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The Role of Human Factors and Ergonomics in Evaluating Employee Well-Being During Digital Technology Implementation: A Systematic Literature Review

Quintal Henry Battle
Department of Industrial Engineering and Management Systems
University of Central Florida
Orlando, Florida 32816
qu998299@ucf.edu

Abstract

Manufacturing organizations have adopted Industry 4.0 and introduced digital technologies within manufacturing organizations to improve productivity and efficiency, as well as support sustainability goals as presented in Industry 5.0. Adopting digital technology will require employees to interact with these technologies to improve performance, enhance safety, and meet productivity goals. When integrating these digital technologies into manufacturing work systems, it is critical to identify and mitigate risks to employee well-being. The author conducted a systematic literature review focusing on a human factors and ergonomics (HF/E) approach to examine how studies measure employee well-being when introducing digital technologies. Approximately 75% of the studies in the literature focus on physical and cognitive ergonomics, which evaluate the design of specific digital technologies and measure the physical risks and mental load impact on employee well-being. The studies also show that many widely accepted evaluation methodologies and tools exist to examine the physical and cognitive ergonomic aspects. However, limited research in organizational ergonomics considers the socio-technical systems in which employees interact. As a result, there are limited frameworks that provide comprehensive HF/E guidance on evaluating, designing, and implementing digital technologies to support employee well-being. Future research could benefit from more empirical research on the impacts of organizational human factors and ergonomic strategies on employee well-being. This includes identifying standardized design and evaluation methodologies and critical organizational success factors that contribute to employee well-being. Additionally, as organizations increasingly implement digital technologies and seek to focus on worker well-being, further research would benefit from a comprehensive examination of physical, cognitive, *and* organizational ergonomic aspects.

Keywords
Industry 4.0, Industry 5.0, Human Factors, Ergonomics, Well-being

1. Introduction
Industry 4.0, or the fourth industrial revolution, was first introduced as a concept in November 2011 by the German government and later became a German national strategy in 2013 to achieve a competitive advantage in manufacturing. Industry 4.0 is now broadly accepted among most global industrialized economies. Research indicates that there is generally no broadly adopted standard definition for Industry 4.0. However, Nosalska et al. (2020), through a systematic literature review and meta-analysis methodology, proposed the following definition: “Industry 4.0 is a concept encompassing organizational and technological changes, value chain integration, and the development of new business models driven by customer needs and mass customization requirements, enabled by innovative technologies, connectivity, and IT integration" (p. 849). Industry 4.0 represents the implementation of digital and advanced technologies in manufacturing, including the Internet of Things (IoT), cyber-physical systems, big data and analytics,

artificial intelligence and machine learning, cloud computing, autonomous robots, additive manufacturing, augmented reality, virtual reality, simulation, digital twins, blockchain, and edge computing. Industry 4.0 provides organizations with competitive advantages, including higher manufacturing quality, operational efficiency, manufacturing agility, and improved customer satisfaction (Sony et al., 2021). As Industry 4.0 becomes integral to modern manufacturing, more organizations will increasingly adopt it to realize its benefits. According to the International Data Corporation (IDC), current trends in Industry 4.0 include predictive maintenance and monitoring, utilization of artificial intelligence and machine learning to enhance processes, and supporting sustainability initiatives (Lee & Hojlo, 2024).

Although Industry 4.0 can benefit organizations, it can come with challenges. Human resource and organizational challenges are among the top issues seen within manufacturing organizations. These challenges often involve employees' resistance to change and a lack of Industry 4.0 training, which provides the skills and expertise required for success (Sony et al. 2021; Dikhanbayeva et al. 2021). Skilled workers and workers' resistance to change can influence a company's decision to start or continue with the Industry 4.0 implementation process (Bajic et al. 2021). Industry 4.0 implementation is also challenged by a need for more organizational interventions, such as changes in management and implementation plans, management support, and poor communication (Dikhanbayeva et al. 2021).

Since employees are critical to the success of Industry 4.0 (Sony et al. 2021), focusing on their needs becomes even more important to the company's implementation of these technologies. Introduced as a concept in 2021, Industry 5.0 builds upon Industry 4.0, focusing on creating a sustainable, resilient, and human-centric manufacturing industry, further supporting the need for work systems with the worker in mind (Zizic et al. 2022). The increasing introduction of digital technology, as seen with Industry 4.0, will require manufacturing workers to use, interact with, and work alongside these technologies. Industrial 4.0 systems are socio-technical systems involving people, so workers' needs must be at the forefront of system design and implementation (Neumann et al. 2021). Human factors and ergonomics (HF/E) that center on employee well-being mediate the successful implementation of Industry 4.0 (Virmani & Salve 2023; Kadir et al.2020).

