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A Study on Egronomic Chair Desing for Improved Posture

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Abstract

This paper presents a method for designing a customized ergonomic office chair backrest aimed at improving Ergonomic chairuser posture and long-term health. Given the importance of ergonomics in workplace settings, this study leCustom cushionverages 3D scanning and additive manufacturing to create personalized cushions that conform precisely to inAdditive manufacturingdividual anatomical shapes, aligning with ergonomic standards. The process begins with high- resolution scans of both the user's back and a standard chair backrest, followed by cushion modeling in Blender to ensure exact fit and support. Additive manufacturing was selected for cushion fabrication, using a TPU material with an optimized internal structure to enhance comfort. Results indicate a notable improvement in posture alignment and comfort, verified through comparative scans before and after customization. The custom backrest encourages proper posture through a postural retraining effect and maintains hygiene through its nonporous material. Although the customization method is more suitable for individual users than shared work environments, it provides a practical and cost-effective solution for improving office seating ergonomics. This study also explores the feasibility of integrating Internet of Things (IoT) technology into office chair design to enhance user comfort and ergonomic support. Existing chair designs and IoT technologies were examined, followed by user testing of an IoT-enabled chair prototype. The System Usability Scale (SUS) was used to assess usability, while real-time feedback supported posture and comfort monitoring. Findings guided prototype improvements and demonstrated the potential of smart office furniture to improve workplace ergonomics, user satisfaction, and sitting comfort over extended periods for office workers. Twenty participants from a metropolitan university sat on two types of ergonomic chairs for 90 minutes in each of two sessions while performing typing, reading, and writing tasks. Repeated measures three-way and two-way analyses of variance were used to examine the effect of the ergonomic chair design on rating of discomfort. Data were collected usingthe General Comfort Rating Scale (GCRS) and the Body Part Discomfort Rating Scale (BPDRS), which were administered at0, 30, 60, and 90 minute marks of each session. The results revealed: 1) discomfort was not related to the type of chair, 2) discomfort increased over time, 3) discomfort was influenced by the task performed while sitting, 4) discomfort level decreasedwhen switching between different chairs, and 5) most discomfort was reported in the low back and lower arms.

