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Exploring Human–AI Dynamics in Enhancing Workplace Safety and Health: A Narrative Review

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Abstract: Background: Artificial intelligence (AI) is revolutionizing occupational health and safety (OHS) by addressing workplace hazards and enhancing employee well-being. This review explores the broader context of increasing automation and digitalization, focusing on the role of human–AI interaction in improving workplace safety, health, and productivity while considering associated challenges. **Methods**: A narrative review methodology was employed, involving a comprehensive literature search in PubMed, Embase, and Scopus for studies published within the last 15 years. The review included studies examining AI applications in OHS, such as wearable technologies, predictive analytics and ergonomic tools, with a focus on their contributions and limitations. **Results**: Key findings demonstrate that AI enhances hazard detection, enables real-time monitoring, and improves training through immersive simulations, significantly contributing to safer and more efficient workplaces. However, challenges such as data privacy concerns, algorithmic biases, and reduced worker autonomy were identified as significant barriers to broader AI adoption in OHS. **Conclusions**: AI holds great promise in transforming OHS practices, but its integration requires ethical frameworks and human-centric collaboration models to ensure transparency, equity, and worker empowerment. Addressing these challenges will allow workplaces to harness the full potential of AI in creating, workplaces can leverage AI to foster safer, healthier, and more sustainable environments.

Keywords: occupational health and safety; artificial intelligence; human–AI interaction; workplace ergonomics; predictive analytics; worker autonomy; ethical frameworks; wearable technology

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1. Introduction

1.1. Rationale

Occupational Health and Safety (OHS) aims to protect workers' physical, mental, and social well-being by preventing workplace injuries, illnesses, and fatalities, primarily through safe work practices, ergonomic design, and by addressing psychosocial risks like stress or bullying [1–2]. Regulations from bodies like OSHA and WHO, combined with hazard assessments and emergency preparedness, help reduce the economic and social impacts of workplace hazards [2]. In many sectors—including manufacturing, construction, logistics, healthcare, and agriculture—Human-AI Interaction now automates high-risk tasks, provides predictive analytics, and offers immersive training simulations to improve safety and ergonomics [3]. For example, Artificial Intelligence (AI) tools can track workers' movements to reduce physical strain, give real-time alerts about environmental hazards, and streamline workflows [3]. Although these technologies boost safety and efficiency, they also raise concerns such as reduced job control, ethical questions, data privacy risks, and the potential for job displacement [4–5]. Studies like Germany's DiWaBe survey illustrate the

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mixed effects of automation on workplace dynamics: while it can enhance performance and lessen physical burdens, it may lower perceived autonomy and heighten mental fatigue [6–7]. AI systems that handle repetitive tasks often raise job satisfaction, but if they interfere with decision-making, workers can feel a loss of control and added stress [3–7]. To address these issues, frameworks like Parasuraman's Levels of Automation and Kaber and Endsley's models recommend balancing human oversight with AI support, ensuring that technology assists rather than dominates [8–9]. Such a responsible integration of AI can improve safety, productivity, and job satisfaction [10]. Nonetheless, for small and medium-sized enterprises (SMEs), the costs of specialized hardware, software, and employee training can be significant, making AI adoption challenging [4–5]. Careful planning, phased adoption, and possible financial support mechanisms can help SMEs overcome budget constraints, paving the way for human-centered AI solutions that prioritize worker autonomy, transparency, and reliability, ultimately facilitating safer and more efficient operations [1–10].

1.2. Objectives

The article aims to explore the impact of human-AI interaction on occupational health and safety, analyzing both the benefits AI offers, such as enhanced decision-making and task automation, and the challenges it presents, including potential reductions in worker autonomy and increased mental strain.

2. Materials and Methods

2.1. Focused Question

How does the integration of artificial intelligence impact workplace safety, employee health, and organizational efficiency in occupational health and safety settings?

2.2. Search

This narrative review aimed to summarize and analyze recent advancements in the application of artificial intelligence in occupational health and safety, with particular emphasis on its transformative potential and associated challenges. Unlike systematic reviews with strict eligibility criteria, this broader narrative review sought to explore a wide range of AI-driven tools and technologies, evaluate their efficacy, and identify existing knowledge gaps. A comprehensive literature search was conducted in PubMed, Embase, and Scopus using both MeSH terms and free-text keywords (see Table 1 for MeSH search terms). The inclusion and exclusion criteria are detailed in Table 2. Publications in English from the last 25 years were included. Two authors (J.F-R. and K.L.) independently screened the titles of retrieved records for relevance. From the selected articles, key data such as study design, AI applications, outcomes related to workplace safety and health metrics, and challenges such as ethical considerations and worker autonomy were extracted. Outcomes related to workplace safety enhancement, employee well-being, and potential adverse effects or limitations of AI implementation were also documented.