According to Kadir & Broberg (2020), introducing new digital technology initially negatively impacts employee well-being and system performance, but successful implementation can improve both. In their study to examine the current state of HF/E research related to Industry 4.0 in manufacturing, Reiman et al. (2021) emphasize threats to workers' well-being when the demands of advanced technology do not align with organizational and human capabilities or needs. However, to address the complexity that transitioning to Industry 4.0 brings to the manufacturing industry and support the goals of Industry 5.0, it will then be necessary to assess a company's HF/E capabilities to prevent the neglect of human needs, as was the case in the previous industrial revolutions (Reiman et al. 2023). Research has shown that considering workers' physical, cognitive, and organizational needs and overall well-being is critical when implementing digital technologies and systems. Therefore, this review aims to understand the current state of the literature concerning efforts to assess human factors and ergonomic impacts on employee well-being during the design and implementation of digital work. systems. The two research questions addressed in this review are:

What Human Factors and Ergonomics (HF/E) strategies or approaches address worker well-being in manufacturing environments with the introduction of digital technology?
What research gaps exist in studying human factors and ergonomics strategies for improving the well-being of manufacturing employees interacting with digital technologies?
The following sections address the following topics: Section 2 establishes the foundation and methodology of the systematic literature review. Section 3 presents the review's key findings, along with a discussion of the implications. Finally, Section 4 outlines conclusions and future recommendations.

2. Methodology

The systematic literature review follows PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) for systematic data collection. To acquire peer-reviewed articles, the researcher accessed the Web of Science and ProQuest databases to gather literature supporting this review. The researchers searched the databases using specific search strings to collect academic papers that (1) were published online between 2011, the introduction of Industry 4.0, and 2025; (2) appeared in journals; (3) included at least one of the search terms in their titles, abstracts, or keywords; and (4) were written in English. To identify search keywords, the researcher searched Web of Science and Google Scholar to understand the keywords used in systematic reviews or literature reviews among leading articles on related topics, as illustrated in Table 1.

Table 1. Keyword Identification Summary

Keyword	Source/Reason for Including
"industry 4.0" OR "industry 5.0" or "smart factor*" OR "fifth industrial revolution" OR "fourth industrial revolution" OR "digital transformation" OR "digital technolog*" OR "digital tool*" OR "digital industry" OR "digital age"	Psarommatis et al. (2023) Zheng et al. (2020) Zizic et al., 2022 - Added Industry 5.0, which moved from a technology-only focus to human-centricity and well-being (add reference)
human factors OR ergonomics OR "user-centered design" OR "user centered design" OR "workplace ergonomics" OR "cognitive ergonomics" OR "physical ergonomics" OR "organizational ergonomics"	Kadir et al. (2019)
well-being OR "well being" OR health OR satisfaction OR stress OR risk*	Included based on the research objective and questions

The search string employed the Boolean search: ("industry 4.0" OR "industry 5.0" OR "smart factor*" OR "fifth industrial revolution" OR "fourth industrial revolution" OR "digital transformation" OR "digital technolog*" OR "digital tool*" OR "digital industry" OR "digital age") AND (human factors OR ergonomics OR "user-centered design" OR "user centered design" OR "workplace ergonomics" OR "cognitive ergonomics" OR "physical ergonomics" OR "organizational ergonomics") AND (well-being OR "well being" OR health OR satisfaction OR stress OR risk*). A search was conducted in the Web of Science database using the topic search fields, which included titles, abstracts, and indexing. A second search took place in the ProQuest database using the 'All abstract & summary text' search fields. The Web of Science search identified 510 unique works. The ProQuest search yielded over 58 unique works. After retrieving the articles and checking for duplicates, the researcher selected relevant journal papers by reviewing the titles and abstracts and excluding those that did not explicitly relate to the research questions. The remaining full-text articles were screened for applicability and excluded based on specified criteria. The exclusion criteria used in the screening included:

(1) conceptual works only, with no application or testing of hypotheses or literature, systematic or bibliometric reviews;
(2) articles not focused on the target population of manufacturing industries or industries employing assembly and production workers;
(3) materials unrelated to the research questions, with little to no emphasis on human factors and ergonomics or employee well-being, or
(4) articles not provided in English.

