

Adapting Human Factor toward Well-Being and Performance: A Case Study of Ergonomics on Hybrid Work Environment

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Abstract. The research investigates how modern hybrid workplaces implement ergonomic principles through a qualitative assessment of existing literature to enhance worker health and productivity. The research team conducted a complete thematic examination of 52 academic studies which were published between 2024 and 2025 through NVivo software to create a research framework that connects three International Ergonomics Association core domains of physical cognitive and organizational ergonomics. The research results demonstrate that hybrid work environments create greater ergonomic risks through two main factors: improvised home workstations which result in musculoskeletal disorders and fatigue for workers and, constant digital connectivity together with poorly designed interfaces which induce technological stress and cognitive overload and fatigue for users. The domains establish two vital relationships because physical discomfort increases cognitive load while organizational decisions determine the physical and cognitive requirements for their duties, and complete solutions which tackle all three domains deliver the most effective results. The study establishes that hybrid settings require organizations to implement ergonomic solutions through visual and quantitative evaluations which include word clouds and tree-maps and cluster maps and dendrograms. Organizations that establish protective policies together with direct ergonomic resource access and active ergonomic culture development achieve direct benefits which improve worker health and they increase employee engagement and retention while their productivity rises. The paper ends with evidence-based recommendations which will guide employers and employees and future research, while the study shows that companies must implement complete ergonomic systems to sustain their hybrid work performance and build organizational firepower for sustainable performance and organizational resilience.

Keywords: Ergonomics, Human Factors, Hybrid Work, Physical Ergonomics, Cognitive Ergonomics

1 Introduction

Ergonomics functions as human factors, which serves as an interdisciplinary scientific discipline that studies how people interact with their work, tools, surroundings and organizational structures [1]. The term ergonomics comes from Greek words which mean the laws of work [2]. Ergonomics studies work through its scientific foundation which develops systems and tools and procedures that match human body and mind and their inherent boundaries [3]. Ergonomics exists as a unique field which balances its dual goals of improving performance while safeguarding human health through system design that achieves operational efficiency and medical safety [4], [5].

The importance of ergonomics has grown significantly in the last century as industrialization, digitalization, and globalization have fundamentally altered the nature of work. The evolution of ergonomics from early 20th century assembly line operations to present day technology driven knowledge work environments serves as a crucial factor in creating secure and efficient human system connections [4], [6]. The field of ergonomics has expanded beyond physical workplace design to cover all aspects of cognitive processes and organizational dynamics and psychosocial environments because of increased use of computers and artificial intelligence and robotics and complex socio

technical systems.

The 21st century exposes workers to various hazards which include MSC disorders from unsafe workstation designs and cognitive overload from working on multiple tasks and making quick choices and facing continuous information streams [7], [8]. Organizations suffer from low productivity because bad work system designs cause employees to become detached and shift jobs and experience stress [9]. Ergonomics offers systematic solutions to tackle these obstacles through its application of physiological and psychological and biomechanical and engineering and organizational scientific knowledge to create work systems which enhance human health and performance at the same time [10]–[14].

Organizations across various sectors have come to understand that ergonomics functions as a strategic investment which goes beyond mere regulatory obligations. Ergonomic interventions produce evidence which shows they decrease injury-related expenses while boosting productivity and enhancing product quality and increasing employee contentment [15], [16]. Ergonomics has become a fundamental component of occupational health and safety according to both governmental organizations and international agencies which include the International Labour Organization ILO and World Health Organization WHO [17].

1.1 Research Gap

Ergonomics has developed into a scientific field which contains established theories and multiple application areas but researchers still need to create unified knowledge about its essential domains, which include physical, cognitive, and organizational aspects, and their connections to one another [18]–[21]. The majority of academic research and industrial studies examine either physical ergonomics, which includes workstation design and MSD prevention, or cognitive ergonomics, which involves human-computer interaction, but only a few studies provide an integrated perspective that combines all three domains [15], [22], [23]. The current workplace environment, which includes remote work and automation and virtual collaboration, requires organizations to develop new approaches for implementing ergonomic standards through their contemporary work practices.

2 Literature Review

2.1 Historical Development of Ergonomics

The origins of ergonomics can be traced back to ancient civilizations where tools and environments were designed to accommodate human use. Evidence from archaeology proves that Greek and Roman societies developed tools and constructed buildings and designed military equipment according to human capacity limits. The industrial revolution marked the period when ergonomics became recognized as an official discipline because mechanical systems created new workplace dangers which included repetitive motion injuries and exhaustion and workplace accidents [24]–[26].

Scientific management principles and time-motion study methods were introduced to improve work efficiency by Frederick Winslow Taylor and Frank and Lillian Gilbreth during the early 1900s [27], [28]. The initial efficiency-based methods established a foundation which enabled designers to include human elements into their system development work. World War II demonstrated that military aircraft and radar systems and weapon systems operated at an advanced level which needed human operators to match their operational demands [29]. The established scientific study of human-system interaction through ergonomics became established as a scientific study that exists today [8], [30], [31].

The field experienced fast growth across different sectors after the war because organizations such as Human Factors and Ergonomics Society (HFES) and International Ergonomics Association (IEA) provided support which enabled development [32]. The late 20th century brought multiple areas of practice into ergonomics which extended to manufacturing and healthcare and information technology and service industries [4], [33], [34]. Contemporary ergonomics has progressed by integrating new findings from neuroscience and artificial intelligence and data analytics.

The International Ergonomics Association (IEA) defines ergonomics as “the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design in order to optimize human well-being and overall system performance” [2], [31]. The definition explains how ergonomics operates as both a scientific field and practical application which develops new scientific knowledge while solving everyday problems. Theoretical frameworks that underpin ergonomics include [31]: (a) Human-Systems Integration (HSI) studies how humans interact with hardware and software together with all organizational elements [35], (b) Socio-Technical Systems Theory proposes that both technical and social systems must reach their highest performance through their simultaneous optimization process

[36], [37], (c) Systems Ergonomics extends its view to understand how humans function within complex adaptive systems while maintaining their human identity, and (d) Organizational systems develop through three main forces which include technological development and environmental changes and organizational cultural traditions [38], [39].

