Anthropometric dimensions from the Malaysian Anthropometric Database were applied to determine seat height, depth, width, and backrest dimensions suitable for local body proportions. Rapid Upper Limb Assessment (RULA) was conducted using digital manikins representing the 5th, 50th, and 95th percentiles to identify postures with minimal musculoskeletal risk. A 3D CAD model was created in SolidWorks, and finite element analysis (FEA) was performed to evaluate structural integrity under a 150 kg load. A full-scale prototype was validated using electromyography (EMG) testing involving 20 participants of varying height, weight, and body mass index (BMI). Root Mean Square (RMS) values of muscle activation were analyzed to assess comfort and fatigue. Results showed a RULA score of 2, strong structural stability, and low EMG activity, indicating minimal muscle strain. The integration of anthropometry, simulation, and EMG validation confirms the chair's ergonomic suitability and establishes a framework for locally optimized furniture design.

Keywords: Chair design, Comfort, Ergonomics, EMG,

I. Introduction

The matter of posture is one that many societies are becoming increasingly concerned with as hybrid working arrangements proliferate. Musculoskeletal disorders can significantly increase the likelihood of poor sitting posture or prolonged static positions. To promote better health and wellness among individuals engaged in such work practices, it is essential to address these issues. Developing a comfortable and secure seating solution, especially for residential use, therefore makes ergonomic chair design an important consideration [II].

There are currently no specialized studies addressing the state of ergonomic design in Malaysia. Nevertheless, ergonomic design refers to the process of creating objects, environments, or systems that are safer and more effective for users. The importance of ergonomics in product design and human–computer interaction continues to grow as technology becomes more integrated into daily life. With government initiatives encouraging ergonomic design in products and environments to enhance safety and efficiency, ergonomics is increasingly becoming a vital component of design practice in Malaysia.

Ergonomic chairs help users feel more at ease in their living spaces. Properly designed furniture and work environments reduce fatigue and discomfort by improving human fit and movement efficiency. To ensure that a chair provides adequate support for the spine, neck, and limbs while allowing natural motion and proper posture, ergonomic principles are applied in its design [XIII]. The anthropometric dimensions of the furniture, as well as the level of risk associated with sitting posture, are important considerations.

Recent research suggests that to create chairs that are ergonomically optimized, designers must consider users' anthropometric and biomechanical characteristics in addition to functionality and aesthetics [XVIII]. These studies highlight the importance of adjustable armrests, lumbar support, and proper spinal and neck alignment. In this project, chair dimensions are defined based on the Malaysian Anthropometric Database [XV]. The researchers recommend developing furniture with ergonomic features that accommodate up to 95% of the Malaysian population.

Anthropometric data were selected as the foundation for ergonomic chair design. Rapid Upper Limb Assessment (RULA) [IX] was conducted to identify sitting postures with the lowest risk of musculoskeletal injury [XVII]. According to research by Dempsey et al. [VIII], this analytical approach is widely used by ergonomics specialists for its effectiveness and practicality. SolidWorks software was used to create a 3D CAD model of the selected design, followed by simulation studies [V] to evaluate durability and safety.

Electromyography (EMG) analysis [VI, VII, XIX, XX], which measures the electrical activity of muscles during movement, was performed on a prototype chair. EMG results must demonstrate that the designed furniture induces low muscle fatigue and minimal contraction. EMG provides objective data on muscle activation and fatigue, assisting designers and ergonomists in creating safer and more comfortable seating solutions. Recent studies evaluating various chair designs—including those with adjustable lumbar support and armrests—have shown that such features can reduce muscular activity and fatigue.

Although ergonomic chair design has been extensively studied in office and educational contexts, limited research has focused on residential furniture specifically tailored for Malaysian users. Most existing studies rely on general anthropometric data or imported design standards that may not reflect local body dimensions. Furthermore, while EMG has been applied in seating studies [I, XIV], it remains uncommon in validating household furniture. This study addresses these gaps by integrating Malaysian anthropometric data, RULA-based posture analysis, structural simulation, and EMG validation to develop and assess an ergonomic chair optimized for residential use.