Figure 1 summarizes the study selection process and the number of studies selected at various stages.

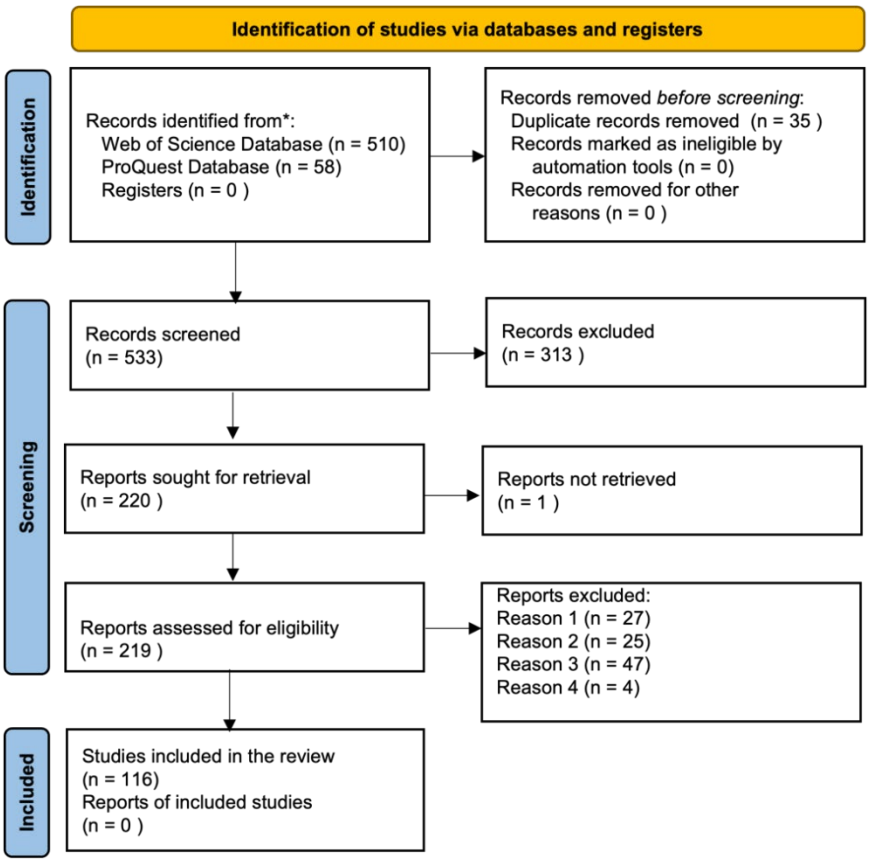

Figure 1. PRISMA Approach to Systematic Literature Review

3. Findings and discussion

3.1 Number of publications per year

A total of 116 articles met the inclusion criteria of the study. Figure 2 presents the number of articles published since the introduction of Industry 4.0 in 2011. Researchers have seen a growing trend in publications starting in 2020. The substantial increase in publications compared to previous years suggests a growing interest, driven by the introduction of Industry 5.0, which emphasizes human well-being. The increase may also indicate the maturation and adoption of Industry 4.0 technologies in manufacturing environments.

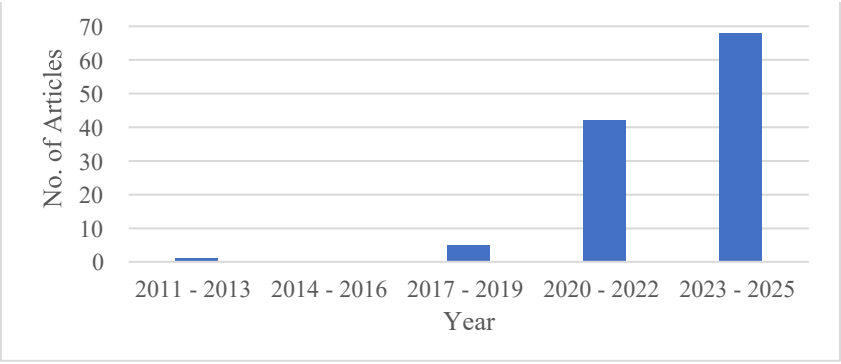

Figure 2. Publications per year

3.1.1 Number of publications per Human Factors and Ergonomics area of study

Figure 3 and Table 2 outline the distribution of articles by the human factor and ergonomic (HF/E) focus area of study. Examining the physical ergonomic impacts of digital work systems on employee well-being is a dominant theme in the literature. A few studies addressed cognitive or organizational ergonomics, though these areas received less attention than physical ergonomics. However, few studies adopted a holistic approach that simultaneously addressed physical, cognitive, and organizational ergonomics. This analysis underscores a strong research focus on physical ergonomics, while revealing a notable gap in comprehensive, integrative studies, highlighting a gap that future research could address.

