American Journal of
Biomedical Science & Research

www.biomedgrid.com
ISSN: 2642-1747

Review Article

Workplace Health and Safety Management in the Digitalization and Artificial Intelligence Era

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To Cite This Article: *Elena Doval* and Oriana Helena Negulescu. Workplace Health and Safety Management in the Digitalization and Artificial Intelligence Era. Am J Biomed Sci & Res. 2024 23(6) AJBSR.MS.ID.003133,* DOI: 10.34297/AJBSR.2024.23.003133

Received: August 20, 2024; **Published:** August 23, 2024

Abstract

The management of any organization seeks to provide its employees with a workplace that is as healthy and safe as possible, both for the good of the people and for reducing fluctuation and increasing productivity. Therefore, attention is paid to ergonomic investments made using Occupational Safety and Health Practices (OSH) standards. In this age of digitization, using Artificial Intelligence (AI) in any field is not to be neglected. The work highlights the importance of using AI to ensure a safe workplace and identify and evaluate the associated risks. Different opinions on this subject are presented, and a model for implementing AI in the management of workplace ergonomics is proposed.

Keywords: Workplace, Health, Safety, Ergonomics, Digitalization, Artificial intelligence, Management

Introduction

Ensuring occupational health and safety is an extremely important goal for the management of any organization. The complexity of the factors that intervene in occupational life makes it necessary to conduct a holistic analysis of people's health and safety systems and analyze and anticipate possible risks. The interconnected components, such as workers, work processes, equipment, environment, organizational culture, and management strategies [1], make analyzing and anticipating risks difficult. Traditional risk assessments tend to provide a fragmented view, focusing on individual behaviors and identifying errors and mistakes that arise from poor reasoning or mistaken beliefs [1].

The progress made in using Artificial Intelligence (AI) in multiple fields of activity makes it possible to apply it in ergonomics as well. The more frequently used and continuously improved technologies are automation, generative AI, robotics, quantum computing, and other details by algorithms [2-3]. When done right, combining this technology and tried and true training methods can create the perfect balance of engagement and mindfulness employees need [4]. AI-based solutions in ergonomics use advanced data analytics to assess human factors, task demands, and environmental conditions, providing a data-driven approach to ergonomic design. This minimizes the risk of workplace injury and fosters environments that promote employee health and productivity [5].

Although the studies carried out so far in the field of AI application in ergonomics are not very advanced for their application in practice, several successes have been achieved, among which emerging technologies such as exoskeletons, portable sensors, artificial intelligence, computer vision, and virtual and augmented reality are integrated into the workplace [6].

According to the specifications in the reference, in short, these technologies refer to:

a) Exoskeletons. An exoskeleton is a "wearable device that augments, enables, assists, or enhances movement, posture, or physical activity" [7]. Exoskeletons can be passive (unpowered) or active (externally powered), most specific to specific body parts (shoulders, arms, knees, legs), or include integrated instrument rockers that connect to the exoskeleton frame.

b) Wearable sensors. These devices range from the simplest (measuring heart rate and number of steps) to more advanced technology that measures posture, movements, muscle activity, and brain waves. More advanced devices use wearable sensor technology, machine learning, and data analysis to understand worker postures and movements and predict risk and proximity (for social distancing). Some also detect environmental factors such as temperature, heat stress, humidity, air quality, barometric pressure, and noise. Other wearable neurotechnology sensors measure mental activity through EEG technology to provide indicators of stress, mental fatigue, attention, and excitement, and can even be used to control other devices.

c) Artificial intelligence. That branch of computer science gives machines the ability to appear to have human intelligence (voice bots, auto-correction, marketing ads, etc.). This can happen through machine logic, machine learning, and perception. Computer vision and predictive analytics are among some of the disciplines associated with AI.

d) Computer vision. Being in the field of artificial intelligence (AI) allows computers and systems to derive meaningful information from digital images, videos, and other visual input and take action (on the data). Computer vision applications include facial recognition software, security systems, detecting damage to equipment or machinery requiring maintenance or service, etc.). For ergonomics, AI and computer vision help automate ergonomic risk assessments. These are available and used by some companies to provide employers with more timely, accurate, and efficient information.

e) Other interesting emerging technologies used in ergonomics include Virtual Reality (VR), which completely immerses the user in an alternate world or reality apart from the real world, and Augmented Reality (AR), which Superimposes digital information on real-world elements (used especially in product design, production, service, and training).

