Avrasya Sosyal ve Ekonomi Araştırmaları Dergisi (ASEAD)
Eurasian Journal of Social and Economic Research (EJSER)
ISSN:2148-9963 www.asead.com

INNOVATIVE TECHNOLOGICAL APPROACHES IN INDUSTRIAL OCCUPATIONAL HEALTH AND SAFETY: AN EXTENSIVE REVİEW

Dr. Cengiz AKYILDIZ[1]

ABSTRACT

Technological transformations in the industrial sector have enabled the design and implementation of advanced devices that continuously monitor health and safety parameters of employees. This study addresses the new technological approaches and methodologies that have the capacity to meticulously track risk scenarios, vital indicators, physical parameters, employee locations, and individual behavioral tendencies within work processes. Using the PRISMA ScR method, this comprehensive review has gathered information from 99 scientific articles related to these technological shifts. The functional characteristics and applicabilities of devices aimed at optimizing the compliance of workers to health and safety standards were identified. The findings revealed significant contributions of technology in gathering and transmitting information. This information can be utilized to provide alerts and feedback for employees to adopt more conscious and safe behavioral patterns. Furthermore, recent technological advancements have been observed to produce devices that minimize operational risks by automating manual procedures.

Keywords: Technological Innovations, Comprehensive Review, Portable Monitoring Device, Occupational Safety, Occupational Health, Risk Management

ENDÜSTRİYEL İŞ SAĞLIĞI VE GÜVENLİĞİNDE YENİLİKÇİ TEKNOLOJİK YAKLAŞIMLAR: KAPSAMLI BIR İNCELEME

Dr. Cengiz AKYILDIZ

ÖZET

Endüstriyel alanda yaşanan teknolojik dönüşümler, çalışanların sağlık ve güvenlik parametrelerini sürekli izleyebilen ileri düzey cihazların tasarlanmasına ve uygulanmasına imkan tanımıştır. Bu çalışma, risk senaryolarını, vital göstergeleri, fiziksel parametreleri, çalışan konumlarını ve iş süreçleri içerisindeki bireysel davranış eğilimlerini detaylı şekilde takip etme kapasitesine sahip olan yeni teknolojik yaklaşımları ve metodolojileri ele almaktadır. PRISMA 2021 metodu kullanılarak yapılan bu kapsamlı inceleme, bu teknolojik dönüşümlere dair 99 bilimsel makale üzerinden bilgi toplamıştır. Çalışanların sağlık ve güvenlik standartlarına uyumluluğunu optimize etme amacı güden cihazların işlevsel özellikleri ve uygulanabilirlikleri tespit edilmiştir. Elde edilen bulgular, teknolojinin bilgi toplama ve transferi konusunda önemli katkılar sağladığını ortaya koymuştur. Bu bilgilerin, çalışanların daha bilinçli ve güvenli davranış biçimlerini benimsemeleri adına uyarılar ve geri dönütler sağlamak üzere kullanılabileceği belirlenmiştir. Ek olarak, son teknolojik gelişmelerin, manuel işlemleri otomatize ederek operasyonel riskleri minimize eden cihazlar ürettiği gözlemlenmiştir.

Anahtar Kelimeler: Teknolojik Yenilikler, Kapsamlı İnceleme, Taşınabilir İzleme Cihazı, Iş Güvenliği, Iş Sağlığı, Risk Yönetimi

---

[1] Üsküdar Un., Department of Cartoon and Animation, ORCID ID: 0000-0001-8004-1037, cengiz9299@hotmail.com
Araştırma Makalesi/Research Article, Geliş Tarihi/Received: 07/10/2023–Kabul Tarihi/Accepted: 14/10/2023