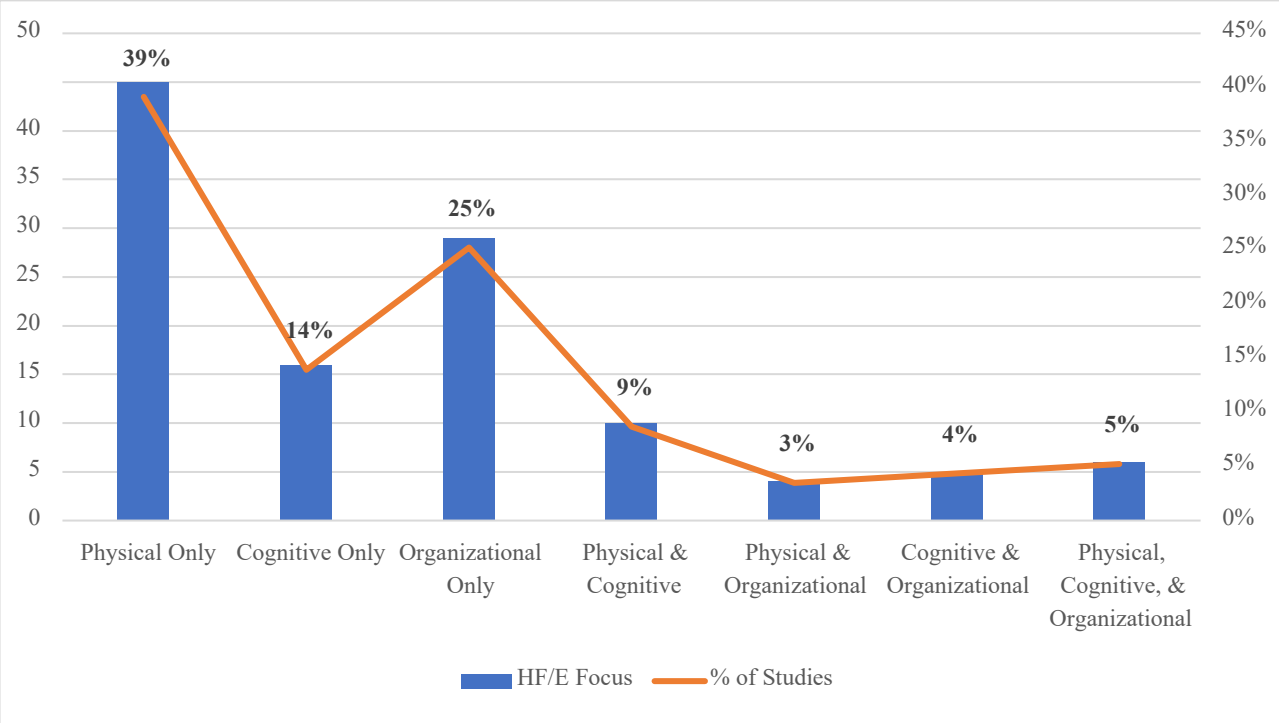

Figure 3. Publications per HF/E focus area

Table 2. Map of Research Gaps to Research Questions and Publications

Research Gap	Research Question	Authors
Limited studies examine organizational ergonomic factors that contribute to employee well-being or lack a holistic approach to examining HF/E's impact on worker well-being using digital work systems. 39% of studies focused only on physical ergonomics. 14% of studies focused only on cognitive ergonomics. 25% of studies focused only on organizational ergonomics. 3% of studies focused on physical and organizational ergonomics. 4% of studies focused on cognitive and organizational ergonomics. 5% of studies focused on physical, cognitive, and organizational ergonomics.	RQ1/RQ2	Studies focused only on physical ergonomics: Abdous et al., 2022, Adem et al., 2020, Alexopoulos et al., 2013, Bajičová et al., 2024, Bortolini et al., 2020, Bortolini et al., 2023, Caputo et al., 2019, Caruana & Francalanza, 2021, Caterino et al., 2022, Ciccarelli et al., 2024, Colim et al., 2021, Colim et al., 2021, Destouet et al., 2024, Di Paolo et al., 2024, Digesi et al., 2018, González-Alonso et al., 2024, Gualtieri et al., 2020, Hémono et al., 2024, Keshvarparast et al., 2024, Khamaisi et al., 2024, Lasota & Hankiewicz, 2024, Laudante, 2017, Lind et al., 2024, Lind et al., 2024b, Ling et al., 2022, Lou et al., 2024, Mao et al., 2023, Mark et al., 2021, Markova et al., 2023, Meregalli Falerni et al., 2023, Nourmohammadi et al., 2023, Papetti et al., 2020bPapetti et al., 2022, Pascual et al., 2021Pistolesi et al., 2024, Ranavolo et al., 2020, Ronzoni et al., 2021, Ruiz de la Torre et al., 2024, Sardar et al., 2023, Selvaraj et al., 2024, Siew et al., 2020, Tirupachuri et al., 2021, Tomelleri et al., 2024, Vijayakumar & Sobhani, 2023, Yu et al., 2021 Studies focused only on cognitive ergonomics: Go et al., 2024, Hijry et al., 2024, Zakeri et al., 2023, Gervasi et al., 2022, Gervasi et al., 2023, Gervasi et al., 2024, Verna et al., 2024, Rojas et al., 2020, Ma et al., 2024, Lagomarsino et al., 2022, Mattsson et al., 2020, Ruiz de la Torre et al., 2024; Gervasi et al., 2023, Mingardi et al., 2020 Borghi et al., 2025, Fournier et al., 2022 Studies focused only on organizational ergonomics: Babamiri et al., 2024, Bolis et al., 2024, Bugvi et al., 2024, Buisine et al., 2024, Ciccarelli et al., 2022a, De Los Pinos et al., 2023, Fraboni et al., 2023, Galey et al., 2022, Galey et al., 2022b, Kadir & Broberg, 2020, Kadir & Broberg, 2021, Kang et al., 2021, Kwiotkowska & Gębczyńska, 2022, Leesakul et al., 2022, Lind et al., 2024, Malik et al., 2021, Markowski et al., 2021, Mubarak et al., 2024, Muñoz et al., 2019, Nadeem et al., 2024, Onofrejova et al., 2021, Paliga, 2022, Pauliková et al., 2021, Shankar & Gupta, 2024, Sitarević et al., 2023, Thylén et al., 2023, Tortorella et al., 2022, Tutak et al., 2020, Wong & Tajudeen, 2024