II. Literature Review

Ergonomic chair design has been widely studied in both office and educational environments, with a strong emphasis on reducing musculoskeletal strain and improving posture. Kumar and Khatavkar [XIII] and Shanmugam et al. [XVIII] noted that adjustable lumbar support, seat depth, and armrests are essential features that improve user comfort and reduce fatigue. To achieve optimal spinal alignment, the chair should support natural body postures, particularly the spine's S-shaped curve, to decrease strain on the lower back and neck. Watanabe [XXI] reported that an ideal recline angle between 110° and 130° promotes spinal alignment and reduces muscular activation. Proper weight distribution is also crucial to prevent circulation issues, pressure ulcers, and discomfort. Murata [XVI] demonstrated that a curved seat with a sloping front edge reduces thigh pressure and enhances leg blood flow, while footrests can ease strain on the feet and lower legs.

Anthropometric data plays a critical role in ensuring a proper fit between the user and the furniture. The Malaysian Anthropometric Database [XV] provides body measurements that serve as valuable design inputs to accommodate the majority of Malaysian users. Designing for the 5th to 95th percentiles ensures inclusivity across body types. Benden [IV] further emphasized that ergonomic furniture in the home environment promotes good posture, reduces stress, and enhances overall health and wellness.

Rapid Upper Limb Assessment (RULA) has been widely applied as an ergonomic evaluation tool in seating design. Dempsey et al. [VIII] identified its effectiveness and accessibility for posture assessment. The impact of RULA analysis on the design of dental professionals' chairs was examined in a 2019 study published in the Journal of Physical Therapy Science [XII]. According to the study, using RULA analysis as a design guide resulted in chairs that were more ergonomic and decreased the incidence of musculoskeletal disorders among dental professionals. Another study conducted in 2020, published in the International Journal of Industrial Ergonomics [XI], evaluated office chair ergonomics using RULA analysis to determine areas for improvement. The findings indicated that lumbar support and adjustability were two aspects of office chair design that improved as a result of RULA-based evaluation.

Electromyography (EMG) has also been adopted in ergonomic research to provide objective measures of muscle activity and fatigue. Studies by Troiano et al. [XIX] and Cifrek et al. [VI] highlighted EMG's role in detecting muscle contraction and potential sources of discomfort. More recently, Maruyama et al. [XIV] found that lumbar support reduced trapezius activation, while Aberdam et al. [I] combined EMG and subjective comfort ratings to validate chair designs. Despite these advances, EMG has primarily been applied in office settings, with limited focus on residential furniture.

In summary, previous research has established the importance of anthropometric compatibility, spinal alignment, RULA-based posture evaluation, and EMG validation in chair design. However, there remains a lack of studies applying these methods to Malaysian residential contexts. This gap underscores the need for research that integrates Malaysian-specific anthropometric data with both simulation and EMG testing to develop evidence-based ergonomic furniture solutions.

III. Methodology

This study employed a systematic approach combining anthropometric data, ergonomic assessment, computer-aided design (CAD), finite element simulation, and experimental validation. The methodology is summarized as follows:

III.i. Anthropometric Data Selection

A typical chair design requires anthropometric data. It is essential to select appropriate dimensions to design a product guided by ergonomic principles, making it easier for users to perform their tasks and minimizing the risk of injuries. With reference to the anthropometric data gathered from this research, the data were based on the Development of a Malaysian Anthropometric Database [XV]. Table 1 displays the anthropometric measurements specifically selected for this project.

Table 1: Selected Malaysian Anthropometric data

Chair Features	Anthropometric Data	Criteria Determinant
Seat Height	Popliteal Height	50th Percentile, Female
Seat Depth	Buttock-popliteal Length	50th Percentile, Female
Seat Width	Hip Breadth	95th Percentile, Female
Backrest Height	Shoulder Height, Sitting	5th Percentile, Female
Backrest Width	Shoulder Breadth	50th Percentile, Female

III.ii. Posture Analysis Using RULA

The Rapid Upper Limb Assessment (RULA) is an analytical method used to evaluate workstation ergonomics and identify potential musculoskeletal disorders. It can also be used to assist in designing chairs that provide sufficient support and reduce the risk of injury. When designing a chair, RULA analysis helps evaluate the user's posture and movement patterns and identify areas that may require improvement. These may include the seat height and angle, armrest and backrest positions, and neck and shoulder support levels.

