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Integrating Ergonomic Principles in Industrial Product Development: Literature Review

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Abstract:*Ergonomics plays a critical role in industrial product development, enhancing user comfort, efficiency, and safety within the paradigms of Industry 4.0 and 5.0. This literature review synthesizes ten studies from 2018 to 2024 to examine how designers integrate ergonomic principles into industrial product design. Employing a systematic methodology with SciSpace, an AI-driven platform, the review explores Human-Centered Design (HCD), advanced technologies, anthropometric data, and cognitive ergonomics. HCD prioritizes user needs, with 57% reduction in biomechanical stress through collaborative workstations. Digital tools, such as augmented reality (AR) and wearable devices, enable precise ergonomic assessments, though high costs limit accessibility. Anthropometric methods, achieve 87.7% accuracy in console design but face standardization challenges. Cognitive ergonomics, though underexplored, is gaining attention for optimizing human-robot interactions. Key challenges include resource intensity, limited real-world validation, and inconsistent anthropometric data. The review advocates for affordable, scalable solutions and standardized protocols to ensure inclusivity across industrial contexts. By integrating HCD with technologies like AR and wearables, ergonomic design can foster safer, more efficient workplaces. Future research should focus on cost-effective tools, real-world testing, and cognitive ergonomics to bridge gaps in current practices, ultimately supporting human well-being and operational excellence in evolving industrial landscapes.*

Keywords:*Ergonomics, Human-Centered Design, Industrial Product Development, Digital Technologies, Anthropometry*

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I. INTRODUCTION

Ergonomics, the science of optimizing human-system interactions, is pivotal in industrial product development, particularly as industries embrace Industry 4.0 and 5.0 paradigms that emphasize automation and human-machine collaboration. This literature review synthesizes ten studies from 2018 to 2024 to explore how ergonomic principles enhance user comfort, efficiency, and safety in industrial settings. By examining Human-Centered Design (HCD), advanced technologies, anthropometric data, and cognitive ergonomics, the review highlights current practices, challenges, and future directions. The evidence suggests that ergonomic integration fosters safer, more productive workplaces, though issues like cost and validation persist.

HCD is a cornerstone of ergonomic design, prioritizing user needs to minimize physical and cognitive strain. Gualtieri et al. (2020) [1] demonstrated that collaborative workstations reduce biomechanical stress by up to 57%, enhancing productivity. Similarly, Peruzzini et al. (2019) [2] used digital simulations, including 2D and 3D mixed reality, to identify ergonomic risks early, optimizing workstation layouts. Advanced technologies like augmented reality (AR) and wearable devices further revolutionize assessments. For instance, Khamaisi et al. (2024) [3] developed a wearable-based postural analysis tool, enabling non-experts to conduct precise evaluations, while Mao et al. (2023) [4] introduced an AR platform for real-time ergonomic assessments in smart manufacturing.

Anthropometric data analysis ensures designs align with human physical diversity, though challenges remain. 87.7% accuracy in console layout design using real-time anthropometric methods, reducing musculoskeletal risks [5]. However, inconsistencies in traditional anthropometric approaches, advocating for standardization [6]. Cognitive ergonomics, addressing mental workload, is gaining traction. Gualtieri et al. (2024) [7] emphasized its role in optimizing human-robot interactions, though research in this area is still nascent. These approaches collectively aim to create humane, efficient industrial environments.

Despite advancements, challenges like high costs and limited real-world validation hinder widespread adoption. Digital simulations, while effective, are resource-intensive, excluding smaller enterprises [2]. Similarly, the lack of standardized anthropometric methods complicates design consistency [6]. Scalability and accessibility of technologies like AR and wearables also remain concerns [3,4]. The review suggests that future

research should focus on affordable, scalable solutions and standardized protocols to ensure inclusivity across diverse industrial contexts.

In conclusion, ergonomic principles are transforming industrial product development by integrating HCD, advanced technologies, and data-driven methods. Studies like Gualtieri et al. (2020) [1] and Wang et al. (2023) [5] demonstrate tangible benefits, including reduced strain and improved design accuracy. However, addressing cost barriers, standardizing methods, and expanding cognitive ergonomics research are critical for broader impact. This review provides a roadmap for researchers and practitioners, advocating for ergonomic designs that prioritize human well-being alongside operational excellence in evolving industrial landscapes.