3.1.2 Physical and cognitive HF/E approaches to employee well-being

Digital technologies, introduced with Industry 4.0, are transforming work environments, prompting research into the impact of these technologies on employee well-being. Researchers utilize human factors and ergonomic methods, particularly physical and cognitive ergonomics, to understand this impact as assessment tools. As shown in Figure 2, a combined 75% of the articles examine employee well-being using physical and cognitive ergonomics. These approaches assess the physical risks and mental workload of digital technologies and work systems using validated methods and tools across various industries and technologies. The Rapid Upper Limb Assessment (RULA), Ovako Working Analysis System (OWAS), Rapid Entire Body Assessment (REBA), National Institute for Occupational Safety and Health (NIOSH), Occupational Repetitive Action (OCRA), and Ergonomic Assessment Worksheet (EAWS) are standard methods found in the literature for assessing postural load and risks of musculoskeletal disorders (Cicarella et al., 2022b; Papetti, Gregori et al., 2020; Peruzzini et al., 2020). Cognitive ergonomics methods incorporate both objective and subjective evaluations, with objective measures reinforced by subjective responses to ensure a comprehensive assessment of worker well-being (Gervasi et al., 2023). Objective measures obtained include physiological responses such as heart rate, blood pressure, breathing rate, and brain activity that assess mental workload. Subjective measures like the NASA Task Load Index (TLX) questionnaire, the Negative Attitude Toward Robots Scale (NARS), and the Self-Assessment Manikin (SAM) tools capture workers' perceptions of mental load, their reactions, and attitudes while interacting with digital technology. These established assessment methods provide comprehensive physical and cognitive ergonomics evaluation techniques, ensuring a thorough approach to understanding and promoting worker well-being in digital work environments, all backed by research and validated methods. The literature demonstrates how established physical and cognitive ergonomic methods serve as tools for

informing the design of human-centered work systems and enabling real-time measurement and monitoring of how digital technologies impact employees' physical and mental states.