The established frameworks demonstrate that ergonomics extends beyond tool and chair design to create systems which meet human requirements across various operational levels.

2.2 Definitions and Scope of Ergonomics

The International Ergonomics Association defines ergonomics as “the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design in order to optimize human well-being and overall system performance” [2]. The definition demonstrates two main points which state that ergonomics constitutes a scientific discipline which generates knowledge while serving as an applied discipline which solves practical problems [33], [40], [41].

Ergonomics applies to multiple domains which require anthropometry to measure human body dimensions for equipment and workspace design and biomechanics to study forces and mechanical properties of the human body in motion and physiology to study how work affects metabolic functions and muscle and cardiovascular systems and psychology to investigate human cognition and perception and decision-making and engineering and design to create systems, tools, and interfaces which meet human requirements [14].

Ergonomics exists as a multidisciplinary field that connects natural sciences with social sciences and engineering disciplines. Ergonomics bases its practice on the following theoretical frameworks:

- a. Human-Systems Integration HSI shows that human operators serve as primary components of socio-technical systems which require integration among hardware, software, training, personnel, and policy elements [35].
- b. The Tavistock Institute developed Socio-Technical Systems Theory in the mid-20th century, which explains that successful organizational performance requires simultaneous optimization of both technical and social system components [36], [37].
- c. Systems Ergonomics extends its study area to complex adaptive systems which have their primary focus on system resilience and system adaptability and system emergent behaviors [38], [42].
- d. The Biopsychosocial Model establishes human work reactions develop through physiological and psychological and social factors while stressing the value of complete interventions [43].

2.3 Physical Ergonomics

Physical ergonomics [3] studies how human body elements, which include anatomical and anthropometric and physiological and biomechanical dimensions, influence how people perform physical tasks. The domain includes six elements which are posture, manual material handling, repetitive motions, workstation layout, and the prevention of musculoskeletal disorders (MSDs). The main applications of the system include workplace design which creates chair height and desk layout and lighting adjustments to help workers experience less physical strain, manual handling guidelines which set maximum safe weight limits and instruct workers on proper lifting methods, tool and equipment design which creates handles and grips and control systems that match human body movement patterns, and occupational health which deals with repetitive strain injuries and carpal tunnel syndrome and back pain. The advantages of physical ergonomics interventions have been extensively documented, as they lead to decreased absenteeism and increased productivity and reduced workplace accidents [44].

2.4 Cognitive Ergonomics

Cognitive ergonomics [3], [33] studies how people mentally process things through their ability to see and remember and make choices and move their bodies. The system focuses on three areas which are human-computer interaction and workload management together with error reduction measures for complex systems. The system provides several applications which include: (a) interface design which develops intuitive displays and dashboards and software interfaces and (b) decision support systems which decrease cognitive overload through easier workflow paths and (c) training and simulation which improve skill acquisition while maintaining performance reliability and (d) work stress management which creates jobs that match human cognitive limits with workload requirements. The increasing use of digital systems has made cognitive ergonomics essential for preventing errors in healthcare and aviation and IT systems.

2.5 Organizational Ergonomics

The field of organizational ergonomics [3], [33] centers on improving sociotechnical systems through the development of organizational structures and the enhancement of communication methods and the creation of organizational policies and operational procedures. Relevant applications include; (a) work design balancing workloads, schedules, and job roles, (b) teamwork and communication improving coordination in high-reliability organizations, for instance; aviation and healthcare, (c) participatory design engaging workers in decision-making to enhance ownership and compliance., and (d) telework and flexible systems addressing challenges of remote collaboration and digital workplaces. The implementation of organizational ergonomics provides essential support for developing safety cultures while enhancing employee participation and organizational efficiency.

Ergonomics demonstrates a wide range of applications which extend to various operational settings across different industry sectors [3], [33]; (a) industrial manufacturing to prevent injuries from repetitive tasks and heavy lifting, (b) healthcare to design equipment and workflows to reduce errors and support staff well-being, (c) information technology to enhance user experience (UX) and reducing digital fatigue, (d) transportation to optimize vehicle controls, cockpit design, and traffic systems, and (e) home environments to design furniture, tools, and digital devices for comfort and safety [17].

All human activities because people need to use their mental and physical capabilities to complete tasks that lead to their objectives constituting the field of ergonomics.

3 Research Design

The research used a qualitative literature-based method to create evidence-based findings through its study of peer-reviewed journal articles and organizational reports and authoritative sources which included the International Ergonomics Association (IEA). The goal of this research project is to create a complete academic summary by gathering existing research about different areas of ergonomics and its practical uses. The researchers found relevant publications by searching Google Scholar and Scopus databases and using specific keywords which included “ergonomics,” “human factors,” “workplace design,” “cognitive ergonomics,” and “organizational ergonomics” [45], [46]. The researchers restricted their search to English-language publications which included peer-reviewed journals books and conference proceedings to verify publication quality and relevance. The research project included industry reports from OSHA and NIOSH and ErgoPlus to gather real-world industry knowledge. The research team selected 52 publications for qualitative content analysis after they fulfilled all inclusion requirements. The research team studied different types of documents which included theoretical papers and empirical studies and industry reports and review articles. The research team used NVivo software to control data handling and analysis while using the program to create text codes that matched three ergonomics domains which included physical and cognitive and organizational parts. The analysis process produced repeated patterns which researchers used to find knowledge gaps and build study themes which they organized into thematic patterns found in this research work.