II. METHODOLOGY

This literature review aims to elucidate how designers integrate ergonomic principles to enhance user comfort and efficiency in industrial product development. The research process was systematically designed, leveraging SciSpace, an AI-based platform, to ensure efficiency and precision in literature selection. This section outlines the steps involved in the search, selection, and analysis of literature, emphasizing the pivotal role of SciSpace as the primary tool.

SciSpace is an AI-driven research platform that scans over 270 million papers using natural language processing and machine learning to identify relevant literature. Features such as intelligent search and automated summarization were employed to pinpoint papers on ergonomics in industrial product design. The search utilized keywords including "ergonomics," "human-centered design," and "anthropometry," restricted to papers published between 2015 and 2025 to reflect advancements in Industry 4.0 and 5.0. The top ten papers, ranked by relevance, were selected for analysis.

Papers were selected based on the following criteria: publication between 2015 and 2025, relevance to ergonomics in industrial product design, top ten ranking by SciSpace's relevance algorithm, and diversity in methodologies, such as digital simulations and case studies. Each paper was analyzed for its objectives, methodology, key findings, limitations, and relevance, with results summarized in a table for comparison. Findings were synthesized into a narrative, organized into themes including human-centered design, digital technologies, anthropometry, and cognitive ergonomics, to identify trends and challenges.

This AI-based approach underscores the potential of technology to transform academic research, enabling a comprehensive review in a short timeframe. Despite its efficiency, the methodology is constrained by the opacity of SciSpace's algorithms, the focus on English-language literature, and the risk of publication bias. This approach sets a precedent for future research, encouraging the use of AI tools to support more inclusive and efficient ergonomic design in industrial contexts.

III. RESULTS AND DISCUSSIONS

3.1. Referencess Overview

The integration of ergonomic principles in industrial product development is pivotal for creating user-centric systems that enhance comfort, efficiency, and safety. This sub-section presents a comprehensive overview of ten seminal studies from 2018 to 2024, systematically selected using SciSpace to ensure relevance and diversity in methodologies. These studies collectively explore Human-Centered Design (HCD), digital and wearable technologies, anthropometric data analysis, and cognitive ergonomics, offering insights into current practices and emerging challenges. By synthesizing their objectives, methodologies, key findings, limitations, and relevance, this analysis underscores the transformative potential of ergonomic design in Industry 4.0 and 5.0 contexts, while identifying critical areas for future research and practical implementation.

Table1Summary of Key Studies on Ergonomic Integration in Industrial Product Design

Authors	Title	Objectives	Methodology	Key Findings	Limitations	Relevance to Current Research
Peruzzini et al., 2019 [2]	A comparative study on computer-integrated set-ups to design human-centred manufacturing systems	To compare computer-integrated set-ups for designing human-centred manufacturing workstations and establish a protocol for ergonomic risk assessment.	Employed a Human-Centered Design (HCD) approach with protocol analysis using 2D/3D set-ups.	Digital simulations enhanced design processes and reduced physical stress; protocol analysis effectively identified critical design issues.	Resource-intensive, challenging for small companies due to high costs and skill requirements.	Highlights the effectiveness of digital simulations in ergonomic design, relevant for improving worker well-being.