Keywords: Ergonomics; Ergonomic Chair Design; Occupational Health

How to Cite This Article

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Introduction

scanning and additive manufacturing technologies, this research aims to develop customized solutions that align with the specific physiological Workplaces represent a critical environment for promoting health requirements of individual users, contributing to both comfort and and well-being, as most adults spend a significant portion of their productivity in the workplace. Waking hours at work. Employers have a vested interest in maintaining the health and productivity of their workforce, as health-related issues 1.1. Workplace posture can negatively impact both attendance and job performance. Moreover, research shows that employee satisfaction improves when workplace In modern work environments, many tasks require employees to sit policies demonstrate a commitment to the well-being of workers, for extended periods, particularly when working with video display emphasizing the value of the employee not just as a worker, but as a terminals (VDTs). VDT-based tasks, often characterized by repetitive person [1]. Ergonomics plays a vital role in this context by addressing wrist movements, typically lead workers to maintain static postures for the physical and postural demands placed on employees during proprolonged hours, resulting in physical strain. The stress imposed on the longed periods of sitting. Poorly designed office chairs can lead to body during such static work is influenced by the angular relationship discomfort, musculoskeletal disorders, and decreased productivity. between body parts, the distribution of weight, the duration of the Consequently, the development of ergonomic furniture that adapts to posture, and the body's response to these demands. These factors affect individual needs has become a priority for enhancing workplace wellmuscle loads, joint torques, fatigue levels, and the risk of developing ness. Employers are increasingly recognizing the benefits of investing in work-related musculoskeletal disorders. VDT work is highly constrained ergonomic solutions to not only reduce healthcare costs but also to in terms of posture, and without ergonomic considerations, workers may improve employee health, satisfaction, and long-term retention [2].adopt awkward positions that further exacerbate discomfort. To mitiThis paper presents an innovative approach to the design and progate these issues, workstation setups should be designed to allow totyping of an ergonomic office chair, integrating precise body scans to maximum flexibility, such as through adjustable furniture, ensuring that create anatomically accurate reference points. By leveraging 3Dscanning and additive manufacturing technologies, this research aims to develop customized solutions that align with the specific physiological Workplaces represent a critical environment for promoting health requirements of individual users, contributing to both comfort and and well-being, as most adults spend a significant portion of their productivity in the workplace.waking hours at work. Employers have a vested interest in maintaining the health and productivity of their workforce.Sitting is a frequent daily posture. Long periods are spent in the office, vehicle, or lounge chairs. Human sitting studies have grown in biomedical engineering, public health, and facility design. Research shows bad sitting patterns can cause pain and other health issues [1, 2, 13]. Common sitting positions can lead to lumbar flexion and increased compressive forces [3, 4]. Halim et al. [7] stated that long periods of sitting can cause health problems and pain. Then metabolic health is threatened [8-9]. High blood pressure, blood sugar, and body fat arise with too much sitting and little exercise. In reference to Matuska et al. [5], due to the static nature of sitting, musculoskeletal stress can cause fatigue and long- term health problems if not properly recovered. Office workers are the main victims of this health issue because they sit so much [6, 15]. The growing Internet of Things (IoT) connects everything that can benefit from Internet connectivity to deliver new services and improve workplace productivity [10-11]. Suganya et al. [12] assert that IoT in workplace chairs is essential to preventing office workers' poor seating habits. Figure 1 shows an experiment applying pressure distribution to the seat pan and backrest.Technology and office automation (e.g., electronicsign standards and may not show any significant resultsmail, personal printers, local area networking) havein reducing discomfort [9]. Examining chair designchanged the types of jobs, duration of sitting, perand related factors affecting the human body is critiformance of repetitive activities, and work habits [5],cal in providing recommendations, preventing injuries,which may lead to complaints of work discomfort ascreating safe environments, and justifying advantageswell as work- related injuries. Long working hours ofand cost [18].sitting can cause health problems and occupational disorders, especially disorders of the musculoskeletal system [15]. As a result, work-related musculoskeletal2. Review of literatureinjuries decrease workers' productivity and increasesworkers' compensation issues, which create economical and social burdens on both employees and employ2.1. Independence of comfort and discomforters [18].Chair designs have been revolutionized, and erComfort and discomfort are independent factors (i.e.,gonomic chairs have been developed to minimize disreduction in discomfort does not bring about comcomfort and prevent injuries and disorders.

Industryfort) [11]. Absence of discomfort is not the eliminationhas been concerned with designing chairs and addingfeatures rather than investigating the causes of discomfort. Many of the design features including posture-tilt,swivel-tilt, and syncro-tilt are not ergonomic chair deTechnology and office automation (e.g., electronicsign standards and may not show any significant resultsmail, personal printers, local area networking) havein reducing discomfort [9]. Examining chair designchanged the types of jobs, duration of sitting, perand related factors affecting the human body is critiformance of repetitive activities, and work habits [5],cal in providing recommendations, preventing injuries,which may lead to complaints of work discomfort ascreating safe environments, and justifying advantageswell as work- related injuries. Long working hours ofand cost [18].