INTRODUCTION

Today, countless workers across various sectors confront a myriad of risks. The integration of innovative technologies can considerably enhance their safety and well-being. Notwithstanding the initiation of safety protocols at workplaces, mortality rates continue to be alarming. Data from the International Labour Organization (ILO) indicates that nearly 2.3 million individuals succumb annually to work-related mishaps or ailments on a global scale, translating to over 6,000 daily fatalities (Tarique, Briscoe, & Schuler, 2022). Annually, there are reports of approximately 340 million job-related accidents and an estimated 160 million occupational diseases worldwide (Rajendran, Giridhar, Chaudhari, & Gupta, 2021). Numerous systematic reviews suggest the availability of a plethora of technologies tailored to monitor individual health. These encompass wearable sensors, fitness trackers, heart rate devices, sleep tracking gadgets, and mobile applications which enable users to oversee their health (Ometov et al., 2021; Kim, Kim, Kwon, & Lee, 2017), granting healthcare practitioners the means to more proficiently detect and treat ailments (Choi, Hwang, & Lee, 2017). Paradoxically, even with strides in handheld devices for job health and safety, a holistic review mapping their industrial application and advantages is noticeably absent (Mohammed & Mahmud, 2020).

This paper offers an insight into potential technological interventions to optimize the oversight and regulation of job health and safety, presented as a systematic review adhering to PRISMA's guiding principles (PRISMA Statement, 2021). The advancements echoed in scholarly works emanate from diverse domains such as nanotech, robotics, data analytics, visual media, and telecommunication. Such tech-oriented solutions yield copious data with enhanced precision and expediency, illuminating aspects like physical strain, physiological metrics, and the extent of workers' risk exposure during professional tasks (Bastani et al., 2016).

Recent tech-driven innovations aimed at bolstering job health and safety have pivoted towards systems like Building Information Modeling (BIM), Radio Frequency Identification (RFID), and Augmented Reality (AR) to fortify safety in the property development and construction sectors (Kelm, Meins-Becker, & Helmus, 2019). This manuscript highlights a selection of alternative strategies and advancements over the past decade that cater expressly to the domain of safety, focusing on health surveillance, risky scenarios for laborers, and health-centric solutions that govern workers' actions, ensuring a health-consistent state during conventional job roles.

Beyond the handheld and wireless gadgets highlighted in this assessment, various robotic solutions have been unveiled, aiding or even substituting laborers in executing jobs traditionally viewed as perilous, such as elevated tasks.

MATERIALS AND METHODS

A meticulous review of scholarly articles adhered to the PRISMA-ScR principles (PRISMA Statement, 2021). For this exploration, PRISMA's checklist and Eriksen and Frandsen's (2018) approach, using PICO criteria to carve out research questions, were harmoniously employed to streamline evidence-backed research conduction and dissemination.

The foundational questions for this investigation included evaluating the sectors that benefit from novel technologies and understanding the benefits and potential challenges of integrating these innovations into the professional health and safety realm. The data set for this study can be accessed via Mendeley Data (Flor & Acosta-Vargas, 2023).