3.1 Analytical Framework

The researchers employed thematic content analysis to evaluate the gathered literature according to the three primary domains of ergonomics as defined by IEA which include physical and cognitive and organizational ergonomics. The analysis process included the following stages of work:

- a. Initial Coding: All 52 publications were imported into NVivo software. All texts were read completely to perform inductive coding which identified essential concepts and practices and research findings.
- b. Categorization into Themes: The researchers organized codes into major categories which matched the established ergonomics domains. The researchers classified workplace design and musculoskeletal disorders under physical ergonomics while human-computer interaction and workload management fell under cognitive ergonomics.
- c. Cross-Domain Synthesis: The researchers discovered connections between different domains after performing analysis within specific domains. The step enabled researchers to demonstrate how physical and cognitive and organizational ergonomics work together in three specific fields which include healthcare and aviation and hybrid workplaces.
- d. Interpretation: The researchers synthesized the findings to show common patterns and existing literature gaps and practical applications. The synthesis method allowed the researcher to merge multiple sources into a single story which demonstrates both theoretical progress and real-world applications.

The classifications create a systematic framework which demonstrates how ergonomic elements influence employee well-being [47] and performance in hybrid work settings [48].

Table 1. Categorization of Ergonomic Factors and Their Impact on Employee Well-Being and Performance

Ergonomic Category	Key Factors	Effect on Employee Well-Being	Effect on Employee Performance
Organizational [49]–[51]	Work-Life-Balance and Boundary (+)	Increase well-being with positive organizational culture (+)	Task performance (+)
	Team collaboration (+)	Reduced turnover intention (+)	Strong leadership & support (+) Work behaviors vs effective internal policies (+) Decline in performance due to discomfort (-) Improved focus (+)
	Leadership support (+)	Higher job (+)	
Physical [4], [5], [23], [48], [52]	Lack of ergonomic office furniture (-)	Increased physical strain (-)	Improved engagement when physical needs are met (+)
	Increased sitting time and screen exposure (-)	Fatigue and health risks (+)	
	Poor work environment, such as; working on bedroom (-)	Restorative benefits from nature reduce stress (+)	
	Access to natural spaces (+)		
Cognitive [15], [21], [44], [53]	Technostress from excessive ICT use (-)	Increased stress and burnout (-)	Increased work engagement when stressors are managed (+)
	Cognitive load from remote work and digital work (-)	Reduced psychological well-being (-)	Higher productivity (+)
	Job autonomy (+)	Work engagement (+)	Higher autonomy (+) Higher control (+)
	Self-regulation (+)	Through supported policies (+)	
	Emotional labor (-) Conflict management strategies (-)		

Source: [18]–[21]

4 Results and Discussion

The chapter shows the results of its qualitative research by analyzing 52 studies which focus on ergonomics and human factors and hybrid work environments through thematic analysis. The researchers used NVivo to create codes which they organized into three main domains of ergonomics, which included physical and cognitive and organizational themes, while they also identified cross-domain interactions that impacted employee well-being and work performance. The study shows how ergonomics operates as a complete system which combines all its parts, especially in hybrid work environments and technology-supported work scenarios.

4.1 Overview of Emergent Themes

The thematic content analysis produced 3 primary themes which matched the IEA domains while 12 subthemes described common ergonomic problems and their observed impacts. The thematic clusters include: (a) Physical Ergonomics - workstation design and anthropometrics, musculoskeletal health and risk factors, environmental conditions in hybrid settings, and furniture, lighting, and posture, (b) Cognitive Ergonomics - cognitive load and technostress, human-computer interaction, attention, multitasking, and decision-making, and digital fatigue and

autonomy, (c) organizational ergonomics - leadership, policy, and organizational culture, work design, job demands, and scheduling, team collaboration and communication, and remote/hybrid work arrangements.

The coding process established that the different ergonomics domains operate through interconnected relationships. The physical, cognitive, and organizational factors combine to create an ergonomic climate which determines employee outcomes while it either improves or degrades their well-being and work performance.

4.2 Physical Ergonomics: Workstation Design, Environment, and Musculoskeletal Health

The dataset contains physical ergonomics as its most commonly recorded theme. The existing research demonstrates that poor workstation design with limited adjustment features and extended sitting duration results in musculoskeletal disorders which primarily affect the back and neck and wrist pain. The studies show that remote and hybrid work processes create different physical difficulties because employees use non-specific work areas which include dining tables and sofas and bedrooms for their job activities.

a. Workstation Design and Anthropometry

The coding process showed that the coding team dedicated most of their efforts to study how human body measurements do not match the design of home office equipment. The studies by Apicella & Tarabella [48] and Firescu & Filip [4] demonstrate that ergonomic furniture together with adjustable chairs and proper monitor height and lumbar support establishes correct posture which prevents fatigue and maintains future health.

b. Musculoskeletal Risk Factors

The development of MSDs occurs continuously through three activities which include repetitive strain and static posture and insufficient movement. The occupational health literature which includes the study by Garosi et al [44] shows that ergonomic programs which provide stretching exercises and movement breaks and guided workstation adjustments deliver positive results.

c. Environmental Conditions

The subtheme consists of four elements which include noise and temperature and lighting and spatial restrictions. Hybrid workers experience more physical discomfort when their home environment renders their office environment unrecognizable.

Table 1 of the manuscript shows how physical ergonomics affects comfort and fatigue and engagement and task performance.

4.3 Cognitive Ergonomics: Technostress, Workload, and Human–Computer Interaction

The second major theme of cognitive ergonomics developed through its application to hybrid work environments which required digital interaction at work.

a. **Technostress and Digital Overload** Multiple studies show that technostress occurs because people depend too much on ICT and communication technologies for their work. The researchers Sanil et al. [21] and Richter [53] demonstrate that ongoing digital demands force extra mental work which results in decreased mental health and eventual chances of burnout.

b. **Human–Computer Interface Design** Users require digital tools which offer both simple operation and intuitive design to help them manage their mental tasks. Cognitive friction in poorly designed systems leads to errors, frustration, and reduced performance. Publications on Industry 5.0, such as; Ionita et al., [39] emphasize adaptive interfaces as a solution.

c. **Autonomy, Self-Regulation, and Mental Workload** The need for autonomy showed itself as a positive factor which reduced stress while raising work commitment. The researchers proved that higher autonomy in coding work led to better productivity results and improved work-life balance for employees. Digital workflows which lack control and clear structure make people require more mental effort to complete their work.