In addition, research examines digital technology's physical and cognitive impacts on employee well-being, compares digital technology to traditional methods, and provides design guidance for creating work systems that prioritize employee needs and well-being through established methodologies. Gervasi et al. (2022, 2023, 2023b) examined the impact of human-robot collaboration on the operator's mental state by objective and subjective measures. Electrodermal activity (EDA), heart rates, and accelerometers objectively measured physiological stress. NARS measured operators' attitudes, and the Self-Assessment Manikin (SAM) measured their reactions to specific events. The results guided the configuration of manufacturing processes that leverage human and robot capabilities to optimize productivity. Sardar et al. (2023) evaluated ergonomic risk, assessed by RULA, REBA, and OWAS, of virtual reality environments for manufacturing applications. The study identified specific postures that posed the most physical risk to operators.

Some approaches compare the impacts of digital technology with traditional methods. Forero Velasco et al. (2022) assessed the ergonomic differences between traditional and human-centered workstations using the RULA method to assess postural load in real-time and the NASA TLX method to evaluate cognitive risk. Pascual et al. (2021) developed an optimization framework to understand the compromise between worker well-being, measured by the Rapid Upper Limb Assessment (RULA), and productivity, measured by cycle time. The study revealed that reducing cycle time resulted in higher RULA scores, indicating an increased risk of musculoskeletal disorders. Rinaldi et al. (2023) developed a design framework for the sustainability of human-robot systems, focusing on employee well-being related to safety as measured by work injury and risk exposure, physical ergonomics as measured by the Ovako Working Analysis System (OWAS), and energy expenditure and work organization as measured by recovery rate. The framework allows designers to understand how different configurations of human-robot collaborative systems contribute to sustainability. In developing a model that identifies ergonomic risks to help in decision-making regarding job scheduling, Battini et al. (2022) recommended sensors to measure heart rate and assessment of work systems for postural risks using the OCRA methodology. Collectively, these studies establish the effectiveness of ergonomic evaluation when designing and implementing digital technology work systems that balance performance with employee well-being.

The literature also details human factors and ergonomic strategies such as the real-time monitoring of employee tasks for physical and cognitive risks. The studies focus on assessing workers' physical and cognitive behaviors to optimize performance, reduce fatigue, and mitigate risks associated with repetitive tasks or mental overload. Many monitoring techniques involve digital technologies, as seen during the implementation of Industry 4.0. Simeone et al. (2023) proposed a human-cyber-physical systems (HCPS) tool to assess and monitor operator risks by integrating multi-dimensional sensors, sensor fusion, and IoT technologies that collect physiological, environmental, and manufacturing data to provide real-time feedback to operators. The HCPS tool guides decision-making by providing recommended system configurations. A study by Hijry et al. (2024) proposed a real-time monitoring of worker stress level response where machine learning models analyze physiological data collected by the Internet of Things (IoT) and smartwatches. The models accurately predicted stress levels and provided a reliable means of monitoring stress. Verna et al. (2024) studied real-time monitoring of electrodermal activity (EDA) and skin conductance response (SCR) via non-invasive biosensors to capture stress response during the use of collaborative assembly systems, where operator stress significantly correlated with assembly complexity (Verna et al. 2024).

The findings improved responsiveness to work design, which impacts workers' health. Ciccarelli et al. (2021) developed a tool that monitored the operator's activities to identify physical risks using inertial sensors for postural analysis, wearable smart devices to detect stress through electrodermal activity, and a motion capture system to monitor full-body movements. Based on the ergonomic analysis of the data, stress and no-stress classification of activities by machine learning algorithms support corrective actions. Velasco et al. (2022) proposed real-time monitoring of workers' posture while executing tasks using computer vision to address the physical risks to workers' health in developing a human-centered workstation. The data collected provides input to RULA (Rapid Upper Limb Assessment) and REBA (Rapid Entire Body Assessment) methods to evaluate postural risks. In combination with other ergonomic strategies, significant improvements were seen compared to traditional workstations (Velasco et al., 2022). These studies support the benefits of real-time monitoring and ergonomic assessments in designing adaptive, human-centered work systems that proactively address digital technologies' physical and mental demands.

The study of physical and cognitive ergonomic impacts on employee well-being in digital work environments is well-supported by established assessment tools. The literature highlights the benefits of measuring and monitoring physical and cognitive risks, demonstrating that these assessments contribute to improved work system design and reduce negative impacts on employee well-being.