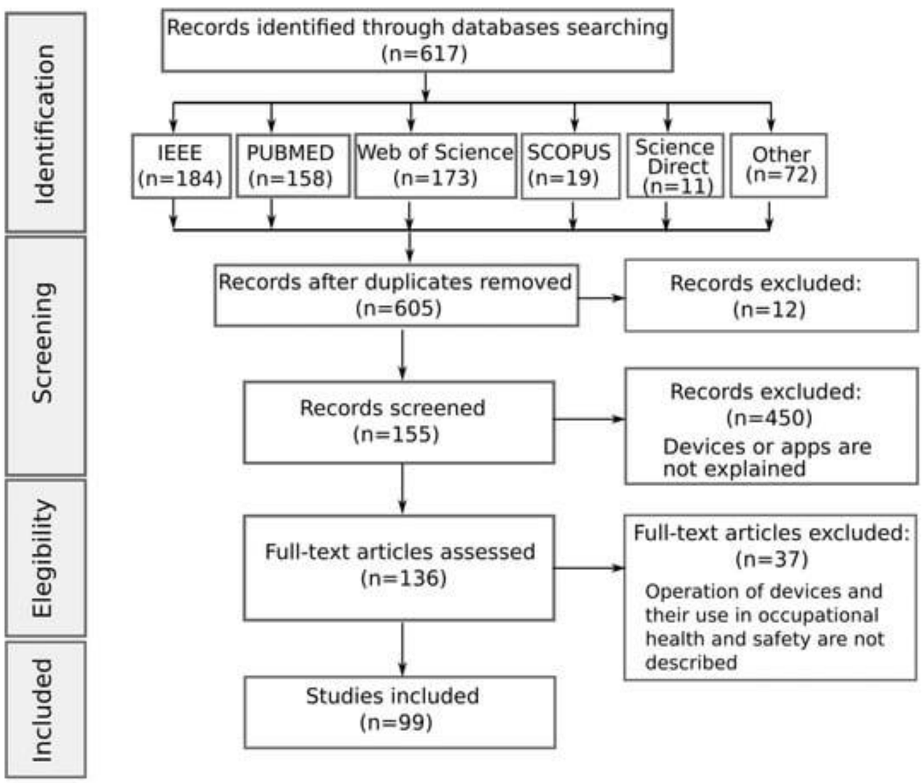

Figure 1: PRISMA Flow Diagram

The quality and relevance of the articles considered as a reference for the development of this article were evaluated. Five Question Assessments (QA) rooted in the PICO criteria (Eriksen & Frandsen, 2018) were utilized for this evaluation. The assessment is detailed in Table 1.

Table 1: Document Quality Assessment Checklist

No	Quality Assessment Questions	Answer
QA1	Does the paper describe devices or technologies for safety and occupational health?	(+1) Yes / (+0) No
QA2	Does the document specify how technology improves working conditions?	(+1) Yes / (+0) No
QA3	Does the paper describe the principles and technical characteristics of the operation of these technologies?	(+1) Yes / (+0) No
QA4	Are the limitations of using these technologies described in the paper?	(+1) Yes / (+0) No
QA5	Is the journal or conference in which the paper was published indexed in SCImago Journal Rank (SJR)?	(+1) if it is ranked Q1, (+0.75) if it is ranked Q2, (+0.50) if it is ranked Q3, (+0.25) if it is ranked Q4, (+0.0) if it is not ranked

The quality and relevance of the articles considered for this study were critically assessed. Five Question Assessments (QA) grounded in the PICO criteria were utilized for this evaluation (Table 1).

The search strings used for various databases, which led to the identification of reference articles for this study, are displayed in Table 2.

Table 2: Selected Scientific Articles and Quality Assessment Outcomes

Database	String Search	Studies Number
IEEE	[title: technolog *] AND [title: “occupational safety”] AND [title: “occupational health”]	184
PubMed	(("technolog *" [All Fields] AND "occupational safety" [All Fields]) AND "occupational health" [All Fields]) AND ((y_5[Filter]) AND (ffrft[Filter]))	158
Web of Science	search: technolog * “occupational safety” “occupational health”	173
Scopus	TITLE (technolog* AND “occupational safety” AND health)	19
Science Direct	Title, abstract, keywords: technology technologies “occupational safety” “occupational health”	11

The outcome of the quality control review for the chosen articles, in accordance with the procedure illustrated in Figure 1, was subsequently normalized. The normalization was based on the criteria illustrated in Table 2 and was determined using the following equation:

$$\text{Normalization}=[\text{maximum(score)}-\text{minimum(score)}]/[\text{Score}-\text{minimum(score)}] \quad \text{(Equation 1)}$$

RESULTS

The world has seen a surge in technology tailored to enhance industrial safety, designed specifically for integration into human attire or even directly onto the human body. Consider, for example, systems that monitor various physiological metrics. These systems extract data from the human body and transmit it to external devices for further processing and statistical analysis (Choi, Hwang, & Lee, 2017). Further, advanced technological innovations leverage robotic tools, including drones, to execute specific tasks. This innovation reduces hazards for human operators in areas identified as high-risk (Bastani et al., 2016). Exoskeletons play a pivotal role by amplifying human capabilities and positioning them in safer stances during tasks (Rajendran, Giridhar, Chaudhari, & Gupta, 2021). Additionally, systems utilizing vision capabilities and artificial intelligence are equipped to recognize and track objects, providing insights into the worker's environment (Chihming, Zexin, Songqing, & Zhongwei, 2020). We delve deeper into these advancements in occupational safety and health below.