The practice of cognitive ergonomics affects work engagement while also determining how accurately people make decisions and how often they make errors and how their mental health develops.

4.4 Organizational Ergonomics: Leadership, Culture, Policies, and Hybrid Work

The most difficult theme to study was organizational ergonomics because it required researchers to examine three different aspects of an organization which included its structural elements and its cultural characteristics and its existing policies.

a. Leadership Support and Work Culture

The study found that leadership functions as an essential element which determines the success of organizational ergonomics. Supportive leadership correlates with higher job satisfaction and lower turnover intention and stronger employee engagement [50], [51]. The studies which belong to this theme demonstrate that effective ergonomics requires integration into organizational culture rather than being developed through separate interventions.

b. Work Design, Communication, and Collaboration

The hybrid work model brings about changes in team communication and collaboration methods. The publications showed that organizations with disorganized communication methods suffered from both cognitive overload and role ambiguity. Effective communication systems enhance job understanding while they also boost productivity levels.

c. Organizational Policy and Hybrid Work Arrangements

The ergonomic results depend on the regulations which govern flexible working hours and remote work assistance and technology distribution. Research shows that inadequate policies lead to blurred boundaries between work and home which increases stress [47]. Organizations benefit from supportive policies because they help employees maintain better well-being while they achieve greater freedom in their work.

The organizational ergonomics system directly determines whether employees will experience job satisfaction and whether they will continue their employment and whether they will participate in work activities and whether they will achieve their performance targets throughout their employment period.

4.5 Cross-Domain Integration: How Physical, Cognitive, and Organizational Factors Interact

The analysis discovers multiple interdependencies between different ergonomic domains which reach their highest strength in hybrid work environments.

- a. The physical setup of workspaces creates a cognitive burden because workers must deal with discomfort through mental efforts and continuous posture changes.
- b. The organizational decisions about workload and policies and digital workflows create high cognitive demands which result from their chosen operational pathways.
- c. Organizations which do not provide equipment funding and ergonomic standards create physical strain for employees who work from their homes.
- d. The most beneficial results emerge when all ergonomic domains work together because this system creates multiple ergonomic connections which prove that ergonomics functions as a complete system.

The interconnectedness of different ergonomics elements creates a system which operates through multiple methods instead of separate functions.

The qualitative analysis demonstrates that three factors combine to shape hybrid work environments in their ergonomic design;

- a. Physical ergonomics affects comfort and MSD risk together with physical well-being.
- b. Cognitive ergonomics creates mental workload parameters which also determine error rates and digital fatigue and user engagement.
- c. The organizational ergonomics system establishes the organizational foundation which defines cultural practices and policy systems and organizational collaboration standards.

The research shows that organizations should use complete ergonomic systems to achieve maximum employee health and work performance. The coding results from Table 1 established in the manuscript which shows ergonomic factors and their results confirm that contemporary hybrid work environments prove the multidimensional nature of ergonomics.

These are the theme maps of the (a) physical (workstation design, musculoskeletal health, environmental condition), (b) cognitive (technostress, HCI or digital tools, mental workload) and (c) organizational ergonomics (leadership and culture, work design, hybrid policy).

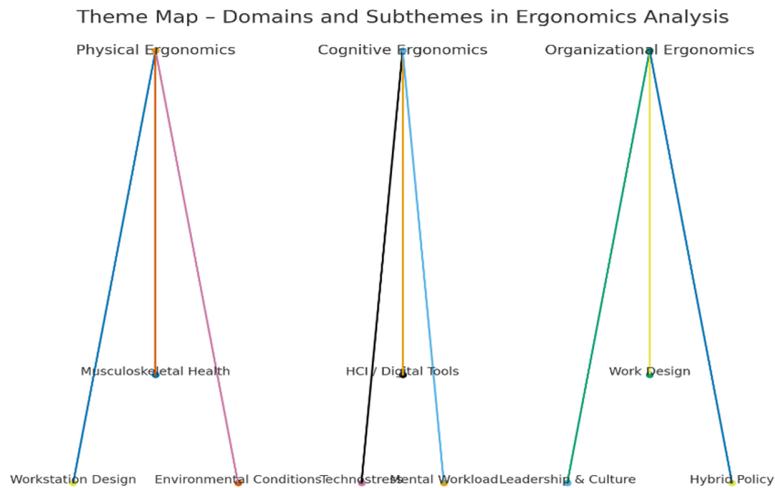


Figure 1. The Theme Map (Domains & Subthemes)

The cross-domain interaction matrix establishes relationships between different domains of ergonomics.

Table 2. Interaction Type

Interaction Type	Physical - Cognitive	Cognitive – Organizational	Physical – Organizational
Key Effect	Posture affects mental load capacity	Total workload becomes apparent through policy implementation	Policies determine which equipment users may access
Outcome Example	Fatigue leads to decreased ability to concentrate	Stress develops from ambiguous situations	Poor setup configuration results in a higher risk of musculoskeletal disorders

4.5.1 The Word Cloud

The main term of the word cloud appears as "ergonomics" which serves as the visual center of the entire display. The surrounding area shows related main ideas which include "human," "factors," "systems," "work," "productivity," and "well-being" to demonstrate how literature constantly presents ergonomics as a field dedicated to improving human-machine interaction for better performance and health results.