The intended sitting position was analyzed and adjusted using CATIA P3 V5R20 [III], taking into account user movement and posture. The Ergonomics Design and Analysis module of the Manikin human digital model was used to initiate the process. The I.K. Behaviour panel applied the simulated RULA analysis data to optimize the sitting posture. Figure 1 illustrates the workflow for using CATIA P3 V5R20 software to perform RULA-based posture optimization.

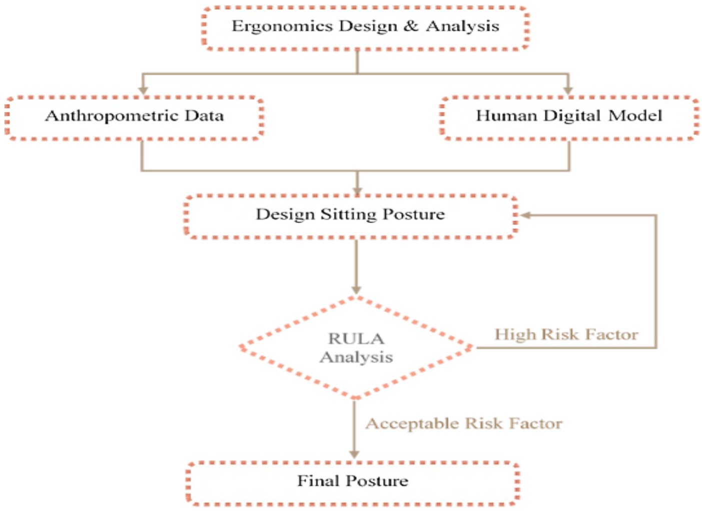


Fig. 1. RULA Analysis Methodology.

During the manikin's RULA Analysis, three body types—slim (5th percentile), normal (50th percentile), and obese (95th percentile)- are examined with the same position in order to determine the posture with the lowest risk factor. While assessing the posture and positioning of the upper limbs and trunk, the RULA analysis does take the person's size into account. This is significant because achieving an ergonomically sound posture may need different adaptations to people's workstations or seats depending on their body types. The manikins are set up in a natural sitting posture. Adjustments are made to the postures until a satisfactory total score of 2 is achieved, as shown in Figure 2.

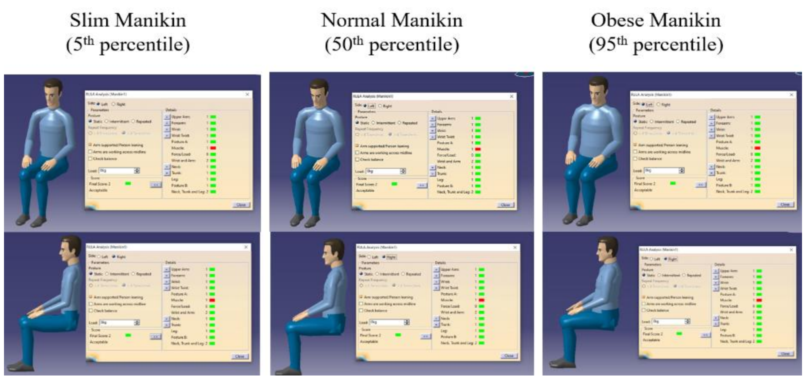


Fig. 2. RULA Analysis for Different Size Manikins.

III.iii. Design and Evaluation of Ergonomic Chairs

An ergonomic chair design was developed using a 3D CAD model, where each part was finalized and dimensioned in SolidWorks software based on anthropometric data and RULA analysis results. The model was analyzed in SolidWorks Simulation to evaluate displacements, strains, and stresses. A 1:1 scale prototype was then fabricated for electromyography (EMG) testing, which provides insights into muscle activation patterns during sitting. The lumbar erector spinae muscles show lower activation when seated on a chair that supports the lower back, helping prevent pain and improve posture.

The Trigno™ Wireless EMG System assessed comfort levels by measuring paraspinal muscle activation patterns during sitting to evaluate the chair's support performance. The posture derived from RULA analysis, rated level 2, was adopted since a low-risk posture minimizes discomfort.