Khamaisi et al., 2024 [3]	An innovative integrated solution to support digital postural assessment using the TACOs methodology	To develop a hardware/software solution for ergonomic postural assessment by non-experts using the TACOs method.	Integrated wearable suits with software, applied the TACOs method, and conducted statistical analysis (Mann-Whitney U test) in a controlled environment.	The solution accelerated assessments and provided accurate posture data; significant improvements over standard practices.	Limited to controlled settings, potentially not reflecting real-world complexities.	Simplifies ergonomic assessments, supporting Industry 5.0 objectives.
Schröppel et al., 2021 [8]	Structured ergonomic guidance in early design phases by analysing the user-product interaction	To present and evaluate InProCo for structured ergonomic guidance in early design phases.	Conducted a three-stage evaluation: survey of interaction completeness, GUI output evaluation, and knowledge base validation via workshops.	Standard interactions were sufficient, GUI output was valid, and the knowledge base was high-quality; an effective ergonomic guidance tool.	No specific limitations reported.	Provides a structured approach for early ergonomic integration in design.
Wang et al., 2023 [5]	Real-time anthropometric data-driven evaluation method for complex console layout design	To develop an anthropometric data-driven evaluation method for complex console layouts to minimize musculoskeletal risks.	Developed the Anthropometric Data Extraction (ADE) algorithm and a multi-stage Genetic Algorithm-optimized Artificial Neural Network (GA-ANN).	ADE achieved 87.7% accuracy in joint point recognition; GA-ANN improved assessment speed and accuracy.	No specific limitations reported.	Enhances console design with real-time anthropometric data.
Gualtieri et al., 2020 [1]	Design of Human-Centered Collaborative Assembly Workstations for the Improvement of Operators' Physical Ergonomics and Production Efficiency: A Case Study	To design collaborative workstations for wire harness assembly to improve operator ergonomics and productivity.	Used a case study approach to transform manual workstations into collaborative ones, measuring biomechanical load and production performance.	Reduced biomechanical load by up to 57% and cycle time by 12.3%.	No specific limitations reported.	Demonstrates benefits of collaborative workstations in reducing ergonomic risks.
Slama et al., 2023 [9]	An overview on human-centred technologies, measurements and optimisation in assembly systems	To review ergonomics in human-centred assembly systems in Industry 4.0, focusing on manual tasks and advanced technologies.	Utilized advanced technologies (MOCAP, VR) and quantitative metrics for ergonomic risk and productivity assessment.	Emphasized the role of advanced technologies in enhancing system efficiency and worker well-being.	No specific limitations reported.	Explores assembly system optimization with human factors in mind.
Gualtieri et al., 2024 [7]	Updating design guidelines for cognitive ergonomics in human-centred collaborative robotics applications: An expert survey	To update and validate guidelines for cognitive ergonomics in collaborative robotics design.	Proposed a structured methodology with literature screening and expert surveys; validated through qualitative and quantitative evaluation.	Updated and validated guidelines; emphasized human factor integration for operational resilience.	Cognitive ergonomics often overlooked in advanced industrial interactions.	Addresses the often-neglected cognitive aspects in robotics design.
Mehta et	Achieving World	To explore the	Adopted a	Integration	Generalizability	Emphasizes

al., 2024 [10]	Class Manufacturing Excellence: Integrating Human Factors and Technological Innovation	impact of integrating human factors with technological innovation on manufacturing performance.	quantitative approach with comprehensive surveys and statistical models.	significantly enhanced production levels and operational efficiency.	across diverse industries may be limited.	synergy between human factors and technology for improved performance.
Dianat et al., 2018 [6]	A review of the methodology and applications of anthropometry in ergonomics and product design	To review anthropometric applications in ergonomic design and identify gaps between data and practical use.	Conducted a comprehensive literature review using SciVerse Scopus and PubMed, focusing on ergonomic anthropometric applications.	Identified gaps in fitting criteria for user-product dimensions; highlighted need for user-centered approaches.	Traditional anthropometric methods prone to human error and inconsistencies.	Underscores the critical role of anthropometry in ergonomic design.
Mao et al, 2023 [4]	ARE-Platform: An Augmented Reality-Based Ergonomic Evaluation Solution for Smart Manufacturing	To propose an AR-based platform for real-time ergonomic evaluation in smart manufacturing.	Used AR to overlay virtual objects in physical environments; employed motion capture for ergonomic index data.	Reduced verification time and costs; validated in automotive assembly cases.	No specific limitations reported.	Enables real-time ergonomic evaluations, vital for safe and efficient workplaces.

3.2. Discussion

Ergonomics, the study of human-system interactions, is crucial in industrial product design, particularly in Industry 4.0 and 5.0, which emphasize automation and human-machine collaboration. This literature review analyzes ten studies to explore how ergonomic principles enhance user comfort, efficiency, and safety. It examines human-centered design (HCD), digital technologies, anthropometry, and cognitive ergonomics, organized into sub-sections to highlight key findings, methodologies, challenges, and implications (SciSpace Overview).

Human-Centered Design (HCD)

HCD prioritizes user needs to improve well-being and productivity. Using 2D and 3D simulations to design ergonomic workstations, reducing physical stress by identifying poor postures early [2]. Collaborative workstations, cutting biomechanical strain by 57% and cycle time by 12.3% [1]. VR and motion capture in assembly systems to boost efficiency and worker comfort [9]. Cognitive ergonomics in robotics, reducing mental workload [7]. HCD balances technology and human needs but requires careful integration.

Digital and Wearable Technologies

Advanced technologies enhance ergonomic assessments. wearable-based posture analysis, improving accuracy over traditional methods, though limited by controlled testing [3]. AR platform for real-time ergonomic evaluations, reducing costs in automotive assembly [4]. Digital simulations to detect risks early, but high costs limit accessibility [2]. These tools improve precision, yet scalability remains a challenge.