Table 1. MeSH keywords used in the study.

Category	MeSH Keywords
General Keywords	"Occupational Health", "Workplace", "Occupational Safety", "Occupational Health Services", "Occupational Exposure"
AI-Related Keywords	"Artificial Intelligence", "Machine Learning", "Deep Learning", "Automation", "Decision Support Systems, Clinical"
Health and Safety Metrics	"Ergonomics", "Risk Assessment", "Workplace Monitoring", "Safety Management", "Health Promotion"
Psychological and Social Aspects	"Stress, Psychological", "Mental Fatigue", "Job Satisfaction", "Mental Health"

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Applications and Tools	"Wearable Electronic Devices", "Sensors", "Predictive Analytics", "User-Computer Interface"

Table 2. Selection criteria for papers included in this review.

Inclusion Criteria	Exclusion Criteria
• Studies and real-world applications of AI in OHS. • Clinical or observational studies assessing the impact of AI on workplace safety, health metrics, and decision-making. • Review articles, meta-analyses, and theoretical frameworks relevant to human–AI interaction in OHS. • Recent and relevant studies focusing on AI tools for improving ergonomics, monitoring hazards, and enhancing OHS outcomes. • Investigations addressing psychological and social dimensions of AI integration in workplaces, such as job satisfaction, mental health, and ethical concerns. • Outcomes related to improvements in workplace safety, health metrics, worker autonomy, productivity, and employee well-being. • Articles published in English within the last 25 years to ensure relevance.	• Studies not related to AI applications in OHS or lacking clear focus on workplace safety and health improvements. • Editorials, commentaries, opinion pieces, and gray literature without empirical evidence. • Studies lacking specific outcomes or mechanisms related to human–AI interaction or safety metrics. • Articles with incomplete or inaccessible data, or without full-text availability. • Publications in languages other than English without translation. • Articles older than 25 years to maintain the relevance of findings.

OHS- occupational health and safety.

4. Discussion

4.1. AI in OHS — Current Landscape

AI-enabled wearables, including smartwatches, biometric wristbands, and electronic textiles, enhance OHS by collecting physiological and environmental data to monitor vital signs, detect fatigue, analyze posture, and track locations in hazardous areas [11]. Industries like construction, manufacturing, logistics, and healthcare leverage these technologies to improve ergonomics, optimize workflows, and deliver real-time hazard alerts while supporting stress monitoring, fatigue detection, and chronic condition management [12]. Advanced AI systems, such as sensors assessing air quality, noise, and employee movements, enable predictive maintenance, hazard prevention, and compliance through real-time and historical data analytics [14]. Despite these advancements, challenges remain, including data privacy, device interoperability, and user adoption, requiring secure and user-friendly AI systems [13]. As AI transforms OHS with proactive risk management and precision-driven safety measures, professionals must navigate its complexities to maximize benefits and minimize unintended impacts, fostering safer, more efficient, and worker-centered workplaces [14].

Wearable monitoring technologies provide real-time data on workers' safety and health through devices like motion sensors (e.g., inertial measurement units, accelerometers, gyroscopes) and physiological sensors (e.g., heart-rate monitors, electrodermal activity sensors, skin temperature sensors, eye trackers, and brainwave monitors) [14-12]. Motion sensors capture kinematic data such as movement patterns, near-miss falls, posture, and gait, aiding in fall prevention and musculoskeletal disorder mitigation [25-21]. Physiological sensors measure parameters like heart rate, variability, stress, and fatigue levels through Electrocardiogram (ECG), Photoplethysmography (PPG), Electrodermal Activity (EDA), while eye trackers assess hazard recognition, and electroencephalogram (EEG) monitors workers’ mental status, including stress and cognitive load [14-16].

