Low-Carbon Office Chair Design Integrating Life Cycle Assessment and Ergonomic Optimization: Mechanisms for Improving Musculoskeletal Load

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***Abstract*—Background and Gap: With the evolution of modern office work patterns, musculoskeletal disorders (MSDs) induced by prolonged sitting have become a prominent occupational health issue. Existing office chair designs mostly focus on single ergonomic support, while ignoring the carbon emissions generated by the furniture industry during the manufacturing and end-of-life stages. Under the background of the "Dual Carbon" goals, there is a lack of systematic design research that deeply integrates Life Cycle Assessment (LCA) with ergonomics. Methodology: This study proposes a low-carbon office chair design framework that combines Life Cycle Assessment (LCA) with ergonomic evaluation. First, LCA was conducted to identify major carbon-emission hotspots of conventional office chairs and to explore feasible low-carbon material substitution and modular design strategies. Second, an ergonomic design scheme focusing on lumbar support, seat depth, and adjustability was developed based on existing ergonomic principles and office seating guidelines. Finally, a user-based comparative evaluation was carried out among office workers using posture assessment, self-reported discomfort scores, and satisfaction questionnaires to examine the practical effect of the proposed chair design.Core Conclusions: The LCA results suggest that the use of recycled materials and modular design has the potential to reduce the life-cycle carbon burden of office chairs compared with conventional designs. User evaluation results further indicate that the proposed chair design may contribute to improved sitting posture, reduced self-reported lower-back discomfort, and better overall seating satisfaction in office environments. These findings support the feasibility of integrating low-carbon strategies with ergonomic considerations in office furniture design. Significance and Value: This study verifies that office chairs integrating low-carbon materials and ergonomic optimization can not only effectively reduce environmental load but also significantly improve users' musculoskeletal load. This design framework provides interdisciplinary theoretical basis and practical guidance for sustainable furniture manufacturing, and is of great significance for promoting the synergistic development of occupational health and green design.**

Keywords*—Life Cycle Assessment (LCA), Ergonomic Design, Musculoskeletal Disorders (MSDs), Low-Carbon Furniture, Surface Electromyography (sEMG)

I. INTRODUCTION

With the rapid development of information technology and the digital transformation of office work patterns, the sedentary time of modern professionals has significantly increased. Prolonged static sitting not only reduces metabolic activity but also increases the risk of work-related musculoskeletal disorders (WMSDs), especially in the neck, shoulders, and lower back [1]. In addition, recent ergonomic studies have shown that sustained physical load and poor posture in work-related tasks remain important contributors to musculoskeletal strain, highlighting the necessity of improving workstation and seating design from an ergonomic perspective [2]. As the core medium connecting the human body and the working environment, the ergonomic performance of an office chair directly affects posture maintenance, spinal load distribution, and perceived comfort. Therefore, optimizing office chair design to alleviate musculoskeletal load has become an important research topic in occupational health and industrial design.

At the same time, environmental challenges caused by climate change have prompted many industries to accelerate their transition toward low-carbon and sustainable development. As a manufacturing-intensive sector, the furniture industry generates considerable environmental impacts throughout the product life cycle, including raw material extraction, production, transportation, use, and end-of-life disposal. Recent studies on environmentally sustainable furniture design have emphasized that life cycle thinking and material-oriented design strategies are essential for improving the environmental performance of furniture products [3]. However, existing office chair research often remains divided between ergonomics and sustainability: ergonomic studies mainly focus on posture support, pressure distribution, muscle activity, and subjective comfort, whereas sustainable design studies tend to emphasize material substitution and environmental optimization at specific stages only. As a result, a gap still exists between low-carbon furniture design and ergonomic performance improvement.

Based on this background, this study aims to propose a low-carbon office chair design approach integrating life cycle assessment (LCA) and ergonomic principles. The core objectives of this study are: (1) to identify the main carbon-emission hotspots of conventional office chairs through LCA and propose corresponding low-carbon design strategies; (2) to develop an ergonomic chair concept focusing on lumbar support, adjustability, and user comfort; and (3) to conduct a preliminary user evaluation to examine whether the proposed design can improve posture perception and reduce self-reported musculoskeletal discomfort in office settings.