3.1.3 Organizational HF/E approaches to employee well-being

Compared to studies on physical ergonomics, researchers have devoted less attention to organizational ergonomics when examining its impact on employee well-being. Additionally, the literature shows well-established tools and methodologies for physical and cognitive ergonomics, whereas organizational ergonomics lacks widely adopted evaluation tools and frameworks. The literature demonstrates the evaluation of organizational ergonomics by predominantly using novel questionnaires and surveys to capture employees' views and perceptions of HF/E strategies in digital work systems. The literature also presents organizational HF/E as encompassing methodologies and guidelines that promote the human-centric design and implementation of digital manufacturing systems. Monitoring and feedback systems that leverage digital technologies further illustrate how organizational ergonomics can optimize socio-technical systems and promote worker health and safety. Several studies in the literature review employ various organizational HF/E methods to improve design and enhance employee well-being.

Questionnaires and surveys, generally novel, are widely used in studies to assess the impact of organizational ergonomic factors on employee well-being. These methods provide insights into their significance and identify key success factors contributing to employee well-being. Many studies have developed new questionnaires to capture relevant factors and to examine how organizational human factors and ergonomic elements impact job satisfaction and overall well-being. Kwiatkowski and Gębczyńska (2022) developed and validated a novel Work Design Questionnaire where employees give feedback on their perceptions of task characteristics, knowledge characteristics, social characteristics, and contextual characteristics as influencing factors of job satisfaction during digital transformation. The study identifies knowledge characteristics such as job complexity, information processing, problem-solving, skill characteristics, and specialization as critical factors to job satisfaction. Bugvi et al. (2024) also explored the contribution of personal characteristics and perceptions of external factors on work design, work performance, and satisfaction through a novel questionnaire.

The authors assessed employee dissatisfaction regarding organizational factors such as incentives, autonomy, job rotation, and satisfaction with training, goal setting, and feedback. Employees also positively resonated with social factors of the work environment, such as communication and cohesiveness among work groups. The questionnaire effectively captured personal characteristics and work design factors that enhance worker satisfaction with digital technologies (Bugvi et al. 2024). Bolis et al. (2024) also aimed to improve worker well-being by proposing a novel employee questionnaire to assess and address psychosocial risks, such as how work is organized and managed, social interactions, and organizational leadership support. The literature presents the importance of organizational ergonomic measures on employee well-being. However, there is no standardized method across these studies for assessing their impacts or determining the contributing factors to employee well-being, as most existing approaches rely on newly developed, study-specific methodologies. Future research could examine whether standardized methods are feasible and beneficial or if customization is necessary based on the specific technology, organizational context, or implementation approach.

Another area of organizational ergonomics presented in the literature is the development of structured guidelines and frameworks to support the implementation of digital technology with organizational erg considerations. Guidelines and frameworks support developing and optimizing organizational structures, policies, and processes, key tenets of organizational ergonomics. Studies propose structured frameworks to integrate Industry 4.0 technologies and support human factors and ergonomics while ensuring worker well-being. These frameworks provide organizational HF/E guidance to identify key challenges, objectives, and strategies for effective digital transformation. Pascual et al. (2021) developed a multi-objective optimization algorithm framework for workstation design to optimize productivity and employee well-being as defined by work-related musculoskeletal disorders and validated by RULA. Pereira et al. (2023) developed the Risk Assessment for Ergonomics and Safety in Logistics (RAES-Log) methodology to identify and mitigate ergonomic risks, mainly work-related musculoskeletal disorders, by integrating augmented reality into work tasks and task monitoring. The findings highlight measures to operationalize organizational ergonomics through frameworks and methodologies, providing practical guidelines to align digital transformation with employee well-

being. However, the study also highlights the need for further empirical validation and integration across diverse manufacturing contexts.

The literature review shows the importance of participatory ergonomics, a key aspect of organizational ergonomics, in which technology users engage in the design and implementation process to enhance system effectiveness and user satisfaction well-being. Galey (2022) examined a methodology integrating a social design approach with participatory ergonomics to develop socio-technical work systems. By involving stakeholders at all levels, including those directly interacting with digital technology, this approach addressed the complexity of socio-technical systems, ensuring stakeholder needs were met and reducing resistance to technological changes. Fraboni et al. (2023) evaluated eight organizational guidelines that promote employee well-being while integrating new technologies. The authors found that demonstrating the effectiveness and reliability of digital technology and consulting users and stakeholders in the decision-making process is critical when integrating digital technology into work systems. The studies highlight the effectiveness of participatory ergonomics in integrating digital technologies into work systems, resulting in increased technology acceptance, fewer implementation challenges, and the identification of best practices.