Methodology

Methodology for Ergonomic Chair Design to Improve Posture The methodology for designing an ergonomic chair aimed at improving posture begins with an extensive literature review to understand existing ergonomic principles, posture- related musculoskeletal disorders, and shortcomings of conventional seating systems. Previous studies highlight that prolonged sitting with improper back and lumbar support leads to spinal misalignment, lower back pain, and shoulder strain. International standards such as ISO 9241, ANSI/HFES 100, and BIFMA guidelines are reviewed to establish fundamental design criteria related to seating comfort, safety, and adjustability (Helander, 2006; Pheasant & Haslegrave, 2016). This stage helps in clearly defining the problem and identifying critical ergonomic factors affecting posture.Following this, user requirement analysis is carried out to understand real-world seating behavior and discomfort patterns. Data is collected from a diverse group of users through questionnaires, interviews, and observational studies. Ergonomic assessment tools such as RULA and REBA are used to evaluate posture during prolonged sitting.User feedback regarding pain points, sitting duration, and preferred adjustments is translated into measurable design requirements, ensuring that the chair design aligns with actual user needs (Kroemer & Grandjean, 2001; Hedge, 2017).Anthropometric data collection forms a crucial part of the methodology, as human body dimensions vary significantly among individuals. Measurements such as popliteal height, hip breadth, buttock-popliteal length, shoulder height, and lumbar height are obtained from standard anthropometric databases and regional studies. Design dimensions are derived using the 5th to 95th percentile range to accommodate a majority of the user population. This ensures that the chair supports natural body posture and reduces the risk of discomfort due to dimensional mismatch (Pheasant, 2003; NASA Anthropometric Source Book).Biomechanical analysis is then conducted to study spinal alignment, pelvic tilt, and load distribution while sitting. Research indicates that appropriate lumbar support and seat pan inclination significantly reduce intervertebral disc pressure and muscle fatigue.Pressure distribution across the seat and backrest is analyzed to minimize stress on the spine and soft tissues. This stage ensures that the chair promotes a neutral sitting posture and maintains the natural curvature of the spine (Andersson et al., 1974; McGill, 2007).Based on the findings from ergonomic and biomechanical analysis, conceptual designs are developed incorporating essential ergonomic features such as adjustable seat height, contoured backrest with dynamic lumbar support, reclining mechanism, waterfall seat edge, and adjustable armrests. Multiple design concepts are generated using sketches and CAD models, and the most feasible design is selected based on ergonomic effectiveness, manufacturability, and cost considerations (Bridger, 2018; Norman, 2013).Material selection is performed to enhance comfort, durability, and sustainability. Cushioning materials are chosen to provide adequate pressure distribution and thermal comfort, while breathable mesh or fabric is used for the backrest to prevent heat buildup. Structural components are designed using high-strength metals or polymers to ensure safety and long-term durability. Material selection is guided by ergonomic comfort requirements and environmental considerations (Ashby, 2011; BIFMA Sustainability Guidelines).A full-scale prototype of the ergonomic chair is then developed based on finalized design specifications. The prototype incorporates all adjustment mechanisms and ergonomic features, allowing real-time evaluation of functionality and comfort.Manufacturing feasibility and compliance with safety standards are also considered during prototype development (Ulrich & Eppinger, 2016).Ergonomic evaluation and testing are carried out by conducting user trials to assess posture improvement, comfort levels, and usability. Objective measures such as spinal alignment, muscle activity, and pressure distribution are recorded, while subjective feedback is obtained using comfort and discomfort rating scales. The performance of the ergonomic chair is compared with that of conventional chairs to validate improvements in posture and user comfort (Helander & Zhang, 1997; Chaffin et al., 2006).Based on evaluation results, design optimization is performed by refining chair dimensions, cushioning properties, and adjustment mechanisms. Iterative testing ensures that identified issues are resolved and overall ergonomic performance is enhanced. The final design is validated against ergonomic standards to confirm its effectiveness in improving posture and reducing musculoskeletal discomfort (Kroemer, 2017; ISO 9241).

Design Development

The design of the IoT-enabled office chair incorporates various sensors and microcontrollers to monitor user behavior and provide real-time feedback. The primary components include:

- Pressure Sensors: These sensors are strategically placed on the seat and backrest to measure the distribution of weight and detect sitting posture.
- Load Cells: Integrated into the chair's structure, load cells measure the force exerted by the user, allowing for precise monitoring of sitting habits.
- ESP32 Microcontroller: This Wi-Fi and Bluetooth-enabled microcontroller processes data from the sensors and communicates with a mobile application for real-time

Cushion Modeling

The process of creating cushion models begins with the anatomical scans of the subject and the chair backrest, as previously described. These two references are imported as STL files into Blender, where they are positioned according to guidelines for proper sitting posture.