Specialists' concerns are focused on developing standards that consider information technology in work safety, such as in [7], which elaborates standards on exoskeletons and exosuits in activities covering industrial, emergency response, medical, military, and consumption.

Scope and Methodology

In this context, this investigation aims to illustrate an overview of the use of digitalization and AI based on workplace risks and current research by professionals. It highlights the main benefits and vulnerabilities of using AI in ergonomics. Finally, a model for implementing AI in the management of workplace ergonomics is proposed.

This article uses secondary data obtained from published materials and direct observations. The methodology includes analyzing and synthesizing the collected data, a brief interpretation of the general view of the research subject, and conceptualization of a specific model.

Literature Review

Digitization of the Activity of Detection and Prevention of Risks at the Workplace

The workplace is not always a safe and healthy place, not even for administrative workers in offices and especially for workers who use physical force. A series of risks have been found (Musculoskeletal Disorders (MSD), accidents, occupational diseases, stress, etc.), due to which in some organizations, people's dissatisfaction and demoralization are increasing, attracting a fluctuation of the labor force and depreciation of productivity.

Also, various alterations capable of endangering the worker's integrity may appear during the phases of return to work for people with dysfunctions, disabilities, or previous pathologies [8].

Traditional methods of monitoring ergonomic risks often rely on manual assessments and periodic inspections, leaving organizations vulnerable to overlooked hazards and delayed intervention [9]. Although the human brain is remarkable, it has its limits. It exceeds the human ability to remember every detail, anticipate every risk, and discern every trend that could affect the safety of workers [1].

AI has revolutionized health and safety occupations through extensive data processing, pattern recognition, and intelligent decision-making, leading to innovations that increase efficiency, accuracy, and overall effectiveness in these critical areas. The following are different applications of AI in ensuring worker safety [10] (Table 1).

Table 1: The main uses of AI in ergonomics.

No	Usage	Details
1	Automation in safety occupations	AI systems can actively monitor environments and quickly identify potential hazards.
2	Integration of safety technology and AI	The fusion of safety technology and artificial intelligence has given rise to innovative solutions for workplace safety (wearable devices - embedded with AI algorithms - monitor vital signs, detect fatigue or stress to prevent accidents rooted in error human, and AI-based software analyzes historical safety data, revealing patterns and recommending improvements in risk mitigation.
3	Occupational Safety	With AI-based automation replacing certain job functions, workers must acquire new skills to coexist safely with these technologies. That is why training courses are needed to use AI-enabled systems, understand the potential risks associated with their implementation, and maintain standards. In safety training, AI creates virtual simulations for workers to practice procedures, improving their understanding and response to hazards.
4	AI-based risk assessment	By recognizing patterns and generating risk profiles for tasks or environments, organizations can identify high-risk areas and implement preventive measures based on AI information to reduce accidents significantly.

5	Innovations in work safety with AI	AI plays a key role in introducing innovations such as exoskeletons that provide ergonomic support, mitigating the risk of musculoskeletal injuries; collaborative robots (cobots) increase both productivity and safety by working alongside humans or AI algorithms that analyze workers' movements and provide real-time feedback, preventing unsafe practices, optimizing ergonomics.
6	Robotics for Workplace Safety	Autonomous robots excel at performing hazardous tasks involving toxic substances or extreme conditions, minimizing the risk of human injury. In addition, AI-based robotic systems are proving valuable for routine inspections and maintenance, ensuring the integrity of equipment and infrastructure.
7	Conversational AI for Safety	Chatbots, equipped with natural language processing and trained in safety procedures and manuals, are invaluable tools for answering employee safety questions. These intelligent systems can understand and interpret natural language, enabling seamless communication. By providing instant responses, chatbots improve the accessibility of safety information, contributing to a proactive safety culture within organizations.
8	Site inspections using drones	Drones provide aerial surveillance, capturing detailed images and data, while autonomous vehicles navigate challenging terrain and conduct inspections without exposing workers to potential hazards.
9	Pattern Spotting by AI	An AI program trained on an organization's historical observations and accident reports can quickly reveal valuable information, recognizing trends that would require extensive manual effort from a health and safety practitioner. AI's transformative impact on occupational health and safety lies in its ability to efficiently analyze large amounts of data, extracting key insights and identifying patterns.