20 participants were involved in EMG testing. Demographic data—age, gender, height, weight, and body mass index (BMI)—were collected for analysis. EMG sensors were placed bilaterally on the trapezius lower fibers, latissimus dorsi, and thoracolumbar fascia to capture muscle signals along the spine. Sensor placement locations are shown in Figure 3.

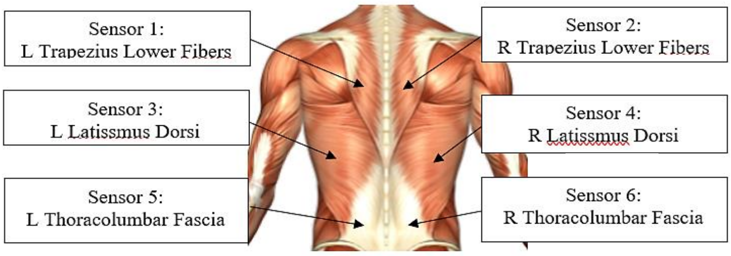


Fig. 3. The EMG Sensors Placement on Paraspinal Muscles.

The EMG sensors will collect the EMG signals through EMGworks Acquisition software. The task time is set to be 3 minutes. During the collection of the EMG data, the participant is required to sit on the ergonomic chair by using a natural sitting posture as referred on the RULA analysis, where: the head and ankles should be straight, shoulders and hips are level, knee caps face the front, and the chin should be parallel to the floor and aligned with the ears as shown in Figure 4, and The process flow on conducting the testing is shown in Figure 5.

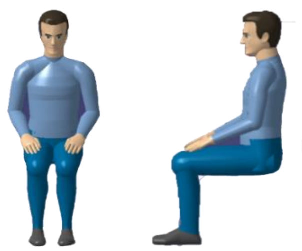


Fig. 4. Proper Sitting Posture from RULA Analysis.

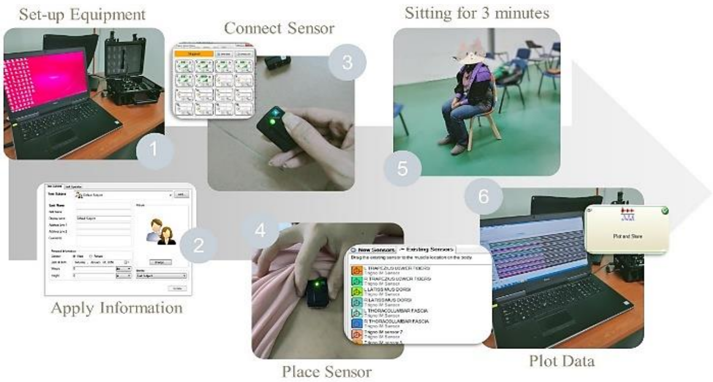


Fig. 5. EMGworks Acquisition Process Flow.

The obtained data were exported and analyzed using EMGworks Analysis software. The raw EMG signals were processed with an RMS calculation script to evaluate muscle contraction and fatigue. The resulting RMS values were then exported and plotted as graphs for analysis.

IV. Results and Discussions

Anthropometric-Based Design Dimensions

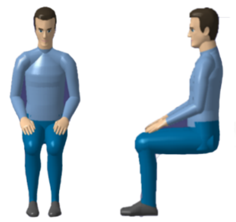
An appropriate set of anthropometric measurements in furniture gives advantages to user accessibility. The list of actual dimensions for home furniture based on the reference to the research: Development of a Malaysian Anthropometric Database [XV] is organized in Table 2. However, designing an ergonomic chair based on these values ensures inclusivity, providing comfort and usability across a wide range of Malaysian users.

Table 2: List of Anthropometric Dimensions for Home Furniture (mm)

Chair Features	Anthropometric Data	Actual Dimension
Seat Height	Popliteal Height	380
Seat Depth	Buttock-popliteal Length	430
Seat Width	Hip Breadth	460
Backrest Height	Shoulder Height, Sitting	420
Backrest Width	Shoulder Breadth	400

IV.i. Posture Evaluation with RULA

RULA analysis was conducted with three different body sizes—slim, normal, and obese manikins—to evaluate the low-risk sitting posture. In a proper sitting position, the manikins were adjusted to identical postures until an overall RULA score of 2 was achieved. The results are presented in Figure 6. The accepted posture was then used to guide the chair's body design, ensuring it could accommodate a wide range of users while maintaining a low-risk sitting posture.