4.2. Benefits of Human-AI Interaction in OHS

Human-AI interaction in OHS provides many advantages, significantly enhancing workplace safety, health, and productivity, as exemplified by various AI-driven solutions. One key benefit is proactive hazard identification, where AI-powered tools analyze data to detect potential risks before incidents occur, thereby preventing accidents [22]; this is further illustrated by the Estimation and Assessment of Substance Exposure (EASE) software developed by the UK's Health and Safety Executive, which uses AI to calculate exposure levels to hazardous substances across diverse work environments, enabling more precise risk management [23,24]. Enhanced monitoring is another advantage, achieved through wearable devices that track vital health metrics such as fatigue, stress, and exposure to harmful conditions, thus enabling real-time interventions to mitigate risks [25]. Training and compliance efficiency are boosted with virtual reality and AI-powered simulations, delivering immersive and effective OHS training experiences [26]. AI-assisted ergonomic evaluations help prevent musculoskeletal disorders by analyzing workplace setups and worker movements to optimize ergonomics [27]; for instance, Lind et al. demonstrated that a wearable haptic feedback system for work technique training can significantly reduce adverse upper-arm postures and is perceived as both effective and user-friendly [28].

Additionally, Ocharo et al. present a YOLO-based Deep Reinforcement Learning system, deployed on an IoT platform integrating BLE tags, GPS modules, Fitbit devices, cameras, and CNN-based image recognition, which continuously monitors PPE usage (helmets, vests, goggles, masks, and boots) on construction sites, ensuring real-time detection of non-compliance and validated by precision, recall, and mean Average Precision metrics [29]. In parallel, Romanssini et al. found that integrating vibration-based monitoring with robust signal processing and diagnostic methods is crucial for predictive maintenance in rotating machinery, allowing industries to minimize downtime, reduce costs, and promptly address potential faults [30]. AI-enhanced personal protective equipment, such as smart helmets and adaptive gear, dynamically adjusts to changing environmental conditions, ensuring continuous protection for workers [31]. Furthermore, AI-driven drones amplify efficiency in construction by enabling automated defect detection, predictive analytics, and real-time flight-path optimization—integrating multi-sensor data to enhance safety, sustainability, and overall project outcomes [32]. Together, these advancements underscore the powerful synergy between human intelligence and AI, driving innovation in OHS practices while fostering safer and healthier work environments [22–32].

4.3. Challenges and Ethical Considerations

Artificial intelligence in occupational health introduces several ethical and practical challenges that must be addressed to ensure its responsible integration. A primary concern is data privacy and security, as the monitoring of employees' behavior and health information raises questions about the protection of sensitive data [32–33]. In the European Union, the General Data Protection Regulation (GDPR) imposes strict requirements for handling personal data, including obtaining valid consent and implementing safeguards to prevent breaches [34]. Poland's labor laws also set specific rules for monitoring employees, overseen by national authorities like the Personal Data Protection Office (UODO) [35]. Additionally, upcoming EU legislation (e.g., the proposed AI Act) may further refine regulations for AI-driven workplace practices [36]. Alongside these legal frameworks, there is the issue of workforce mental health: employees may develop anxiety over AI surveillance and worry about potential job losses, which could negatively affect well-being [33]. Another key concern is bias in AI systems, where discriminatory algorithms could unfairly impact performance evaluations, promotions, or hiring, thus aggravating workplace inequalities [37]. Financial and access barriers, including high costs and uneven distribution of AI tools across various sectors, especially for small and medium-sized enterprises (SMEs), also lead to inequitable adoption [38]. Confronting these legal, ethical, and logistical challenges is crucial to ensure that AI-based occupational health and safety measures enhance the work environment without compromising employee rights, equality, or mental health [32–38].

4.4. Human-AI Collaboration Models

The Human-in-Control model in Human-AI collaboration builds upon frameworks like Parasuraman's Levels of Automation, which categorizes automation into levels based on the degree of human involvement, and Kaber and Endsley's models, which emphasize the importance of situational awareness and human decision-making in complex systems [8-10, 39]. For instance, in OHS, AI systems can autonomously monitor fatigue and stress levels in workers (lower automation), but the final decision to intervene remains with supervisors to ensure contextual appropriateness [39]. Additionally, theories like Ulrich's resource-based view and the Job Demand-Control (JDC) model highlight how AI can alleviate workload while still requiring humans to manage cognitive and ethical oversight, preserving both performance and well-being [39]. This structured cooperation ensures that AI enhances decision-making without compromising human authority or accountability, fostering safer and more efficient workplaces [8-10]. The DiWaBe survey conducted in Germany found that while digitalization and AI can improve efficiency and reduce physical workloads, they also increase job demands, workplace stress, and the need for upskilling, highlighting the importance of balancing technological integration with employee well-being and autonomy [6, 10].