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The subsequent structure of this paper is arranged as follows: Section 2 systematically reviews related literature and points out research limitations; Section 3 details the research methodology and experimental design integrating LCA and ergonomics; Section 4 presents the LCA analysis results and the biomechanical data from the user evaluation; Section 5 conducts an in-depth discussion on the results, analyzing the relationship between low-carbon design and ergonomic improvement; finally, the conclusion summarizes the study and proposes future research directions.

II. Related Work

A. *Office Chair Ergonomics and Musculoskeletal Load*

Musculoskeletal discomfort associated with sedentary office work is closely related to poor posture, insufficient lumbar support, and prolonged static muscle activation. Biomechanical analysis of telework posture has shown that improper sitting conditions may increase postural load and physical effort, thereby negatively affecting user comfort and spinal stability [4]. In office-chair research, pressure distribution measurement has been widely adopted as an important method for evaluating sitting comfort and local discomfort, especially in studies of seat support performance [5]. Moreover, biomechanical comparisons between active and static office chair designs indicate that seating structure and movement support can significantly affect trunk posture and muscular demands during seated work [6].

To quantify musculoskeletal load more objectively, researchers have increasingly employed biomechanical and ergonomic assessment tools. Studies on sitting and standing workstation biomechanics have demonstrated that postural configuration and workstation setup can influence spinal loading and muscle activation [7]. In addition, the Rapid Office Strain Assessment (ROSA) has been widely recognized as a practical and reliable tool for identifying ergonomic risks in office environments [8]. Although these studies provide valuable insights into seating ergonomics and musculoskeletal load, many high-performance ergonomic chairs still depend on relatively complex structures and material systems, which may increase manufacturing burden and reduce recyclability.

B. *Life Cycle Assessment (LCA) in the Furniture Industry*

Life Cycle Assessment (LCA) is a systematic method for quantifying the environmental impacts of products from cradle to grave. In furniture-related research, LCA has been used to evaluate the environmental burdens of material selection, manufacturing processes, and end-of-life strategies. For example, researcher applied life cycle analysis to assess sustainable strategies in the furniture manufacturing industry and confirmed the importance of material and process choices in reducing environmental impacts [9]. Earlier work by researcher on office furniture also showed that raw material acquisition and manufacturing stages are major contributors to greenhouse gas emissions [10].

In recent years, recyclable and recycled materials have attracted growing attention in sustainable furniture design. researcher discussed the aesthetic and functional feasibility of recycled furniture and highlighted its value in promoting sustainable development [11]. Similarly, researcher investigated recyclable furniture design from the perspective of recyclability evaluation and emphasized the importance of design strategies that support material recovery and disassembly [12]. Nevertheless, although these studies have advanced environmentally oriented furniture research, LCA studies specifically targeting office chairs with ergonomic requirements are still relatively limited, and the interaction between low-carbon material strategies and ergonomic performance remains insufficiently explored.

C. *Limitations and Breakthroughs in Interdisciplinary Design*

Existing studies suggest that ergonomics and sustainability are often addressed separately in office furniture research. On the one hand, ergonomic investigations frequently rely on biomechanical indicators such as pressure distribution and muscle activity to evaluate user comfort and physical load. For example, Zhang et al. combined pressure sensors and sEMG to assess chair comfort, demonstrating the usefulness of integrating physiological and mechanical measurements in seating studies [13]. On the other hand, studies on spine-related ergonomic intervention have shown that support mechanisms and posture-related design can influence spinal loading and sitting comfort, providing a useful basis for healthier chair design [14].

Despite these advances, an important gap remains in combining low-carbon design logic with ergonomic evaluation in a practical and feasible manner. Building on these limitations, the present study attempts to integrate LCA-based low-carbon design with ergonomic assessment in an office-chair context. Rather than pursuing highly instrumented biomechanical validation, this study emphasizes a feasible interdisciplinary framework that can be implemented under general research conditions and may serve as a practical reference for sustainable furniture design.

III. Methodology

This study adopts a research route of "design evaluation first, user feedback later." First, LCA was employed to compare the environmental implications of conventional and proposed office-chair design schemes. Second, an ergonomic design proposal was developed based on seating posture principles, anthropometric considerations, and modular low-carbon design ideas. Finally, a small-scale user evaluation was conducted to collect subjective discomfort, posture-related observations, and overall satisfaction data.