Technologies Enhancing Occupational Safety

Recent scientific publications over the past decade highlight a range of technological innovations and their respective applications, specifically tailored to various industrial operations (Tamers et al., 2020). Consider handheld devices as an instance. They serve as a conduit to access vital information, conduct operations, process data, and relay information, predominantly through wireless channels (Schall, Sesek, & Cavuoto, 2018). Innovations in the field of robotics and drones, designed for bolstering occupational safety, invariably include foundational components like sensors, actuators, microprocessors, and energy sources (Kim, Yun, & Oh, 2022). Mobile safety apps are conceived for touchscreen smart devices, facilitating data input and providing valuable insights (Álvarez et al., 2020). Immersive tech solutions, encompassing augmented reality (AR), mixed reality (MR), and virtual reality (VR), offer workers enhanced clarity and efficiency in hazard identification, thus preventing potential mishaps (Hemavani & Kumar, 2015). The inherent adaptability, swiftness, and precision of handheld devices make them a prime choice for supervising occupational safety (Hwang & Lee, 2017). Robotics and drones excel in risk mitigation by offering remote surveillance capabilities (Nakanishi, Taguchi, & Okada, 2010). Mobile apps dedicated to worker safety provide immediate access to essential workplace details, continuous communication, and real-time data documentation (Sadeghi, Soltanmohammadlou, & Nasirzadeh, 2021). Advanced materials and tech tools, devised for safety, furnish custom protection and amplify task efficiency, concurrently diminishing injury risks.

Worker safety tools are explicitly designed to alleviate task constraints and augment operational ease (Niehaus, Hartwig, Rosen, & Wischniewski, 2022). Take autonomous mobile robots for instance, which streamline the transportation of vehicles across designated zones. When such tasks are regularly handled by human operators, they become susceptible to weariness, especially when the tasks are repetitive in nature.

Robots and Drones for Occupational Safety

Industry regulations, specifically in Articles 14 and 15 of the Law on Occupational Risk Prevention (Flores & Da Silva, 2017), endorse the deployment of drones for supervising safety measures to enhance the wellbeing of the workforce. Drones primarily aim to minimize human involvement in operations, subsequently reducing potential risks to worker health and safety (Bottani & Vignali, 2019).

Given the hazardous nature of the construction sector (Tender et al., 2022), drone adoption has significantly risen due to their ability to access difficult locations, cost-effectiveness, and task efficiency. Businesses have seen value in shifting from manual to aerial methods for functions like site analysis, surveillance, and risk assessment. This shift has brought to light previously overlooked hazards, such as worker distractions or potential collisions (Zhang et al., 2023).

In outdoor settings, drones serve functions in elevated locations or over aquatic environments, even venturing underwater (Duraisamy, 2020). Such technological solutions diminish operations dangerous for humans. Notably, in regions like Norway, drones have optimized data accuracy and enhanced surveillance in the oil and gas sectors (Johnsen et al., 2020).

Certain drone systems are equipped to monitor environmental factors, periodically carrying sensors that analyze air components (De Fazio et al., 2022). Moreover, drones play a vital role in identifying harmful gases, defining safety zones (Khalid & Knightly, 2022). Companies often deploy drones for inspecting large infrastructures, negating the need for workers to perform potentially perilous evaluations (Nooralishahi et al., 2021). For instance, since 2014, drones have been instrumental in inspecting urban infrastructure and potentially hazardous sites (Liu et al., 2014). Their versatility extends to functions like structural assessments, material quality checks, pipeline evaluations, and monitoring renewable energy operations. They also monitor woodlands, alerting to anomalies like forest fires (Kinaneva et al., 2019).