3.1.4 Comprehensive HF/E approaches to employee well-being

A comprehensive approach to employee well-being in digital work systems requires the integration of organizational ergonomics with physical and cognitive ergonomics, ensuring that work environments are not only physically and mentally supportive of employee well-being but also structured and introduced to optimize socio-technical systems. A limited number of studies in the literature comprehensively consider the three domains of human factors and ergonomics. Papetti et al. (2020) took a comprehensive ergonomic assessment approach in redesigning work systems to enhance workers' well-being, incorporating organizational, cognitive, and physical ergonomics. The study quantifies physical workloads using posture analysis, vital signs, and electrooculography to measure cognitive load. In contrast, the study did not directly measure organizational factors but considered them during the factory assessment by examining elements such as plant layout, resource mapping, and environmental conditions like air quality.

Additionally, Forero Velasco et al. (2022) examined a four-phased methodology for human-centered workstation design of cyber-physical production systems that ensures worker well-being by evaluating physical, cognitive, and organizational factors. The study assessed physical dimensions through noise exposure and postural effort and evaluated cognitive aspects by measuring mental workload and human error. However, a limitation of the study is that it only includes organizational ergonomic factors in measuring work design and job scheduling. In their Human Work Sustainability Tool, Ciccarelli et al. (2022) measured cognitive ergonomics by evaluating workers' perceptions of mental load and anxiety levels and physiological indicators such as heart rate, breathing rate, and eye metrics. The authors also assessed physical ergonomics by analyzing postural load. Although the primary emphasis was on physical and cognitive factors, the authors acknowledged the importance of integrating organizational ergonomics to achieve human-centered work systems, proposing the consideration of work design and scheduling practices. These studies demonstrate the need to address all three domains of ergonomics; however, they also illustrate how organizational ergonomics is often secondarily considered or constrained to work design or environmental conditions, highlighting a critical gap in comprehensive evaluation and the need for more integrated and measurable approaches.

While physical and cognitive ergonomics are well-researched and have established evaluation methods, organizational ergonomics remains under-researched, often only considered as a secondary factor or recommendation to address physical and cognitive ergonomic risks. The few studies that specifically assess organizational ergonomic strategies focus on environmental factors such as air quality, lighting, and noise. Future research could emphasize a comprehensive integration of all HF/E dimensions, highlighting social and organizational factors alongside physical and cognitive ergonomic evaluations. Additional research is also necessary to determine the feasibility and potential benefits of standardized evaluation methods for organizational ergonomic processes. Furthermore, future studies could develop methodologies to systematically gather employee feedback on the impacts and effectiveness of organizational ergonomic strategies.

4. Conclusions and Future Research

The literature review emphasizes the necessity for further research on organizational HF/E approaches to worker well-being, especially those that adopt a holistic perspective by collectively assessing physical, cognitive, and organizational ergonomics. Only 5% of studies utilize this comprehensive approach, while most focus on the physical or cognitive ergonomic effects of specific technologies, neglecting the broader work system from an organizational

ergonomics viewpoint. Many studies either exclude organizational ergonomics, limit it to aspects of the work environment, or only consider it to address physical and cognitive issues and challenges. Among the studies that incorporate organizational ergonomics, a common theme in the literature is that it enhances employee well-being, particularly from a social perspective that addresses worker needs and preferences. However, research examining how organizational and social factors influence well-being during the integration of digital technology in manufacturing remains limited. Most studies focus on the physical and cognitive aspects of work design, such as reducing repetitive movements, managing mental workload, or optimizing environmental conditions, including noise and lighting. Additional empirical research is required in organizational ergonomics, which focuses on standard evaluation measures and understanding the effects of organizational ergonomic strategies, or the absence thereof, on employee well-being with the introduction of digital technology.

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Biography

Quintal Henry Battle is a Ph.D. candidate in the Industrial and Management Systems department at the University of Central Florida with over 20 years of industry experience in manufacturing, quality, systems engineering, and

program management. He holds a Bachelor of Science degree in Mechanical Engineering from Florida A&M University and a Master of Science degree in Industrial Engineering from the University of Central Florida. Her research focuses on engineering management, process management and improvement, organizational dynamics, human factors, and systems engineering. With a strong background in both industry and academia, she is dedicated to advancing knowledge in these fields through research and practical applications.