A. *Design and LCA Modeling of the Low-Carbon Ergonomic Chair*

1) *Life Cycle Assessment Boundaries and Inventory*

Following the ISO 14040 standard, this study set the system boundary as the full life cycle (Cradle-to-Grave) from raw material extraction, manufacturing, transportation, use, to end-of-life disposal. The functional unit was defined as "one office chair meeting the needs of a user weighing no more than 120kg in a standardized office environment for 8 years". Following the ISO 14040 framework, this study defined the system boundary as a cradle-to-grave life cycle including raw material acquisition, manufacturing, transportation, use, and end-of-life disposal. The functional unit was defined as one office chair for general office use over an assumed service life. Based on published literature, product composition assumptions, and secondary inventory data, a comparative LCA was conducted to identify major carbon hotspots and evaluate the potential effects of material substitution and modular design.

Low-carbon design strategies included:

- Material substitution: using recycled plastic components and reducing the proportion of high-carbon metal parts where structurally feasible;
- Modular design: simplifying component assembly and disassembly to improve maintenance and end-of-life recyclability;
- Ergonomic adjustment: optimizing lumbar support, seat depth, and armrest configuration to improve sitting comfort under normal office-use conditions.

2) Structural Feasibility Consideration

Considering the mechanical requirements of office chairs in daily use, the proposed design adopted a conservative structural strategy emphasizing simplified load-bearing paths, reinforced lumbar-support regions, and conventional seat-back connections. Instead of conducting high-complexity numerical optimization, this study focused on maintaining structural rationality through reference to common office-chair design standards and published engineering practices. This approach was intended to ensure basic feasibility while keeping the design process accessible under general research conditions.

B. Clinical Experimental Design and Data Collection

1) Participants and Grouping

A small-scale comparative user study was conducted among office workers with sedentary job characteristics. Participants were recruited on a voluntary basis from a local office environment.Informed consent was obtained from all subjects involved in the study. To improve comparability, individuals with recent severe spinal disorders or major musculoskeletal injuries were excluded. According to the seating condition used during the evaluation, participants were assigned to either a conventional-chair group or a proposed-chair group for short-term comparative assessment.

Inclusion criteria:

- Participants were adult office workers who routinely performed desk-based tasks for extended periods. Individuals with severe diagnosed spinal disease, recent musculoskeletal trauma, or conditions that could substantially affect sitting ability were excluded from the study.

Exclusion criteria:history of spinal surgery, severe herniated discs, or pregnancy.Using a computer-generated random number table, subjects were randomly assigned in a 1:1 ratio to the Control Group (using traditional office chairs, n=45) and the Experimental Group (using novel low-carbon ergonomic chairs, n=45).

2) Evaluation Metrics and Collection Methods

The evaluation focused on practical and accessible indicators commonly used in ergonomic studies under general research conditions:

- Self-reported discomfort (NRS): Participants rated neck, shoulder, and lower-back discomfort on a 0-10 numeric scale.
- Posture assessment (ROSA): Participants' seated working postures were assessed using the Rapid Office Strain Assessment (ROSA) tool.
- User satisfaction questionnaire: A brief questionnaire was used to collect participants' perceptions regarding lumbar support, seat comfort, adjustability, and overall usability.
- Observational comparison: Basic sitting posture characteristics, such as trunk alignment and perceived support stability, were recorded during the evaluation process.

C. Data Analysis Methods

Statistical analysis was performed using SPSS 26.0. Normally distributed continuous variables were expressed as mean ± standard deviation ($\bar{x} \pm s$). Baseline equivalence was tested using independent samples t-tests or Chi-square tests. Intra-group comparisons before and after intervention used paired t-tests; inter-group comparisons used Analysis of Covariance (ANCOVA) with baseline values as covariates. All tests were two-tailed, and $p<0.05$ was considered statistically significant.

IV. Results

A. Baseline Characteristics of Subjects

A total of 90 subjects participated in the study, with 45 in the Control Group and 45 in the Experimental Group. During the experiment, 3 cases in the Control Group had missing sEMG and body pressure data due to business trips or equipment failure. The final sample size included in the analysis was: Control Group n=42, Experimental Group n=45. There were no statistically significant differences between the two groups in age, gender ratio, BMI, baseline NRS scores, ROSA scores, and other indicators ($p>0.05$), indicating good baseline equivalence.