Body Size	Risk Factor
Slim (5^{th} Percentile)	2
Normal (50^{th} Percentile)	2
Fat (95^{th} Percentile)	2

Fig. 6. Sitting Posture with Acceptable Risk Factor.

Using the accepted posture as the basis for the chair design ensured that the chair provides adequate body support during sitting. This support helps prevent discomfort or injury resulting from poor sitting posture.

IV.ii. Structural and Ergonomic Validation

The 3D model of the ergonomic chair was developed and analyzed using SolidWorks Simulation to evaluate its structural integrity, load-bearing capacity, and durability under residential conditions. Static analysis simulated the most critical loading scenario, in which a user applies full body weight on the seat surface, allowing the assessment of stress distribution, strain response, and deformation based on standard furniture testing procedures [X].

Finite Element Analysis (FEA) was performed under linear static conditions with complete material characterization to ensure modeling accuracy and mechanical reliability. The chair frame was modeled using mild steel (AISI 1018), a common material in furniture manufacturing due to its balanced strength, ductility, and cost efficiency. The properties assigned were: Elastic Modulus (E) = 210 GPa, Poisson's Ratio (ν) = 0.29, Yield Strength = 370 MPa, and Density = 7850 kg/m^3. The seat panel, modeled in polypropylene (E = 1.7 GPa, ν = 0.35, Yield Strength = 30 MPa), represented a typical molded seating component. These parameters were verified using ASTM E8 and ISO 6892-1 data to ensure realistic material behavior.

A static load of 1470 N (equivalent to a 150 kg user) was uniformly distributed over the seat surface, while all four leg-bottom nodes were fixed to simulate floor contact. Seat–frame and backrest–frame interfaces were defined as bonded to emulate welded joints. Mesh convergence testing using tetrahedral elements (12–4 mm) showed that stress and deformation stabilized within 2% beyond a 6 mm mesh size, confirming mesh independence. Sensitivity analysis indicated less than 5% displacement variation between fixed and frictional supports, verifying model robustness.

The maximum von Mises stress observed was 195 MPa, well below the steel yield limit, resulting in a factor of safety (FoS) of 1.89. Local stress concentrations were found near the seat–leg junctions but remained within EN 1335-3:2020 allowable limits. Experimental strain validation using three strain gauges under incremental loading up to 150 kg showed close agreement with simulation results (ε_measured = 0.0011; ε_simulated = 0.00105), with less than 5% deviation. Figure 7 illustrates the stress and deformation contours, confirming that the chair can safely withstand user loads without yielding or fracturing. Overall, the FEA verified sufficient strength, stiffness, and safety for long-term residential use.

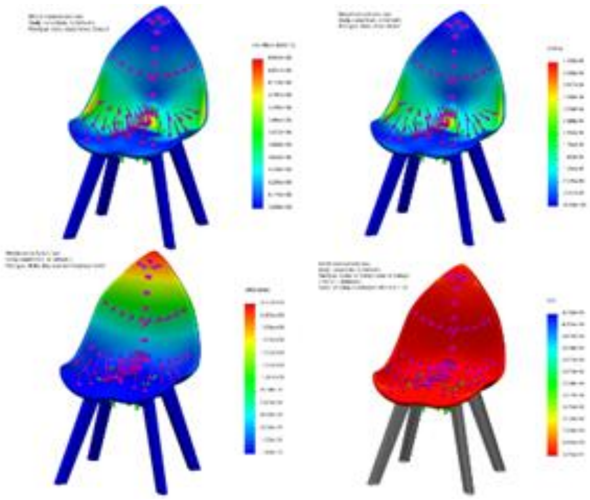


Fig. 7. Sitting Posture with Acceptable Risk Factor.

The analysis of stress, strain, displacement, and the factor of safety provided essential insight into the ergonomic chair's ability to withstand normal residential loads. The results indicate that the chair possesses sufficient structural integrity and is mechanically safe for prolonged use.