Occupational Security Applications

To augment worker efficiency and safety, specialized eyewear can display real-time data, guides, and safety information. They play a pivotal role during emergencies by swiftly guiding workers to safe zones through geolocation (Bottani & Vignali, 2019). In emergencies, these systems alert specialists, prompting immediate assistance.

Various mobile applications, compatible with iOS and Android, have been developed for occupational safety. For instance, the First Aid app, in collaboration with the American Red Cross, provides immediate emergency support (Thygerson et al., 2012). Such apps furnish expert advice and sequential guidelines to tackle unexpected challenges, accidents, and injuries (Poy & Duffy, 2014; Pattaraporn et al., 2018; Spies, Khalaf & Hamam, 2017).

Heat-induced risks, prevalent in certain regions or seasons, can be managed with apps that notify workers about protective measures, rest periods, and hydration, based on the OSHA heat safety standards (Dillane & Jo Anne, 2020). Ladder-related accidents are commonplace; hence, apps offer guidance on safe ladder use (Park et al., 2021; Ariza & Baltao, 2015). To counteract the risks of prolonged sitting, apps remind users to take breaks and offer appropriate stretches (Araguillin et al., 2018; Gan, Liu & Zhu, 2011). Machine maintenance checklists in apps help reduce hazards from malfunctioning machinery (Wang et al., 2019). Apps also assist in determining weightlifting protocols, ensuring safe load-bearing practices (Ricketts, 2015).

Noise monitoring applications measure decibel levels, safeguarding against excessive noise exposure (Jacobs et al., 2020). Pocket guides on smart devices inform about chemical risks, essential for first responders (Gualandi et al., 2021). Apps that gauge worker fatigue are vital for remote work settings, ensuring efficient task delegation and promoting worker safety (Masoud & Esmaeili, 2016).

The Role of VR, AR, and MR in Enhancing Occupational Safety

The emergence of technological advancements in virtual reality (VR), augmented reality (AR), and mixed reality (MR) has revolutionized the realm of workplace safety. Coupled with the pervasive use of affordable mobile and smart gadgets, the applications of VR, AR, and MR have become increasingly prevalent and straightforward to use (Valero, Sivanathan, Bosché, & Abdel-Wahab, 2016).

Research indicates that machinery operator injuries primarily stem from three factors: lack of proper training, limited work experience, and the monotony associated with repetitive tasks. To address these issues, innovations have been introduced to curtail mistakes and mitigate injuries (Ranjan, Zhao, & Misra, 2016).

AR platforms have been curated to simulate a variety of work-related scenarios, helping to gauge an operator’s reaction time and judgment in potentially hazardous situations. Furthermore, AR has simplified the training modules for employees. For instance, AR modules guiding machinery maintenance offer concise technical data, minimizing the chances of mishaps during the process. These systems supersede traditional manuals, making the task more intuitive and safe, even for complex operations (Nnaji, Awolusi, Park, & Albert, 2021).

AR training modules present a virtual roadmap for industrial processes. These modules overlay critical instructions within a worker's field of view, ensuring they don’t overlook vital steps, thus safeguarding their physical and psychological well-being. The immersive nature of these applications allows workers to rehearse tasks in a virtual environment, enabling them to recognize and rectify mistakes, reducing future accidents (Xu, Lu, Wu, Lou, & Li, 2022).

Innovative apps tailored for sectors like utilities, manufacturing, and construction have been crafted to provide real-time safety information, hazard identification, and protocols. They play an essential role in heightening workers' situational awareness, particularly in potentially hazardous zones (Yiqing, 2021).

Moreover, advancements have been made to assist with emergency evacuations. In dire situations, dynamic path indicators can be projected onto workers' visors, showing them the quickest and safest exit routes. Table 3 presents a compilation of VR innovations that have been positively received in the industrial sector. This table delineates the application field, a brief description, and the advantages realized upon its deployment as per related literature.