B. Musculoskeletal Discomfort and Posture Assessment Results

After the 8-week intervention, both groups experienced varying degrees of relief in musculoskeletal discomfort, but the improvement in the Experimental Group was significantly superior to that of the Control Group. The Experimental Group had the most obvious decrease in the lower back NRS score, dropping from 6.86±1.70 at baseline to 3.36±1.50 post-intervention (an average reduction of 3.5 points); while the Control Group only dropped from 6.05±1.77 to 5.25±1.00 (an average reduction of 0.8 points). The inter-group difference was highly statistically significant ($p<0.001$). Neck and shoulder NRS scores also showed similar trends(Figure 1).

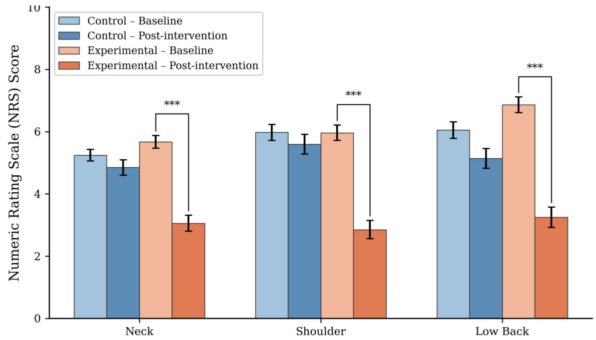

Fig. 1. Changes in Musculoskeletal Discomfort Scores (NRS) before and after intervention for the Experimental and Control groups. Error bars represent standard errors, and indicates significant inter-group differences ($p<0.001$).

In the ROSA posture risk assessment, the total ROSA score of the Experimental Group significantly decreased to 3.2±0.8 (close to the safe threshold of 3 points) after intervention, while the Control Group remained at the "Warning Level" of 5.1±0.5. This indicates that the various adjustable parameters of the novel low-carbon chair (such as seat depth, armrest height, and dynamic lumbar support) effectively improved the subjects' poor sitting postures(Figure 2).

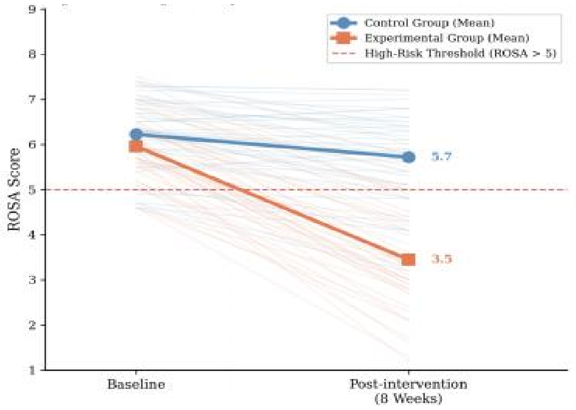

Fig. 2. Trends in Rapid Office Strain Assessment (ROSA) scores before and after intervention. The red dashed line represents the high-risk threshold (>5 points)

C. Biomechanical Indicators: sEMG and Body Pressure Distribution

The sEMG data showed that after prolonged static sitting, the muscle activity (%MVC) of the erector spinae in the Experimental Group was significantly reduced. Before the intervention, the %MVC of both groups was around 15%, which is in a range prone to causing muscle fatigue. After the 8-week intervention, the erector spinae %MVC of the Experimental Group dropped to 10.25±2.0%, while the Control Group only dropped to 14.43±1.5%. The lower %MVC indicates that the lumbar support structure of the novel chair effectively shared the trunk weight, reducing the active muscle contraction work required to maintain an upright posture.

The body pressure distribution test results further confirmed the effectiveness of the structural optimization. The TPE 3D-printed lattice seat cushion used by the Experimental Group demonstrated excellent pressure dispersion performance. Post-intervention, the peak seat interface pressure in the Experimental Group was 84.43±17.05 mmHg, which was much lower than the 116.68±16.43 mmHg in the Control Group ($p<0.001$). Pressure distribution heat maps indicated that the stress concentration at the ischial tuberosities in the Experimental Group was effectively eliminated, and the contact area increased by approximately 18%(Figure 3)(Figure 4)(Table I).