4.5. Examples of Human-AI Collaboration

Human-AI cooperation in OHS is increasingly common in countries with strong industrial sectors and robust research ecosystems—such as the United States, Germany, Japan, and select EU member states—where AI has moved from experimental studies to routine practice [40–43]. In these regions, AI-powered predictive analytics, fed by data from sensors and wearables, already helps identify potential hazards like fatigue or harmful exposures in real time, enabling managers to intervene by adjusting shifts or updating safety protocols [40]. In the field of ergonomics, AI systems frequently analyze workers' posture to prevent musculoskeletal disorders, while human supervisors validate those insights and tailor solutions to the specific workplace context [41]. AI-based surveillance tools also monitor machinery, flagging malfunctions early so that technicians can respond proactively—an approach that is gradually becoming standard rather than experimental [42]. During emergencies, AI simulations project fire or chemical spill trajectories, allowing human experts to interpret the data and oversee evacuations [43]. Although AI adoption in some smaller or less-funded organizations remains in early stages, these examples underscore how AI increasingly supports day-to-day decision-making and hazard mitigation in OHS, while human expertise ensures ethical deployment, contextual understanding, and worker trust [40–43].

4.6. Future Directions

Future directions in OHS involve not only developing ethical and transparent frameworks for responsible AI integration but also addressing legislative challenges and the need for comprehensive training [44-46]. As AI becomes more prevalent in daily work environments, policymakers must refine existing regulations—such as the GDPR in the European Union and emerging AI-specific legislation (e.g., the proposed EU AI Act)—to account for algorithmic bias, data privacy, and accountability [34,36]. Simultaneously, governments and professional bodies should create standards and guidelines that support the safe deployment of AI across various industries, ensuring these systems do not compromise equity or worker well-being [4, 20-40, 46].

Long-term studies remain essential for evaluating AI's psychological effects on workers, including stress, concerns over job security, and overall mental health, helping organizations develop mitigation strategies [20–40]. OHS research must also explore AI's role in predictive safety measures, ergonomics, and mental health monitoring, aligning these technologies with sustainable, equitable, and worker-centric practices [43,46]. Beyond workplaces, there is a growing need to incorporate AI literacy and human-AI collaboration skills into educational curricula [49]. By familiarizing students—future members of the workforce—with advanced AI systems, schools and training programs can help them adapt more easily to emerging OHS technologies and cultivate responsible innovation [4, 36-40].

Ultimately, these efforts will require a balanced approach, combining robust legislation, industry-specific standards, and ongoing education to foster AI adoption that enhances worker safety and autonomy without undermining equity or well-being. Through collaboration between policymakers, educators, industry leaders, and OHS professionals, future workplaces can leverage AI responsibly, protecting workers while empowering them to thrive in increasingly automated environments.

5. Conclusions

AI's integration into OHS can significantly reduce workplace hazards, improve ergonomic design, and streamline workflows. Real-time hazard detection, wearable monitors, and predictive analytics can lower injury rates, promote healthier environments, and boost productivity. By using machine learning to identify risks and recommend interventions, organizations can adopt a more proactive safety stance, mitigating both immediate dangers and long-term health issues. These AI tools also support OHS professionals by helping them tailor interventions and optimize resources. However, challenges accompany this technological progress. Data privacy and security are paramount, as sensitive information—from biometric markers to mental health indicators—must be protected under strict regulations. Algorithmic biases can create unfair assessments and disparities among workers, while overreliance on AI can reduce worker autonomy and increase stress if systems are seen as intrusive. Smaller organizations may also face implementation barriers, widening the gap with larger enterprises. Balancing these benefits and drawbacks calls for a human-centred approach in which AI supports, rather than replaces, human oversight. Transparent communication, clear ethical guidelines, and inclusive stakeholder engagement can ensure AI-driven OHS systems nurture worker well-being and organizational efficiency. By addressing privacy, bias, and autonomy concerns, AI can be used responsibly to create safer, healthier, and fairer workplaces.

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