Table 3: Innovative VR Implementations for Enhancing Worker Safety

Application	Field	Description	Benefits of VR	Reference
Immersive VR for Enhanced Training and Decision-making	Chemical	Scenario generation for accident-based VR training	Enhanced operator decision-making speed and precision	Nazir & Manca (2014)
VR Simulation for Skill Augmentation in Military and Industry	Energy	VR training modules for machinery on oil and gas platforms	VR introduced an improved sense of scene authenticity, aiding effective training	Koźlak, Kurzeja, & Nawrat (2014)
VR Pilot Programs for Subterranean Coal Miners	Mining	VR training assessment for underground coal extraction	Miners found VR modules beneficial, noting positive impacts persisting months post-training	Grabowski & Jankowski (2015)
VR Tools for Elevating Construction Safety Standards	Construction	VR's role in bolstering construction safety	VR-based training enabled a hazard-free environment for rehearsing tasks with electrical equipment prevalent in construction	Zhao & Lucas (2015)
Collaborative VR Systems for Safety Education in Construction	Construction	Using VR for collaborative safety training in construction	Demonstrated that VR settings mimicking real-world social situations enhance safety and health education	Le, Pedro, & Park (2015)
VR Simulations for Biodiesel Production from Waste Cooking Oil	Chemical	A scenario to train for biodiesel production with realistic malfunctions	Training became more immersive, enabling operators to adapt to realistic challenges swiftly	Ahmad, Patle, & Rangaiah (2016)
Virtual Reality-Enhanced Training in Shipyards	Nautic	Simulating immersive sessions for fire safety and hazard identification	Safety training via VR amplified knowledge retention by 14.05%	Wahidi, Pribadi, Rajasa, & Arif (2022)
VR for Enhancing Safety Attitudes in Construction	Construction	VR modules focusing on hazard identification and safety demonstrations	Empirical evidence showcased improved safety dispositions in workers due to fear arousal in VR training	Hoang et al. (2021)
VR-Infused Training for Urban Construction Sites	Construction	Multiplayer VR platforms emphasizing workers' safety cognizance	Workers displayed better recall and proficiency, benefiting from a risk-free, immersive VR training environment	Xu & Zheng (2020)

Numerous cutting-edge nanomaterials are now incorporated in a variety of protective industrial garments to mitigate work-related hazards (INSST, 2023). Intelligent fabrics are being tailored to meet specific needs, such as enhanced permeability, through the use of substances like shape-memory polymers, grafted polymer brushes, and polymeric ionic liquids (Cochrane, Hertleer, & Schwarz-Pfeiffer, 2016).

The proliferation of nanomaterials has catalyzed the emergence of novel textile properties (Jozef & Ľudmila, 2013).

Several innovative materials employ different mechanisms to retain particles (Dhinakaran, Gokhulabalan, Kumar, & Ravichandran, 2020). By leveraging methods such as filters, electrostatic interactions, hydrophobic surfaces, and specialized chemical treatments, intelligent textiles enhance protection against airborne particles in industrial settings. The specific retention method employed depends on the nature of the particles in question. The comfort of workers can also be augmented by fabricating materials that modulate thermal comfort through phase change (Vukicevic, Macužic, Milicevic, Shamina, 2021).

Wearable health tech has seen an uptick in its adoption in workplace settings, despite some viewing them as mere novelties (Chen, Ma, Song, Lai, & Hu, 2016). These devices, like sensor-equipped watches, monitor cardiovascular activity, sleep patterns, and stress indicators, sounding alarms during anomalies (Simpson, Maharaj, & Mobbs, 2019). There are also solutions that alert users when they adopt potentially harmful postures (Yang et al., 2018). Some wearables, designed to be worn discreetly under clothing, gauge stress by monitoring respiratory and heart rates (Yeung et al., 2020).

Devices estimating an individual's metabolic rate, based on the body's processing of fats, carbs, and proteins, are emerging. These gadgets analyze users' breath after a brief inhalation, and conveniently sync the data with mobile devices (Jebelli, Choi, & Lee, 2019).