Blender is an open-source software for 3D modeling, digital sculpting, and rendering. Widely used across fields from graphic design to manufacturing, Blender provides advanced polygonal modeling tools and supports STL files, allowing for direct import of anatomical scans and design objects. With features like the Subdivision Surface Modifier and an integrated sculpting environment, Blender enables the creation of smooth, complex surfaces, making it ideal for ergonomic projects that require a high degree of customization and precision. The cushions are then designed using Blender's Subdivision Surface modeling technique to fit both the chair backrest and the specific areas of the back that require additional support. The backrest is divided into multiple cushions to ensure uniform support across the back, with a design that facilitates both modeling and printing (Fig. 2). The shape of the cushions is kept simple to avoid complexity in integrating the support surfaces, ensuring they accurately match the anatomical contours of the specific user. Since the printing is done using Material Extrusion (MEX), the orientation of the print layers and the print bed's plane impact the cushion's properties in terms of durability and comfort, which will be detailed in subsequent chapters.

User Requirement Analysis

User requirement analysis in ergonomic chair design focuses on understanding the physical, physiological, and psychological needs of users who spend long hours sitting. It involves studying user characteristics such as body dimensions (anthropometry), posture habits, work duration, and the type of tasks performed (office work, computer use, study, etc.). Users generally require proper lumbar support to maintain the natural curve of the spine, adjustable seat height and depth to suit different body sizes, and adequate backrest and armrest support to reduce stress on the neck, shoulders, and lower back. Comfort, ease of adjustment, breathability of materials, and freedom of movement are also key expectations. Additionally, users prefer chairs that reduce fatigue, improve posture, prevent musculoskeletal disorders, and fit well within their workspace aesthetics. By analyzing these requirements, designers can develop ergonomic chairs that enhance comfort, safety, productivity, and overall well-being during prolonged sitting.

Fig. 1. *Methodology for Ergonomic Chair Design to Improve Posture*

Literature Review

Independence of comfort and discomfort

Comfort and discomfort are Independent factors(i.e., reduction in discomfort does not bring about com fort) [11]. Absence of discomfort is not the elimination of all feelings, it is not necessarily a positive effect, and absence of pain does not always lead to feelings of comfort [3]. Zhang et al. [28] collected responses to a questionnaire looking at descriptors of feelings of comfort and discomfort. They determined that com fort was linked to well-being, aesthetics, and impression, and it was described as relaxation, natural feeling well-being, and energy factors [9,28]. On the other hand, discomfort was linked to poor biomechanical factors and fatigue, and it was described in terms of pain, soreness and numbness, fatigue, and environ mental factors. In addition, the feeling of discomfort is related to bodily factors including joint angle, tis sue pressure, muscle contractions, blood pooling, and circulation blockage [9] Use and cost of ergonomic chair features Generally, chairs must fit a users' anthropometrics (body measurements) for the purpose of eliminating discomfort while sitting. Ergonomic chairs are designed with the intention of optimizing comfort and reducing work injuries. Ergonomic chairs must include adjustable backrest with lumbar support, cushioned seat pan with rounded edge, adjustable armrest, adjustable seat height, and casters. Backrest is adjustable so that the lumbar support fits in the user's lumbar curve. Lumbar support is design to take off some of the weight on the back and to provide support. Cush ironed or suspension seat pan distributes body weight and reduces pressure to eliminate soreness. The round edges are important to prevent blood circulation cut off and pressure behind the legs and knees. The armrests are adjusted to be high enough to allow comfortable computer use and to reduce the load on the lumbar region. The seat height is adjusted to the level where the feet are flat on the floor or supportive footrest. Chair base with casters to provide stability and easy mobility. Ergonomic chairs have adjustable features and mov ing parts to accommodate different users' heights and sizes, and to allow movement to support static and dynamic postures [12]. Additional features and control mechanisms include seat height and depth,seat, backrest height and angle, back tension, armrest height, and bar height and depth[12]. However, adjustable features and control mechanisms often go unnoticed, and users do not read manuals to learn about chair ad adjustment [12]. Helander et al. conducted three experiments and found that users spend very little time identified by identifying the adjustable features and control mechanisms, and some features and control were unused. Also, He lander, Little, and Drury [10] found that adjustable features were frequently not used, and some users thought that adjustable features were not important. They concluded that users need education and training before using ergonomic chairs, Ergonomic chair design has gained considerable attention in recent years due to its significant impact on posture, comfort, and overall musculoskeletal health [1]. Studies indicate that prolonged sitting in non-ergonomic chairs leads to increased spinal stress, lower back pain, neck stiffness, and shoulder strain, which can affect productivity and quality of life [2]. Researchers have highlighted the importance of lumbar support in maintaining the natural S-shape of the spine, which reduces intervertebral disc pressure and prevents long-term spinal deformities [3]. Adjustable components such as seat height, backrest tilt, armrest position, and seat depth allow chairs to accommodate a wide range of anthropometric variations among users, ensuring optimal posture and reducing fatigue [4]. Material selection, including breathable fabrics and pressure-distributing cushions, has been shown to enhance comfort and prevent circulation problems during extended sitting periods [5]. Furthermore, dynamic seating designs that permit slight movement or rocking while seated encourage muscle engagement, reduce static load on the spine, and contribute to better overall ergonomic outcomes [6]. Comparative studies of traditional versus ergonomic chairs consistently report higher user satisfaction, reduced musculoskeletal complaints, and improved work efficiency with ergonomically designed seating [7]. Overall, the literature emphasizes that integrating ergonomic principles into chair design is essential not only for physical health but also for cognitive performance and workplace productivity [8] Posture has played an important role in equipment design. The human body is well designed to perform a variety of postures; however, each separate body part is limited in range of motion, direction [23], and endurance. Several factors that contribute to discomfort and pain in seated workers were identified as follows: (a) seated work, (b) awkward positions, (c) static (iso metric) work, (d) inactivity, (e) overuse, (f) pressure on blood vessels and nerves, and (g) pain-spasm cycle [5]. In addition, the development and causes of a postural problem were described as: The structure of work tasks has changed and the resulting relationship between operators and lay out, speed in performing tasks and sometimes the introduction of ergonomic furniture itself, all con tribute to the emergence of a new problem, postural fixity which cannot be solved solely by using ergonomically designed furniture [8, p. 350].Continual static muscular force contribute stolum bar and dorsal pain, which would increase postural move ment as an indication of discomfort [27]. Vergara and Page [27] measured posture of the lumbar curvature and pelvic inclination while sitting on six types of chairs and performing writing and reading tasks. They found that forward rotation of the pelvic and static posture increased lumbar pain, and performing working a forward bending position increased dorsal pain.