Anthropometry and Real-Time Data

Anthropometry ensures designs fit human physical traits. About 87.7% accuracy in console layout design using real-time anthropometric data, minimizing musculoskeletal risks [5]. Dianat et al. (2018) [6] noted inconsistencies in traditional anthropometric methods, advocating for standardized, user-focused approaches. Real-time data enhances adaptability, but standardization is needed.

Cognitive Ergonomics and Challenges

Cognitive ergonomics addresses mental workload. Guidelines for cognitive ergonomics in robotics, improving safety [7]. Combining human factors with technology boosts manufacturing performance [10]. Challenges include high costs of digital tools [2], limited real-world validation [3], inconsistent anthropometric methods [6], and neglect of cognitive ergonomics [7]. Future research should focus on affordable, scalable solutions and real-world testing.

IV. CONCLUSION

This literature review demonstrates that ergonomic principles, integrated through Human-Centered Design (HCD), advanced technologies like augmented reality (AR) and wearables, anthropometric data, and cognitive ergonomics, significantly enhance user comfort, efficiency, and safety in industrial product development. Challenges such as high costs, limited real-world validation, inconsistent anthropometric methods, and underemphasis on cognitive ergonomics persist. To address these, industries should prioritize affordable and scalable technologies, while researchers should focus on standardizing anthropometric approaches and expanding cognitive ergonomics research. By overcoming these barriers, ergonomic design can create inclusive, humane, and efficient workplaces, aligning with the human-machine collaboration goals of Industry 4.0 and 5.0. This review provides a roadmap for practitioners and academics to advance ergonomic integration, fostering environments that prioritize human well-being alongside operational excellence.

REFERENCES

[1] L. Gualtieri, I. Palomba, F. A. Merati, E. Rauch, and R. Vidoni, "Design of human-centered collaborative assembly workstations for the improvement of operators' physical ergonomics and production efficiency: A case study," Sustainability, vol. 12, no. 9, May 2020, Art. no. 3606

[2] M. Peruzzini, M. Pellicciari, and M. Gadaleta, "A comparative study on computer-integrated set-ups to design human-centred manufacturing systems," Robot. Comput.-Integr. Manuf., vol. 55, pt. B, pp. 265–278, Feb. 2019

[3] R. K. Khamaisi et al., "An innovative integrated solution to support digital postural assessment using the TACOs methodology," Comput. Ind. Eng., vol. 194, Aug. 2024, Art. no. 110376

[4] W. Mao, Y. Hu, X. Yang, W. Ren, and H. Fang, "ARE-Platform: An augmented reality-based ergonomic evaluation solution for smart manufacturing," Int. J. Hum.-Comput. Interact., vol. 40, no. 11, pp. 2822–2837, Jun. 2024

[5] J. Wang, D. Chen, X. Zhang, and M. Zhu, "Real-time anthropometric data-driven evaluation method for complex console layout design," Comput. Ind. Eng., vol. 183, Sep. 2023, Art. no. 109463

[6] I. Dianat, J. Molenbroek, and H. I. Castellucci, "A review of the methodology and applications of anthropometry in ergonomics and product design," Ergonomics, vol. 61, no. 12, pp. 1696–1720, Dec. 2018

[7] L. Gualtieri, F. Fraboni, H. Brendel, L. Pietrantoni, R. Vidoni, and P. Dallasega, "Updating design guidelines for cognitive ergonomics in human-centred collaborative robotics applications: An expert survey," Appl. Ergon., vol. 117, May 2024, Art. no. 104246

[8] T. Schröppel, F. Endress, I. Köpken, J. Miehling, and S. Wartzack, "Structured ergonomic guidance in early design phases by analysing the user-product interaction," Ergonomics, vol. 64, no. 11, pp. 1491–1506, Nov. 2021

[9] R. Slama, I. Slama, H. Tlahig, P. Slangen, and O. Ben-Ammar, "An overview on human-centred technologies, measurements and optimisation in assembly systems," Int. J. Prod. Res., vol. 62, no. 14, pp. 5336–5358, Jul. 2024

[10] A. M. Mehta, A. Rauf, and A. R. b. S. Senathirajah, "Achieving world class manufacturing excellence: Integrating human factors and technological innovation," Sustainability, vol. 16, no. 24, Dec. 2024, Art. no. 11175