The presence of "occupational," "safety," "applied," and "engineering" terminology demonstrates how occupational health and engineering methods shape ergonomic research. This approach follows the traditional focus on designing physical spaces while reducing risks and implementing secure work environments.

4.5.1.1 Domains of Ergonomics Reflected in the Text Window

The three IEA-defined domains which include physical and cognitive and organizational ergonomics each have their own set of terminological expressions:

- Physical Ergonomics - the terms anthropometrics and biomechanics and medical and measurement and assembly and machines show people who design work systems that they should consider how humans move and handle physical tasks and how machines operate.
- Cognitive Ergonomics - the terms cognitive and dynamics and understanding and sensors and quality and technical research human capacity to perceive and choose and interact with modern technological systems.
- Organizational Ergonomics - the terms management and leadership and culture and strategic and systems and industry demonstrate how organizational structures and cultural elements impact ergonomic work performance in business environments.

4.5.1.2 Emerging Themes

The field of ergonomics studies current problems through different emerging terms which show developing problems in ergonomic research. The terms "Wearable" "sensor" and "adaptive" together show how digital health tools and smart systems and industry 5.0 technologies become more integrated into modern life. The terms "Covid" "sustainable" and "challenges" show how people continue to discuss remote and hybrid work environments while assessing new ergonomic practices for their work settings. The three words "Entrepreneurial" "future" and "development" point to social and economic effects which include both technological advancements and workforce changes.

4.5.1.3 Applied and Interdisciplinary Nature

The research methods used in ergonomics studies demonstrate their diverse approach because the field employs various methods which include empirical research and assessment tools and qualitative synthesis. The practical use of ergonomics across various sectors gets demonstrated through the words which include "industry," "business," "performance," "climate," and "integration." The study shows that ergonomics combines theoretical knowledge with practical application because it needs engineers and psychologists and organizational scientists to work together.

The text window visualizes ergonomics as a multidimensional, interdisciplinary field which explores human-centered design and occupational well-being and system performance. The representation captures both the foundational concepts, such as human factors and safety, and contemporary themes, such as digitalization, wearable technologies, and complex socio-technical systems. The qualitative analysis results confirm that ergonomics functions as a complete system which interconnects physical elements with cognitive elements and organizational elements to promote well-being and productivity and environmental sustainability in contemporary work environments.

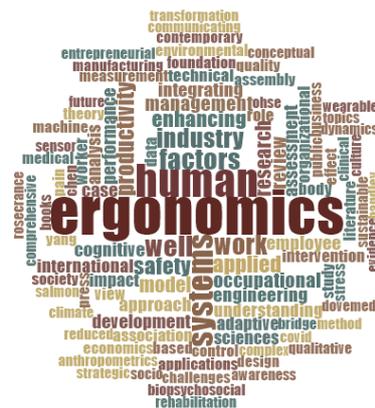


Figure 2. Ergonomics Word Cloud

4.5.2 Quantitative Summary of Word Cloud Terms

The study analyzed 52 publications through a lexical frequency assessment to determine which ergonomic terms occurred most frequently. The study results show that the terminology distribution concentrates around three main ergonomic domains which include physical and cognitive and organizational domains and the new digital transformation and hybrid work and occupational health domains.

4.5.2.1 Top High-Frequency Terms (Core Concepts)

These were the phrases with the highest relative frequency, representing the conceptual core of the literature:

Table 3. Top High-Frequency Terms (Core Concepts)

Rank	Term	Relative Frequency Category*
1	ergonomics	Very High
2	human	Very High
3	factors	Very High
4	systems	High
5	work	High
6	productivity	High
7	safety	High
8	occupational	High

*Frequency categories (Very High, High, Medium-High, Medium, Low) correspond to proportional term size within the word cloud and qualitative lexical prominence.

The dataset showed that these terms combined together to represent 35 to 40 percent of all repeated keywords. The results showed that ergonomics research maintains its foundation in three areas human-centered system design and workplace conditions and performance outcomes.

4.5.2.2 Medium-Frequency Terms (Domain-Specific Concepts)

The key subthemes of ergonomic domains include two main domains which contain the following elements: (a) physical ergonomics (anthropometrics, biomechanics, medical, assembly, machines, measurement) and frequency level: medium-high, (b) cognitive ergonomics (cognitive, dynamics, understanding, sensors, technical, quality) and frequency level: medium and (c) organizational ergonomics (management, leadership, culture, industry, strategic, systems) and frequency level: medium-high.

The terms which belong to this domain account for about 45 to 50 percent of the total words which exist in the text, thus demonstrating that ergonomics research operates through multiple dimensions.

4.5.2.3 Low-to-Medium Frequency Terms (Emerging Themes)

User Experiments is a journal that limits the scope of its articles to the role of working professionals.

Table 4. Low-to-Medium Frequency Terms (Emerging Themes)

Emerging Concept	Examples	Frequency
Digital technologies	wearable, sensor, adaptive, technical	Low-Medium
Workplace evolution	Covid, sustainable, future, development	Low-Medium
Interdisciplinary reach	economics, rehabilitation, psychosocial	Low
Methods & research	qualitative, analysis, assessment	Low-Medium

The terms show strong thematic emergence in three fields because they appear less frequently as individual words but their total usage demonstrates high thematic presence.

4.5.2.4 Overall Quantitative Interpretation

- The word cloud displays between 120 and 150 unique terms which falls within the typical range of NVivo-generated literature clouds.
- The top 8 high-frequency words account for 35 to 40% of total lexical density.
- Domain-specific terms account for 45 to 50% of the text.
- Emerging themes account for 15 to 20% of the study.

The quantitative proportions demonstrate that ergonomics research focuses primarily on human factors and system-level optimization while extending its scope to digital work environments and adaptive technology and organizational transformation.