Performance evaluation was conducted using electromyography (EMG) on a 1:1 scale prototype. EMGworks Analysis software recorded and processed the signals, which were further analyzed in Microsoft Excel. To monitor muscle activity, sensors were placed bilaterally on the trapezius lower fibers, latissimus dorsi, and thoracolumbar fascia. The Root Mean Square (RMS) method quantified muscle contraction over a three-minute period.

Data were analyzed to assess how user characteristics—height, weight, and Body Mass Index (BMI)—influenced muscular activity. The RMS results, displayed in Figures 8–10, demonstrated consistently low muscle activation across all categories, confirming reduced fatigue and enhanced postural comfort. Slightly higher RMS values observed in heavier or taller participants were attributed to greater muscle mass rather than design inefficiency. Overall, EMG analysis verified that the ergonomic chair design provides effective support, minimizes muscle strain, and delivers comfort for a wide range of users.

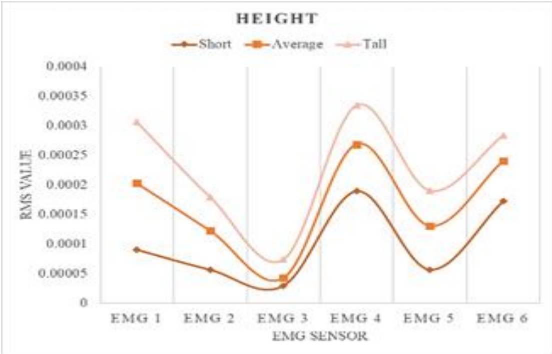


Fig. 8. Graph of RMS Value Categorized in Height.

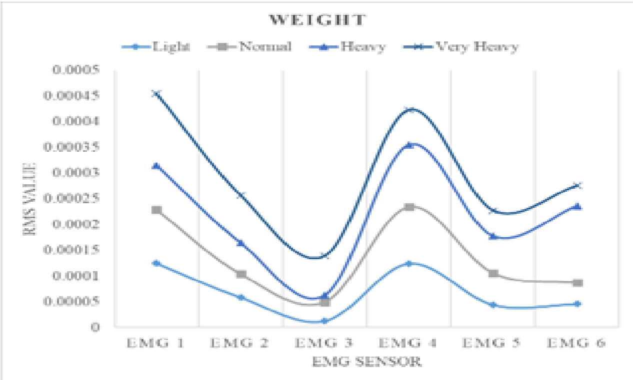


Fig. 9. Graph of RMS Value Categorized in Weight.

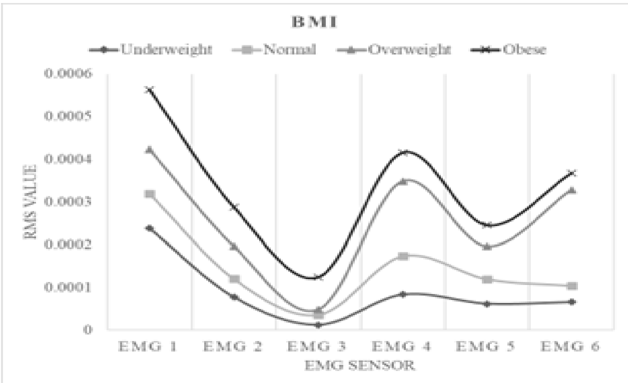


Fig. 10. Graph of RMS Value Categorized in BMI.

Based on the graph patterns, the EMG 1 and EMG 4 sensors recorded the highest RMS values. Postural stabilization occurred in the trapezius lower fibers (EMG 1), which required slightly higher muscle activity. The latissimus dorsi (EMG 4) also showed increased activity, as it is the widest muscle in the upper body.

For height, the graph patterns were similar across all categories, with taller participants showing higher RMS values. For weight and BMI, participants with heavy and very heavy weights, or those classified as overweight and obese, exhibited greater RMS fluctuations. This finding indicates that the RMS value is influenced by a person's height, weight, and body size.

The ergonomic chair may induce slightly higher muscle activity in taller or heavier individuals due to their larger muscle volume. However, this does not affect overall comfort, as the obtained RMS values were very low—ranging from 10^{-4} to 10^{-6} V—indicating minimal muscle fatigue and excellent comfort performance.