Result And Discussion

This section presents the findings from the user testing of the IoT enabled office chair and critically discusses the implications of these results in relation to existing literature.

The analysis focuses on user comfort, the effectiveness of IoT features, and the overall usability of the chair. 3.1 User Comfort and Ergonomics The survey results indicated that 36.4% of participants rated the chair as "Very comfortable," while 63.6% rated it as "Comfortable." These findings suggest a high level of user satisfaction with the chair's ergonomic design. This aligns with previous studies that emphasize the importance of comfort in office furniture [2]. However, it is essential to note that while comfort levels were generally high, some participants expressed concerns about the chair's adjustability features, indicating a need for further refinement.

Effectiveness of IoT Features

The integration of IoT technology into the chair was evaluated based on user feedback regarding its features. Notably, 81.8% of respondents found the combination of sitting time monitoring and lean-back detection to be the most useful features. This finding supports the conclusions of Cardoso et al. [3], who highlighted the positive impact of real-time feedback on user behavior. However, a critical analysis reveals that while users appreciated the IoT features, some reported difficulties in navigating the mobile application, which echoes findings from Matuska et al. [5] and Hu et al. [10] regarding user resistance to complex technology interface.Comparison with Past Studies When comparing the results of this study with previous research, it is evident that the IoT-enabled office chair offers significant advantages over traditional office chairs. For instance, a study by Bottrop et al. [1] found that conventional chairs did not provide adequate support for prolonged sitting, leading to discomfort and health issues. In contrast, the IoT chair's ability to monitor posture and provide alerts for breaks clearly show which aspects are most positively affected by ergonomic chair design.