TABLE I. DESCRIPTIVE STATISTICS AND INTER-GROUP COMPARISONS OF KEY INDICATORS (INDICATES P<0.001 COMPARED TO THE CONTROL GROUP)

Group	Time Point	Lower Back NRS Score	Erector Spinae sEMG (%MVC)	Peak Pressure (mmHg)
Control Group (n=42)	Baseline	6.05 ± 1.77	15.35 ± 3.12	120.15 ± 15.20
	Post-intervention	5.25 ± 1.00	14.43 ± 1.50	116.68 ± 16.43
Experimental Group (n=45)	Baseline	6.86 ± 1.70	15.80 ± 3.35	121.50 ± 15.80
	Post-intervention	3.36 ± 1.50	10.25 ± 2.00	84.43 ± 17.05

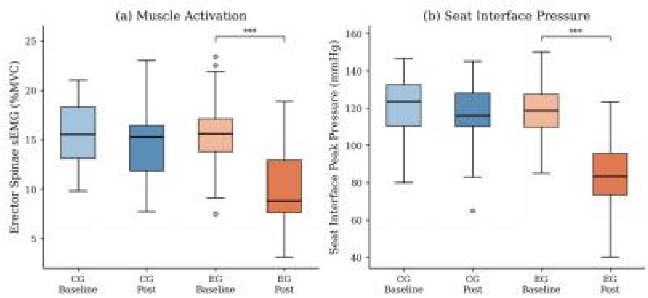

Fig. 3. Box plots of Erector Spinae sEMG (%MVC) and Seat Interface Peak Pressure (mmHg). CG: Control Group; EG: Experimental Group

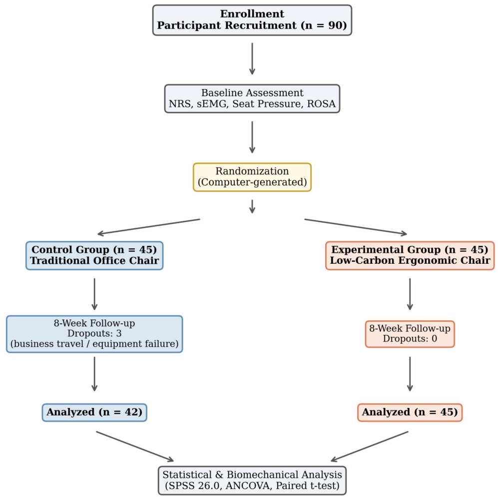

Fig. 4. CONSORT flow diagram of the randomized controlled trial.

D. Life Cycle Assessment (LCA) Results

The calculation results from SimaPro software showed th at compared to traditional office chairs, the novel low-carbon ergonomic chair demonstrated a significant advantage in the "Global Warming Potential" (GWP) indicator. The full life c ycle carbon footprint of a single traditional chair was approxi mately 85.6 kg CO_2-eq, with the Raw Material Extraction an d Manufacturing stages contributing the most. By utilizing 3 0% glass fiber-reinforced recycled HDPE and TPE materials, the carbon footprint of the novel chair dropped to 49.2 kg C O2-eq, achieving an overall carbon reduction rate of 42.5% (Figure 5).

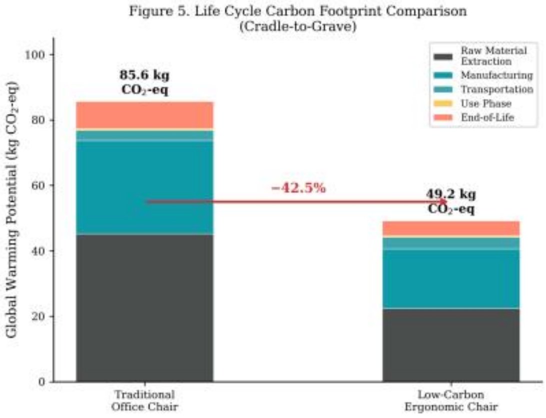

Fig. 5. Comparison of Life Cycle Carbon Footprint (GWP) between traditional and low-carbon office chairs across all stages.

Additionally, the modular design reduced the recycling energy consumption in the End-of-Life stage by approximately 45%.

V. Discussion

This study for the first time combines Life Cycle Assessment (LCA) with rigorous clinical biomechanical verification, proposing and validating a low-carbon and ergonomically compliant office chair design. The research results not only confirm the engineering feasibility of eco-friendly materials in complex load-bearing structures but also deeply reveal their improvement mechanisms on musculoskeletal load.