***Source:** *Enano, et al.* [10]

Digital ergonomic transformation means using a cloud-based platform to track and manage practices and data [11]. This platform ensures communication throughout the organization, allows data storage and control, and integrates AI with sophisticated sensors and algorithms. It results in proactive indicators of potential risks, which are graphically represented, showing trends in different operational areas and risk categories. Integrating these with behavioral observations, on-site risk assessments, and other risk-related forms effectively provides a more comprehensive understanding of evolving risks and where to intervene before harm occurs [12]. The accuracy of the results is unprecedented [9].

Sensors can be attached to an employee while performing a work task. Different versions of sensor-based technology are on the market, many of which have been around for several years (e.g., electromyography) [11]. Sensors placed on a certain body part provide various information to classify workers' postures or recognize motor patterns related to workers' activities [8]. Some sensors are designed to help determine force application, while others collect electrical muscle activity and awkward posture measurements for specific body segments and is sometimes used as a training tool [11].

The ergonomic analysis technique using sensors and AI is mainly aimed at risk prevention and particularly affects the body sectors of the upper limbs and the back, which are widely treated in ergonomics. However, the body's posture has also been partially explored [8].

AI can immediately identify ergonomic risks through sophisticated algorithms, enabling prompt risk control actions [1]. AI with machine learning algorithms and predictive analytics can monitor real-time safety data and identify potential hazards before they lead to accidents, enabling rapid corrective action [13].

Computerized video technology is more advanced. This technology allows a user to assess an operation or task using video, and no sensors or devices need to be placed on an employee's body [11]. Current research also focuses on using portable robots to " reduce the burden on an employee and the possibility of injury" [11].

Benefits and Vulnerabilities of AI Regarding Workplace Safety

Perhaps ergonomics is one of the fields in which people's fears of being replaced by machines are among the smallest because AI assists them in their work by offering "safety professionals a wider and deeper perspective" since they "can be "present virtual" in multiple locations, ensuring that safety standards are maintained everywhere without wasting resources [1,14].

Table 2 exemplifies the main benefits of digitization and AI in correlation with the main applications and the way to achieve them for workplace safety.

Table 2: The main benefits brought by AI in ergonomics.

No	AI Benefit	Application	Modality	Source
1	Big data storage	Printed documents are replaced, and large databases are created	Through digitization, platforms, and cloud	[12]
2	Predictive analytics for risk assessment	-Organizations can detect subtle indicators of ergonomic risk with unprecedented accuracy; Provides non-stop, real-time risk monitoring and management capabilities and detects hazards before they lead to accidents	By harnessing the power of machine learning algorithms and real-time data analytics	[9,15-16,13,17]

3	Reducing the incidence of workplace injuries (including physical, psychosocial, and organizational aspects)	It opens the way to the analysis and consideration of the multiple conditions of exposure to physical, chemical, environmental, and organizational factors at the workplace, for which no consolidated risk assessment methodologies are currently available	By proactively identifying and mitigating ergonomic risks	[8-9,14]
4	Driving innovation and shaping the future of workplace safety	-Organizations can optimize resource allocation and streamline safety protocols; -It helps to study the characteristics of force, repetitiveness, and posture and the kinematic features of the worker's behavior; -Contribute to the design of appropriate work environments and equipment	By leveraging data-driven insights	[9,8,3,18-19]
5	Provides cost-effective learning opportunities in safety and health	-It can detect when workers are not following safety protocols; -Detects blocked exits, leaks, near-accident situations, or other environmental hazards and can warn them before injuries occur; -Speech recognition and incident reporting	Through security cameras	[13-14]
6	Promotes fair safety practices	Minimizing bias, ensuring correctness, and other ethical principles	By purchasing and using algorithms and cyber security	[13-14,3]

VR and AR are expected to increase activity efficiency: decrease development time, decrease risk for employees or end users, improve cycle time, improve product quality, and decrease production and service costs for companies [6].