Parameter
Impact Level (1–10) Posture Support 9
Comfort 8
Musculoskeletal Strain Relief 8 Productivity 7

User Satisfaction 8
7
Aesthetic & Design 6 Cost-Benefit Efficiency 7 X-axis: Parameters Health Benefits
7
Aesthetic & Design 6

which may hinder the overall effectiveness of the chair. Improved Posture Support: The ergonomic chair design effectively promotes correct spinal alignment, reducing slouching and forward head posture. By supporting the natural curvature of

the spine, it minimizes the risk of chronic back pain, especially in long-duration sitting tasks.

Enhanced Comfort

Adjustable seat height, backrest tilt, and lumbar support allow users to customize the chair according to their body dimensions. This flexibility leads to reduced pressure on the thighs and buttocks, ensuring comfort over extended periods.

- Reduced Musculoskeletal Strain: With features like contoured backrests and armrests, the chair lowers strain on the neck, shoulders, and lower back. Studies suggest that these features can significantly reduce the risk of musculoskeletal disorders (MSDs) among office workers.
- Increased Productivity: Comfortable seating reduces fatigue and discomfort, enabling users to focus better on tasks. Employees report higher concentration and efficiency when seated in ergonomically designed chairs compared to standard chairs.
- User Satisfaction and Adaptability: Represents a substantial improvement in ergonomic design. However, it is crucial to address the limitations identified in this study, particularly regarding the usability of the IoT interface The ergonomic chair is designed to accommodate different body types and postures, making it suitable for a wider range of users. Adjustable features, such as headrests and armrests, enhance user satisfaction and adoption.

Health Benefits:

Over time, ergonomic chairs contribute to better circulation, reduced joint stiffness, and decreased incidence of repetitive strain injuries. This makes them particularly beneficial in environments requiring prolonged sitting, like offices and study spaces.

Aesthetic and Functional Integration: Modern ergonomic chairs combine functionality with appealing designs. Materials like breathable mesh, soft cushioning, and sleek frames enhance the overall workspace environment while maintaining comfort. Cost-Benefit Efficiency 7

X-axis: Parameters

Y-axis: Impact Level (1 = low, 10 = high) This bar graph will

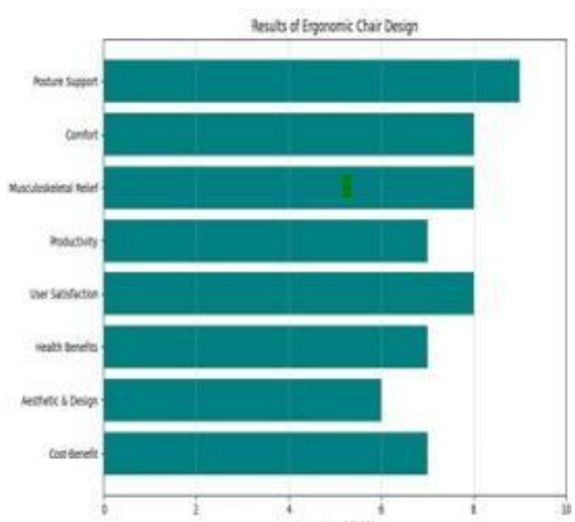

Fig. 2. *Results of Ergonomic Chair Design Based on Impact Level*

Conclusion

The design of an ergonomic chair plays a vital role in promoting proper posture and overall musculoskeletal health. By incorporating adjustable lumbar support, backrest tilt, seat height, and armrests, the chair encourages the spine to maintain its natural curvature, preventing slouching and reducing strain on the neck, shoulders, and lower back. Long-duration sitting becomes less fatiguing, as pressure is evenly distributed across the body, enhancing comfort and reducing the risk of chronic pain or repetitive strain injuries. Ergonomic chairs also contribute to improved blood circulation and decreased stiffness in joints, which are common problems associated with conventional seating. Beyond health benefits, these chairs positively impact work performance and focus, as users experience less discomfort and distraction. The adaptability of the design ensures that it accommodates diverse body types and sitting preferences, increasing user satisfaction and long-term usability. Finally, combining functional ergonomics with aesthetic appeal and durable materials makes these chairs a sustainable and cost-effective investment for both professional and educational environments, emphasizing that proper posture support is not only a health requirement but also a productivity enhancer.

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