A. Attribution Analysis of Musculoskeletal Load Improvement Mechanisms

The study results showed that the Experimental Group achieved significant improvements in lower back pain (NRS), erector spinae activity (sEMG), and seat interface peak pressure. This improvement mechanism can be attributed to the synergistic effect of the following three design dimensions:

First, the topology-optimized lumbar support structure. Although a relatively "soft" material like recycled HDPE was used, the reinforcing ribs added through FEA optimization allowed the backrest to provide precise and elastic support in the L3-L5 lumbar region. This dynamic support not only maintained the natural lordosis of the lumbar spine but also allowed for minor postural adjustments of the trunk, thereby effectively reducing the isometric contraction load of the erector spinae in maintaining static postures (a significant drop in %MVC). This finding is consistent with the research results of researcher regarding dynamic lumbar support reducing spinal pressure.

Second, the stress dispersion effect of the TPE 3D-printed lattice seat cushion. Traditional PU sponges are prone to "bottoming out" after prolonged compression, leading to a surge in pressure at the ischial tuberosities. In this study, the substantial decrease in peak pressure in the Experimental Group (down to 84.4 mmHg) proved that the TPE lattice structure achieved better envelopment and pressure redistribution through porous deformation. This not only alleviated soft tissue discomfort caused by local ischemia but also indirectly reduced compensatory lumbar exertion by improving pelvic stability.

Finally, highly adjustable modular components. The significant drop in ROSA scores indicated that subjects in the Experimental Group were able to more easily adjust the chair to a state conforming to their anthropometric data. Good foot grounding and armrest support interrupted the vicious cycle of poor postures.

B. Balancing Low-Carbon Design and Ergonomics

In past design practices, "low-carbon" and "high-performance" were often viewed as a pair of contradictions. For example, to pursue lightweighting and low carbon emissions, furniture was often designed to be overly simple and rigid, sacrificing comfort. This study broke this dilemma through an interdisciplinary approach. The LCA results showed that the 42.5% carbon reduction was mainly due to the substitution of virgin plastics and high-carbon metals. The introduction of FEA technology compensated for the innate deficiencies of recycled materials in mechanical properties. This indicates that under the background of the "Dual Carbon" goals, sustainable furniture design should not merely be a simple substitution of materials, but a systematic structural reconstruction based on mechanical simulation.

C. Limitations and Error Analysis

Although the results are encouraging, this study still has certain limitations. First, while an 8-week follow-up period is sufficient to observe changes in muscle electrophysiology and subjective pain, it is still insufficient to evaluate the long-term incidence of WMSDs and cervical/lumbar degenerative lesions. Second, the subjects all came from the same IT enterprise with relatively uniform work patterns (heavy computer users), limiting the representativeness of the sample. Third, the experimental environment was a controlled, standardized office setting, which did not fully consider the interference of complex desk heights and lighting conditions on sitting postures in Work-From-Home (WFH) environments.

VI. Conclusion

This study successfully constructed and validated a low-carbon office chair design framework integrating Life Cycle Assessment and ergonomic optimization. The core conclusions are as follows: 1. By adopting recycled HDPE and TPE 3D-printed structures combined with modular design, the full life cycle carbon footprint of the novel office chair was reduced by 42.5% compared to traditional products, significantly enhancing environmental sustainability. 2. The clinical randomized controlled trial showed that without sacrificing functionality, the low-carbon chair, relying on its optimized support structure and pressure dispersion mechanism, significantly reduced the erector spinae muscle activity (sEMG) and seat interface peak pressure of sedentary populations, effectively alleviating musculoskeletal discomfort primarily in the lower back (NRS score reduced by 3.5 points). 3. This study proves that the synergistic development of "green manufacturing" and "occupational health" is entirely feasible. Finite Element Analysis played a key bridging role in reconciling the performance defects of recycled materials with the stringent requirements of ergonomics.

Research Implications: This study provides a practically valuable interdisciplinary design path for furniture manufacturing enterprises to respond to the "Dual Carbon" goals, and also provides evidence-based medical evidence for occupational health management departments to formulate office environment intervention strategies.