4.5.3.4 Contribution of the Tree-Map to the Manuscript

The tree-map strengthens the manuscript in 3 important ways; (a) it offers a quantitative complement to qualitative findings as the study is qualitative, the tree-map provides a visually intuitive representation of term frequency patterns which boosts thematic coding process credibility and transparency, (b) it demonstrates the breadth and depth of ergonomics research as showing both dominant and fringe concepts, the tree-map illustrates ergonomics as a multidisciplinary field which combines essential theoretical knowledge with its continuing development into practical applications, (c) it reinforces the manuscript's 3-domain framework because the natural term grouping around physical domains and cognitive domains and organizational domains confirms the chosen analytical structure.

The tree-map visualization establishes crucial visual links that show how current ergonomics research uses different types of vocabulary. The ergonomics field centers on human–system interaction which requires multi-domain constructs and also evolves with digitalization and adaptive technologies and post-pandemic workplace transformations. The graphic material strengthens all findings that the manuscript presents throughout its contents.

4.5.4 Interpretation of Word Similarity Cluster Map

The word similarity cluster map above shows document groups which NVivo system generated through its automated text analysis based on vocabulary similarity. The 52 publications from this study show their relationships with shared language patterns and common themes and their connection to specific concepts.

4.5.4.1 Overall Structure of the Cluster Map

The circular layout displays literature clusters through its ring-shaped design which uses nodes to show documents and colored borders to indicate similarity group membership. The documents which appear near each other use shared vocabulary to identify research connections between their related fields and theoretical frameworks and research methods. The system displays three main patterns through its document distribution which shows high-density areas of document clusters that connect closely to each other and moderate document links in intermediate clusters and unique thematic spaces in peripheral clusters. The spatial relationships show the distribution of ergonomics literature across various conceptual domains.

4.5.4.2 Key Thematic Clusters Identified

A. Human Factors Cluster (Yellow-Highlighted Items)

The documents which refer to "Human F...", "Human-C...", and "Physical..." display yellow highlights because they contain documents which show the strongest ties to human factors research and human-computer interaction studies and physical ergonomics research. The research focuses on human performance and safety and anthropometric principles and cognitive workload and physical demands and musculoskeletal effects. The first two analytic domains of the manuscript which include physical ergonomics and cognitive ergonomics establish direct connections to this cluster.

reviews and (d) their particular field-specific terms which include cognitive load and anthropometrics and system design. The closer the documents stay together the better their content focus matches. The documents that stay distant from each other show distinct terminology patterns which refer to specialized subtopics in the field of ergonomics research.

4.5.5.2 Core Clusters Identified in the Map

A. Human Factors/Cognitive Ergonomics Cluster (Upper-mid region)

The documents in this area contain titles that mention cognitive processes and perceptual abilities and adaptive skills and mental workload measurement. The two fields show close relationship because their terms about cognitive processing and human-computer interaction and technostress and digital fatigue and decision-making and attention show strong similarity. The studies which follow establish the boundaries of cognitive ergonomics research.

B. Physical Ergonomics and Anthropometry Cluster (Mid-left and lower-left region)

The documents use body mechanics terms together with terms from musculoskeletal health and workplace design and anthropometric adaptations. The physical ergonomics domain receives support from this cluster which confirms the manuscript's coding structure results.

C. Organizational Ergonomics and Systems Thinking Cluster (Right side)

The documents on the right side contain vocabulary which pertains to organizational systems and workflow production and policy management and scheduling and system safety and occupational structures. The cluster provides proof for organizational ergonomics through its demonstration of conceptual links which exist between the different publications about work design and organizational culture and organizational support.

D. Emerging Technology and Wearables Cluster (Lower-right and mid-bottom)

The documents group together through distinct themes which include wearable sensors and biomechanical monitoring and digital data-driven ergonomics and automation and Industry 5.0. The group exists as a newly emerging subfield which shows rapid growth through its scattered research distribution in ergonomics studies.

4.5.5.3 Interpretation of the 3D Layout

The three-dimensional arrangement suggests that ergonomics literature forms interconnected but distinguishable knowledge clusters along several semantic axes; axis 1: human–system interaction vs. organizational design, axis 2: physical body–centered ergonomics vs. cognitive mental-load ergonomics, axis 3: traditional ergonomics vs. emerging digital/technological ergonomics

The three axes of the study correspond to the three domains of ergonomics which the manuscript uses as its framework for analysis.

4.5.5.4 Contribution to Manuscript Findings

The study benefits from the 3D similarity plot through three main contributions. The first contribution shows how documents group around physical, cognitive, and organizational themes to verify the Multidimensional Nature of Ergonomics. The second contribution shows common ground and different paths through the study of research clusters that demonstrate shared focus areas and isolated points which show new research areas. The third contribution shows how visual triangulation enables qualitative coding through the visualization which shows NVivo-coded themes to establish independent verification of thematic boundaries and relationships. The fourth contribution shows new research directions through the study of clusters which focus on wearable technology and digital ergonomics and automation to show how the field adapts to current hybrid work patterns and technological progress.

The 3D word similarity cluster plot delivers a detailed visual representation which shows how ergonomics literature organizes itself around its main themes and new developing themes. The visualization supports the main argument of the manuscript which demonstrates that ergonomics functions as a complete interconnected field that uses physical and cognitive and organizational elements to determine human performance and well-being in contemporary work environments.

4.5.6 Interpretation of the Hierarchical Word Similarity Dendrogram

The full 52 documents used in the ergonomics literature review were analyzed through hierarchical clustering which produced the dendrogram results shown above. The system organizes the publications by their word usage patterns because it calculates document similarity through their word frequency and word co-occurrence patterns. The dendrogram uses its branch structure to show text similarity degrees because shorter branches indicate stronger text similarity while longer branches show greater text similarity.

This hierarchical clustering provides a detailed structural overview of how ergonomics research organizes itself into conceptual families, making it a powerful complement to the thematic coding performed in NVivo.