IV.iii. Relationship Between Anthropometric Design Parameters and EMG Validation Outcomes

Anthropometric data in this study served as the design foundation rather than as a variable in physiological modeling. Chair dimensions for seat height, depth, width, and backrest were derived from the Malaysian Anthropometric Database to accommodate users between the 5th and 95th percentiles. Electromyography (EMG) testing was conducted to validate that this anthropometrically optimized design minimizes muscle activation and enhances sitting comfort.

Since anthropometric inclusivity was established during the design stage, EMG functioned as a validation tool rather than a predictive model. Participants representing the 5th, 50th, and 95th percentiles exhibited consistently low Root Mean Square (RMS) values (10^{-4}–10^{-6} V), indicating minimal muscular strain. Slightly higher readings among taller and heavier users reflected natural differences in muscle volume rather than design inadequacy. All results remained within the ISO 9241-5 comfort threshold (<10% MVC), confirming biomechanical adequacy across a diverse user group.

The ergonomic chair demonstrated an effective balance between structural integrity and comfort. Finite Element Analysis (FEA) confirmed load resistance up to 150 kg, while EMG validation verified low physiological strain consistent with EN 1335 and BIFMA standards. Minor dimensional adjustments were made to represent Malaysian body proportions. Overall, the design achieves international ergonomic equivalence while maintaining local anthropometric relevance

V. Conclusions

This study developed and validated an ergonomic chair specifically designed for Malaysian residential users through the integration of anthropometric data, ergonomic analysis, structural simulation, and electromyography (EMG) testing. By incorporating the Malaysian Anthropometric Database, the chair dimensions were tailored to accommodate users between the 5th and 95th percentiles. Rapid Upper Limb Assessment (RULA) confirmed a low-risk posture across slim, average, and obese body types, while Finite Element Analysis (FEA) verified structural safety under load up to 150 kg. EMG evaluation with 20 participants demonstrated low muscle activation, indicating that the chair effectively reduces fatigue and enhances sitting comfort.

The novelty of this work lies in combining Malaysian-specific anthropometry with biomechanical validation methods, bridging the gap between theoretical design and experimental verification. Unlike previous studies that rely primarily on imported design standards or subjective comfort assessments, this research provides evidence-based insights into residential chair ergonomics for the local population. Furthermore, comparative assessments against ISO 9241-5, EN 1335, and BIFMA X5.1 standards demonstrated that the Malaysian anthropometry-based chair design conforms to international ergonomic and safety tolerances. Minor dimensional deviations were justified based on localized body measurements, confirming that the chair maintains global ergonomic quality while optimizing comfort for Malaysian users.

Future studies should include a larger and more diverse participant pool, assess long-term sitting comfort in everyday home use, and explore adjustable features such as lumbar support and armrests. These efforts will further enhance the chair's adaptability and strengthen its contribution to improving musculoskeletal health in residential environments.

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Conflict of Interest:

There was no relevant conflict of interest regarding this paper.

References

I. Aberdam, A., B. Pierrat, and F. Lavaste. "Evaluation of the Comfort of a Novel Chair Design Using Electromyography and Subjective Feedback." *Applied Ergonomics*, vol. 82, 2020, pp. 102951, 10.1016/j.apergo.2019.102951.

II. Ansari, S., et al. "Design and Development of an Ergonomic Chair for Students in Educational Settings." *Health Scope*, vol. 7, no. 4, 2018, pp. e60531. 10.5812/jhealthscope.60531.

III. Atef, B. "Ergonomics Study and Analysis of Workstations in Tunisian Mechanical Manufacturing." *Human Factors and Ergonomics in Manufacturing & Service Industries*, vol. 28, 2018, pp. 166-85. 10.1002/hfm.20713.

IV. Benden, M. R. "Ergonomic Design of the Home Environment." *Journal of Occupational and Environmental Medicine*, vol. 60, no. 3, 2018, pp. 150-55. 10.1097/JOM.0000000000001227.

V. Bi, Z. M. "Computer Implementation." *Finite Element Analysis Applications: A Practical Guide to the FEM Project of Production Engineering Domains*, edited by Z. M. Bi and Donald W. Mueller, Springer, 2018, pp. 227–80.

VI. Cifrek, M., et al. "Surface EMG Based Muscle Fatigue Evaluation in Biomechanics." *Clinical Biomechanics*, vol. 24, no. 4, 2009, pp. 327–40. 10.1016/j.clinbiomech.2009.01.009.