Vulnerability of AI Regarding Workplace Safety

Although optimism remains high, AI technology's challenges are video sharing and data security, scalability, accuracy, and required data processing power [6].

AI generally introduces a series of vulnerabilities, including excessive trust, inaccurate information, cyber insecurity, and dehumanization through online communication [15-20].

Some questions arise in Occupational Safety and Health (OSH) as AI is integrated into workplaces. Stress, discrimination, increased precariousness, musculoskeletal disorders, and the possibilities of work intensification and job loss have already been shown to pose psychosocial risks, including physical violence in digitized workplaces. These risks are exacerbated when AI enhances existing technological tools or is newly introduced for workplace management and design, i.e., AI increases OSH risks in digitized workplaces as it can enable increased monitoring and tracking and, therefore, can lead to micro-management, which is a major cause of stress and anxiety [21]. Also, other negative aspects are reported [22], among which:

i. The possibility of violating the private right to confidentiality through the use of biometric data.

ii. Supervision of employees for purposes not allowed from a legal point of view.

iii. Violation of the principles regarding clear governance systems, procedures, human oversight, and evaluation processes for AI systems for use in the workplace.

However, it is not technology in isolation that creates OSH benefits or risks; it is the implementation of technologies that creates negative or positive conditions [21].

Addressing human factors and ergonomics is important for smoothly implementing AI applications and fully exploiting their potential [23].

Observations, Results, and Discussion

The different opinions selected regarding ensuring the health and safety of the workplace offer a general picture of the future of this important aspect of the organization's management. Five relevant aspects can be observed in OSH management:

1) This field applies a series of more or less sophisticated technologies, depending on the industry, the organization's specific activities, and the workplace's needs (exoskeletons, wearable sensors, computer vision based on AI, robotics, predictive analysis, etc.).

2) A series of equipment and technologies (VR, AR) are in the research phase, but they will revolutionize ergonomics.

3) The transformation of ergonomics from the traditional to the digital one brings a series of benefits, among which storing more databases, reducing the incidence of workplace injuries, predictive analysis for risk assessment, stimulating innovation in identifying new analysis criteria and design of suitable AI-based equipment that will ease physical work and improve the posture and behavior of employees, decrease the violation of ethical principles, help in training employees and others.

4) We do not yet know all the vulnerabilities that can intervene through this transformation, but some are anticipated, among which stress and anxiety of some employees due to resistance to change and fears caused by difficulties in changing skills, learning, and accumulating new knowledge or /and the possibilities of work intensification and job loss; the possibility of violating the private right to confidentiality through the use of biometric data and continuous surveillance; physical violence or discrimination.

5) The transition from traditional ergonomics is not complete. Organizations and professionals are still researching differ-

ent efficiency methods with the help of digitization, AI, and different implementation projects.

In this sense, a system model is proposed that fully or in steps implements the ergonomics management assisted by AI (Figure 1).