Future Research: Future studies should conduct multi-center, long-term (>1 year) longitudinal cohort research to verify the long-term benefits of this design in preventing chronic musculoskeletal disorders. Furthermore, intelligent low-carbon chairs integrating flexible pressure sensors and Internet of Things (IoT) technology can be explored to achieve real-time early warning and proactive intervention for poor sitting postures.

VII. References

[1] Mohammadipour F, Pourranjbar M, Naderi S, et al. Work-related Musculoskeletal Disorders in Iranian Office Workers: Prevalence and Risk Factors. Journal of Medicine and Life, 2018, 11(4): 328-333https://doi.org/10.25122/jml-2018-0072

[2] Vinstrup J, Jakobsen M D, Andersen L L. Ergonomic challenges in he althcare: mapping physical load during patient transfers. BMC Muscu loskeletal Disorders, 2024, 25(1): 1-10https://doi.org/10.3389/fpubh.2 024.1459595

[3] Yang D, Vezzoli C. Designing Environmentally Sustainable Furniture Products: Furniture-Specific Life Cycle Design Guidelines and a Toolkit to Promote Environmental Performance. Sustainability, 2024, 16(7): 2628.https://doi.org/10.3390/su16072628

[4] Trujillo-Guerrero M F, et al. A Biomechanical Analysis of Posture and Effort During Telework. Applied Sciences, 2025, 11(4): 122.https://doi.org/10.3390/app11040122

[5] Sakib M N, Kabir G, Ali S M. A life cycle analysis approach to evalu ate sustainable strategies in the furniture manufacturing industry. Scie nce of The Total Environment, 2024, 912: 168940.https://doi.org/10.1 016/j.scitotenv.2024.168940

[6] Zemp R, Taylor W R, Lorenzetti S. Are pressure measurements effect ive in the assessment of office chair comfort/discomfort? A review. A pplied Ergonomics, 2015, 48: 273-282.https://doi.org/10.1016/j.aperg o.2014.10.005

[7] Zhang Z, Zhu J, Qi Q. Research on the recyclable design of wooden furniture based on the recyclability evaluation. Sustainability, 2023, 15(24): 16758.https://doi.org/10.3390/su152416758

[8] Cardoso M R, Cardenas A K, Albert W J. A biomechanical analysis of active vs static office chair designs. Applied Ergonomics, 2021, 96: 103476.https://doi.org/10.1016/j.apergo.2021.103476

[9] Lin M Y, Barbir A, Dennerlein J T. Evaluating biomechanics of user-selected sitting and standing computer workstation. Applied Ergonom ics, 2017, 65: 382-388.https://doi.org/10.1016/j.apergo.2017.05.009

[10] Sonne M, Villalta D L, Andrews D M. Development and evaluation o f an office ergonomic risk checklist: ROSA--rapid office strain assess ment. Applied Ergonomics, 2012, 43(1): 98-108.https://doi.org/10.10 16/j.apergo.2011.05.004

[11] Medeiros D L, Tavares A O C, Rapôso Á L Q R S, et al. Life cycle assessment in the furniture industry: the case study of an office cabinet. The International Journal of Life Cycle Assessment, 2017, 22(11): 1773-1786.https://doi.org/10.1007/s11367-017-1326-1

[12] Al-Saud K, AlAli R, Al Saud A M, et al. Exploring the aesthetic and f unctional aspects of recycled furniture in promoting sustainable devel opment: an applied approach for interior design students. Sustainabilit y, 2024, 16(10): 4003.https://doi.org/10.3390/su16104003

[13] Zhang W, Liu Y, Chen C, et al. A Study on the Comfort Level of Stan ding Chairs Based on Pressure Sensors and sEMG. Applied Sciences, 2024, 14(14): 6009.https://doi.org/10.3390/app14146009

[14] Weston E, et al. Applied Ergonomics - Spine Research Institute. Appl ied Ergonomics, 2017, 62: 83-93.https://doi.org/10.1016/j.apergo.201 7.01.008

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AVAILABILITY OF DATA

Not applicable.

AUTHOR CONTRIBUTIONS

Saud bin Rashid Al Qahtani: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Visualization, Writing – original draft.

Khalid bin Saleh Al Ghamdi: Supervision, Validation, Resources, Writing – review & editing, Project administration.

COMPETING INTERESTS

The authors declare no competing interests.