VII. Delvaux, F., J. F. Kaux, and J. L. Croisier. "Lower Limb Muscle Injuries: Risk Factors and Preventive Strategies." *Science & Sports*, vol. 32, no. 4, 2017, pp. 179–90. 10.1016/j.scispo.2017.02.003.

VIII. Dempsey, P. G., R. W. McGorry, and W. S. Maynard. "A Survey of Tools and Methods Used by Certified Professional Ergonomists." *Applied Ergonomics*, vol. 36, 2005, pp. 489–503. 10.1016/j.apergo.2005.01.007.

IX. Ghazali, M. F., et al. "RULA and REBA Assessments in Computer Laboratories." *National Symposium on Advancements in Ergonomics and Safety (ERGOSYM2009)*, Universiti Malaysia Perlis, 2009, pp. 3-13.

X. Intertek. "The Definitive Guide to North American Furniture Testing." *Intertek Testing Services, NA, Inc.*, 2020. *Intertek*. https://www.intertek.com/furniture/.

XI. Khairuzzaman, M., and S. M. Aljunid. "An Ergonomic Evaluation of Office Chairs Using the Rapid Upper Limb Assessment (RULA) Tool." *International Journal of Industrial Ergonomics*, vol. 79, 2020, pp. 103020. 10.1016/j.ergon.2020.103020.

XII. Kim, D. H., et al. "Effect of Rapid Upper Limb Assessment (RULA) Analysis on the Design of Dental Practitioner Chairs." *Journal of Physical Therapy Science*, vol. 31, no. 4, 2019, pp. 292-95. 10.1589/jpts.31.292.

XIII. Kumar, S., and A. Khatavkar. "Ergonomic design of office chair: A review." *Journal of Ergonomics*, vol. 9, no. 1, 2019, pp. 1-8.

XIV. Maruyama, T., N. Kajii, and M. Gotoh. "Electromyographic Evaluation of the Effect of Lumbar Support Shape and Armrest Height on Upper Body Muscle Activity and Perceived Comfort during Office Work." *Industrial Health*, vol. 57, no. 3, 2019, pp. 300-10. 10.2486/indhealth.2018-0055.

XV. Mohamad, D., et al. "Development of a Malaysian Anthropometric Database." *World Engineering Congress 2010: Proceedings of the Conference on Manufacturing Technology and Management*, Sarawak, Malaysia, 2010, pp. 4-5.

XVI. Murata, S. "Effect of Seat Shape with a Sloping Front Edge on Leg Blood Flow and Discomfort during Low-Intensity Tasks." *Journal of Occupational Health*, vol. 61, no. 4, 2019, pp. 345-52. 10.1539/joh.18-0249-OA.

XVII. Pascual, S.A., and S. Naqvi. "An Investigation of Ergonomics Analysis Tools Used in Industry in the Identification of Work-Related Musculoskeletal Disorders." *International Journal of Occupational Safety and Ergonomics; JOSE*, vol. 14, no. 2, 2008, pp. 237-45. 10.1080/10803548.2008.11076774.

XVIII. Shanmugam, M., et al. "Ergonomics design of office chair: A review." *IOP Conference Series: Materials Science and Engineering*, vol. 1122, no. 1, 2021, pp. 012073.

XIX. Troiano, A., et al. "Assessment of Force and Fatigue in Isometric Contractions of the Upper Trapezius Muscle by Surface EMG Signal and Perceived Exertion Scale." *Gait & Posture*, vol. 28, no. 2, 2008, pp. 179–86. 10.1016/j.gaitpost.2007.08.002.

XX. Wang, L. J., et al. "A Comparative Study of EMG Indices in Muscle Fatigue Evaluation Based on Grey Relational Analysis during All-Out Cycling Exercise." *BioMed Research International*, 2018, pp. 1-8. 10.1155/2018/9341215.

XXI. Watanabe, M. "Optimal Reclining Angle of the Backrest of Office Chairs Based on Comfort and Muscle Activity." *Journal of Physical Therapy Science*, vol. 32, no. 2, 2020, pp. 136-41. 10.1589/jpts.32.136.