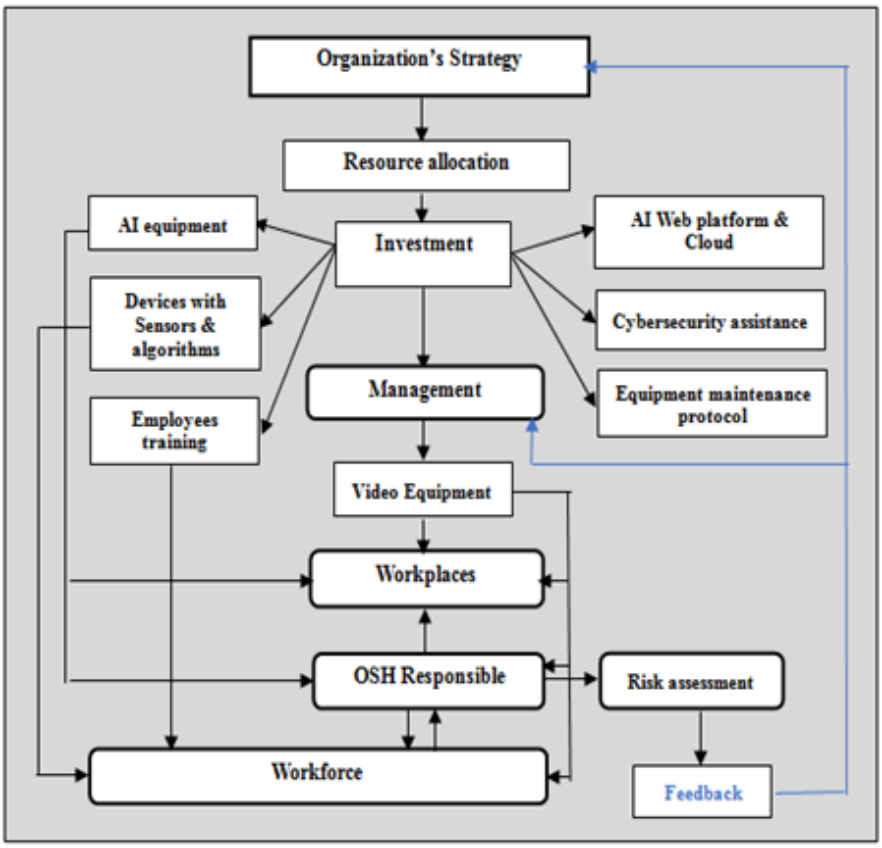

Figure 1: A model of an AI ergonomics management system (authors' conceptualization).

The proposed model is based on the organization's strategy, approved by the owner or shareholders, and aims at its long-term future.

Within the strategy, a primary place is occupied by investments and, of course, the financial resources that can be allocated for their realization. In this sense, the commercial organization must obtain profit, and the shareholders must allocate a part of the capital for reinvestments or increase their contribution to the capital. Also, the organization needs to cover the financial expenses of resorting to bank loans.

Investments can be made in full or staggered according to the strategy and are the responsibility of the organization's management.

First, a web platform must provide a communication and data storage interface. A platform connected to the cloud is more efficient because it allows large databases to be stored, and hackers' access to it is lower. To protect data, it is necessary to contract cyber security services.

Second, AI-assisted work equipment is needed. One such system is a computerized video system that allows viewing workplace activity and employees' behavior in real time. A maintenance protocol is concluded to maintain the equipment's efficient functioning.

Thirdly, in certain workplaces, employees need wearable devices that transmit certain violations of the regulations and occupational standards regarding workplace posture through sensors.

The OSH manager coordinates all collected information. Using different AI algorithms, the OSH team analyzes historical and real-time data, resulting in diagrams, trends, and reports. Potential risks are anticipated, based on which immediate countermeasures are taken. Actions are proposed to remedy vulnerabilities, modify work procedures, or even improve ergonomically designed equipment and devices assisted by AI through collaboration with suppliers and feedback to the organization's management. In situations of new investments, shareholders are informed to update the strategy.

Last but not least, investments in training and retraining are needed so that employees are trained in using AI equipment, behavior at work, and compliance with the rules regarding ethics and data security. Only in this way can the well-being of employees increase, including ensuring health and safety at work, professional satisfaction, and a pleasant and efficient work climate.

When the model is implemented in steps, the investments' phasing and implementation are carried out according to each organization's short-term or medium-term strategic plan.

In this way, the organization gains increased productivity, reduced staff turnover, increased quality of products/services, reduced indirect costs, overall performance, and reputation.

Conclusion

As in other fields of activity, transformations occur in the OSH system as digitization and AI develops and research into OSH algorithms and equipment advances.

The literature presents a series of opinions regarding the transition from traditional to digitalized ergonomics that uses AI algorithms. Some authors present generalities or different details regarding how AI is applied in OSH practice or the main equipment based on digitization and AI already used in practice. Most opinions show the benefits that can be brought to organizations, especially employees, who can work in a safer and healthier environment. In this sense, the implementation of AI in ergonomics leads to an increase in the identification of potential dangers that may appear at the workplace, but also to a reduction in the risk of exposure to accidents, making the application of preventive and corrective actions faster. Although some vulnerabilities of the use of AI in ergonomics are highlighted, it is obvious that everything depends on the approach to the problem, both in the organization's strategy and in management.

To facilitate an understanding of the complexity of this paradigm shift from classic to modern, a model of an AI ergonomics management system is proposed. This system can be adapted to any organization and updated according to the development of other methods and techniques applicable to OSH.

Acknowledgement

None.

Conflict of Interest

None.

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