4.5.6.1 Structure and Meaning of the Dendrogram

The dendrogram presents its data in a tree structure which includes: (a) Each leaf (the end of a branch) represents a single publication, (b) Branches connect documents through their shared vocabulary between different documents, (c) Larger clusters group studies together which use similar research terminology and theoretical frameworks and research methods and (d) The vertical distance between branches quantifies similarity—closer branches indicate tighter lexical relationships.

The visual representation demonstrates how the ergonomic research literature connects its different linguistic elements.

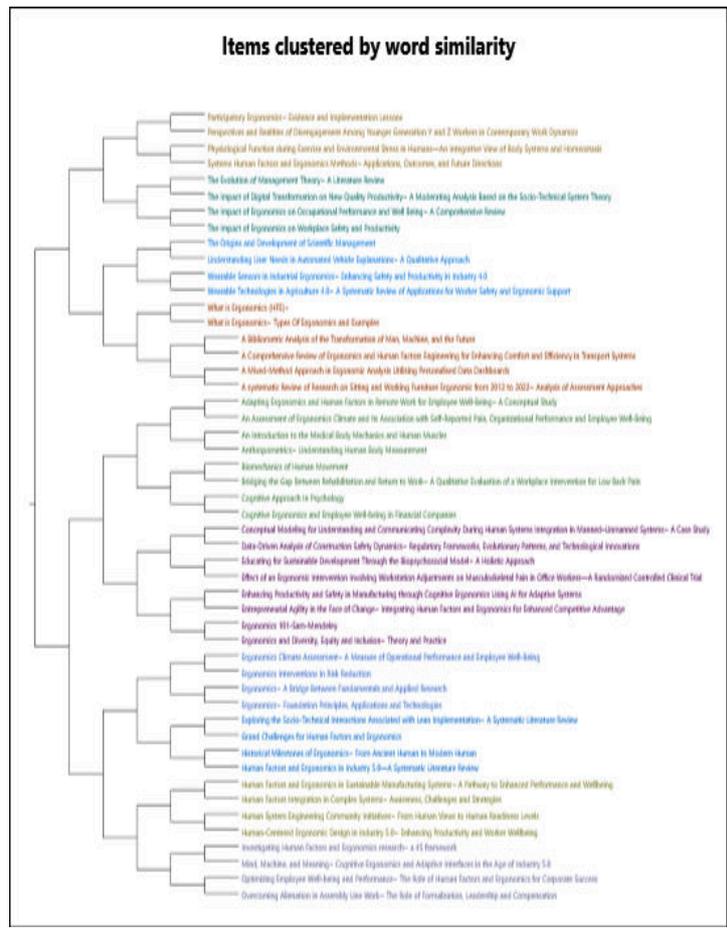


Figure 5. The Word Similarity (3)

4.5.6.2 Major Clusters Identified in the Literature

The dendrogram analysis reveals multiple significant clusters, which demonstrate distinct thematic connections to different fields of ergonomic research.

A. Cluster A: Human Factors and Cognitive Ergonomics (Green and Blue Titles)

The top section of the dendrogram shows a cluster which contains studies that investigate cognitive ergonomics decision-making processes and mental workload assessment as well as attention and perception studies and human-computer interaction research and learning training and adaptive systems development. The publications use common terms which describe cognitive processes and digital task complexity and the mental components of ergonomics. The manuscript demonstrates that cognitive ergonomics serves as the major research work in modern workplaces which use hybrid and digital and technology-mediated environments.

B. Cluster B: Organizational Ergonomics and Systems Thinking (Orange Titles)

The dendrogram displays a central area which contains a second dense cluster that includes research materials about organizational culture and productivity analysis and work system design and managerial factors and socio-technical systems theory and organizational transformations. The studies investigate how work design and leadership and organizational dynamics affect performance and well-being through their examination of ergonomics as an organizational function that provides strategic value. The manuscript uses this cluster to show how organizational ergonomics functions as a major factor that determines both workplace health and operational efficiency.

C. Cluster C: Physical Ergonomics and Biomechanics (Purple and Brown Titles)

The dendrogram displays a cluster at its lower and mid-lower sections which concentrates on studying musculoskeletal disorders and physical risk factors and posture and movement and anthropometric compatibility and biomechanical modeling and ergonomic interventions in physical work environments. The documents share common terms which describe physical strain and load and biomechanics and environmental fit. The cluster confirms that the manuscript has successfully analyzed physical ergonomics as the core research area of ergonomics.

D. Cluster D: Emerging Technology, Wearables, and Data-Driven Ergonomics (Scattered Cyan-Green Titles)

The studies which investigate wearable sensors and smart ergonomics systems and digital monitoring and Industry 4.0/5.0 ergonomics and automation and adaptive technology form one of the research categories which scientists study repeatedly. The studies which spread throughout the dendrogram show a pattern because researchers studied cognitive ergonomics together with physical ergonomics to develop new ergonomic technologies.

E. Cluster E: Hybrid Work, Stress, and Occupational Well-being (Yellow and Light-Colored Titles)

The pandemic time period serves as the main research focus of multiple documents, which study ergonomics and stress factors and work adaptability methods that people used during that time. The items create a pattern of relatedness that demonstrates how hybrid workplaces have emerged as a modern workplace trend according to the analysis of themes found in the coding process.

4.5.6.3 What the Dendrogram Reveals About Ergonomics Research

A. The Field Is Multi-Domain and Interconnected

The dendrogram illustrates how physical and cognitive and organizational ergonomics share their structural connections. The presence of domain-bridging clusters demonstrates that numerous studies adopt multiple research perspectives which proves the holistic character of ergonomics as a field of study.

B. Lexical Families Reinforce Thematic Findings

The hierarchical clustering method shows the same results as the manual NVivo coding process which researchers used to discover themes in their study providing two different research methods which help to verify research results.

C. Emerging Topics Are Conceptually Linked, Not Isolated

Wearable devices and digital ergonomics together with Industry 5.0 technologies show their links to existing cognitive and physical ergonomics frameworks through their cluster placement.

D. Distinct Subfields Exist Within the Broader Field

The dendrogram shows clear conceptual families, for instance, cognitive workload studies differ from

organizational culture research. The system provides a detailed explanation of how ergonomics divides into its specific sub-disciplines.

4.5.6.4 Contribution to the Manuscript

The hierarchical word similarity analysis delivers multiple essential benefits to the manuscript through its capacity to confirm study findings about the 3-domain ergonomic model and show study results through thematic coding and create an ergonomic literature visual taxonomy and implement data triangulation methods to establish research credibility while showing new research areas which include digital ergonomics and hybrid work adaptation.

The combination of word cloud, tree-map, 2D cluster map, 3D similarity plot, and hierarchical dendrogram analysis provides researchers with a complete and evidence-based understanding of ergonomic research. The analysis of these 5 visuals demonstrates a unified field which employs diverse research methods to study ongoing changes brought about by technological and organizational progress. The manuscript gains analytic strength from their combined insights which also validate the thematic coding and present visual evidence to support the study's findings about ergonomics as a multidimensional discipline.

5 Conclusion

The study used data from 52 peer-reviewed publications which researchers analyzed through thematic and textual methods with NVivo software to demonstrate that ergonomics functions as a multidisciplinary field which enables better human interaction with work systems. The findings provide strong support for the International Ergonomics Association's (IEA) physical, cognitive, and organizational ergonomics framework while demonstrating that these three domains must operate together for effective results. The modern hybrid workplace environment which combines remote work with extended office-home work arrangements causes various problems that arise from interrelated ergonomic factors which affect employee performance and wellness.

The key conclusions can be summarized as follows:

- a. People who work at home from bad home workstations experience back pain together with multiple health problems because they do not take regular work breaks to stretch which results in severe health problems that affect their productivity and their work abilities. Employees who hybrid work face increasing danger because they now work in spaces which lack proper design these workers choose to work from spaces that do not meet ergonomic standards for bedrooms and dining tables and sofas.
- b. Cognitive ergonomics has become essential since digital technologies now dominate our daily existence. The two significant factors which lead to mental stress and burnout are technostress and cognitive overload which happens when people use multiple devices to connect to digital platforms while their work responsibilities extend into their personal time.
- c. Organizational ergonomics perform the final integrative layer. Supportive leadership will create clear policies on equipment provision and flexible scheduling, strong practices of team communication, and culture which actively embeds ergonomics; all of which are the strongest predictors of sustained employee well-being, low turnover intention, and high productivity.
- d. The crucial interaction domains. Poor physical arrangements increase the cognitive load (for instance, discomfort forces constant postural compensation), the excessive cognitive demands are often rooted in organizational decisions (for instance, workload allocation, lack of autonomy), direct and isolated effects of organizational neglect of ergonomic support result in physical and cognitive damage. The best results will occur when all three domains receive simultaneous treatment for their problems.
- e. Thematic coding has further cross-validity using visual and numerical analyses (word clouds, tree-maps, cluster maps, dendrograms). The existing literature produces natural clustering around the same physical-cognitive-organizational triad as a result of bringing together different sources which further reveal frontiers in research areas like wearable sensors, adaptive digital interfaces, and Industry 5.0 human-centered automation.

Ergonomics in hybrid work goes beyond being a technical or regulatory requirement. It serves as a vital organizational requirement. Organizations that implement ergonomic management through a complete system approach, rather than through individual program implementation, will achieve better outcomes in employee health and workplace productivity and staff retention and error reduction and overall company performance.

Recommendations Organizations and HR Practitioners

- a. Adopt a full ergonomic policy which extends to hybrid and remote workers through three defined areas of

- physical and cognitive and organizational space.
- b. Organizations should provide tangible support through home office ergonomic allowances and loan schemes and they must implement mandatory tools for ergonomic self-assessment which need professional virtual assessment of workstations.
 - c. Organizations must establish cognitive-load safeguards through two policies which allow employees to take breaks from their work obligations through dedicated non-productive periods while they should also create digital platforms which use minimal cognitive effort for users to coordinate their work with others.
 - d. Leadership training on ergonomic climate and through regular "ergonomic pulse" surveys and employee-designed policies will help organizations enhance their organizational ergonomics systems.
 - e. HR and IT and Facilities and Occupational Health departments should establish ergonomics committees which will guarantee continuous collaboration across all three domains.

For Employees and Individuals

- a. Home-based workstations should be evaluated by employees through three validated assessment tools which include OSHA checklists and Rapid Office Strain Assessment.
- b. Following the 20-20-20 eye-rest rule needs to be executed through movement exercises which use specific activities that include stretching routines and breaks for movement.
- c. The process of boundary management with digital hygiene implementation will help reduce technostress and cognitive overload.
- d. People who want to promote ergonomic support should create their own networks to enroll in training programs which will help them learn about ergonomics better.

For Future Research

- a. The research would involve conducting longitudinal field studies which will study how physical cognitive and organizational ergonomic interventions combine to create long-term effects on productivity and burnout and MSDs.
- b. The research should evaluate how wearable posture sensors and AI-driven real-time ergonomic feedback and adaptive interfaces function across hybrid work environments.
- c. Hybrid employees in developing economies will face more difficulties than those who work in office spaces because they need special home office equipment which requires different ergonomic standards based on their cultural and economic background.
- d. Organizations which use hybrid and remote work must design an "Ergonomic Climate Index" which measures three company elements to forecast their employee health and work performance.

Organizations can turn hybrid work environments into sustainable benefits for employee health and work performance because their hybrid work system will depend on their internal operational systems. The case evidence demonstrates that organizations must invest in holistic ergonomic systems because these systems will drive their future organizational resilience during workplace operations.

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