In occupational health, drones have emerged as vital tools for emergency response. An "emergency drone" can quickly reach accident sites, connecting injured individuals to paramedics through a video camera that transmits a live stream to a control room [Hiebert et al., 2020]. Such advancements in safety and health technology are increasingly integrated into businesses, aiming to enhance occupational safety and health conditions. This provides workers with more flexibility and reduces job-related stress [Carrillo et al., 2018]. These technologies not only improve worker adaptability to changing job demands but also eliminate monotonous and exhaustive tasks [Zwęgliński, 2020].

In healthcare, drones are vital for transporting medical essentials such as medicines, vaccines, and blood packets [Claesson et al., 2016]. Their ability to navigate efficiently makes them suitable for providing better accessibility to hard-to-reach areas. Drones are also instrumental during natural disasters, locating survivors, and providing emergency care [Mayer et al., 2019]. Specifically, drones have demonstrated significant potential in out-of-hospital cardiac arrest situations by swiftly delivering defibrillation equipment [Claesson et al., 2016]. For rescue missions in challenging terrains, such as deserts or snow-covered landscapes, drones have emerged as an efficient response mechanism [Mayer et al., 2019].

In the industrial sector, the convergence of robotics, biomechanics, and informatics has led to the development of exoskeletons [Riccò et al., 2021]. These wearable devices facilitate human-robot interaction, enabling workers to perform tasks with reduced physical effort [Fritzsche et al., 2021]. Several exoskeleton designs aim to minimize the risk of back injuries, although their real-world effectiveness remains to be fully assessed. Nonetheless, current technology has shown reduced strain on the chest and back when handling heavy materials [Li et al., 2022]. Exoskeleton classifications vary based on their kinematic structure and actuator type. Some are rigid, while others offer flexibility. Their designs can be anthropomorphic, aligning with human anatomy, or non-anthropomorphic [Godoy et al., 2018]. Based on actuators, there are passive, semi-active [Wang et al., 2021], and active exoskeletons [Khairul & Adel, 2022].

Health Applications

Technological solutions, especially mobile apps, are increasingly focusing on promoting worker health [Zhao et al., 2017]. These apps offer relevant health information and alerts, especially related to ergonomics [Sun et al., 2018], stress [Jebelli et al., 2018], and repetitive actions that can degrade well-being. Some devices use computer vision systems to detect elevated body temperatures, indicative of SARS-CoV-2 infection [Ulhaq et al., 2020]. Other apps offer flexible work routines, reducing stress and enhancing holistic worker health [Petz et al., 2021]. In structured work environments, vision-based technologies can identify basic emotions, enabling stress-level assessment [Jebelli et al., 2018].

The "Blue Dot" app is introduced in a study, designed to support worker mental health, ensuring peak performance and a better working environment [Granger & Turner, 2022]. Another application by Google named “Workers Health” helps in managing occupational health. It aggregates data on worker statuses and facilitates risk assessment, promoting workplace safety [Google Play, 2023].

Virtual, Augmented, and Mixed Reality in Occupational Safety

In recent research, augmented reality (AR) has been explored for its potential to alleviate stress. For instance, a study referenced in (Beverly et al., 2022) evaluated a virtual reality (VR) tool using VR glasses, aiming to offer tranquility to medical professionals. The technology showcased immediate positive effects. During the pandemic, these immersive technologies were also assessed for their impact on anxiety, emotional upheaval, cognitive function, and self-efficacy (Kaiser et al., 2021).

There are applications where AR glasses project 3D displays of a patient's inner anatomy, assisting surgeons in enhancing their precision and surgical results (Yeung et al., 2021). Innovations like those suggested by (Proffitt et al.i 2023) investigate the use of VR to support rehabilitation processes, where both caregivers and rehabilitation specialists play a significant role in the user-centric design.

Medical advancements are significantly propelled by AR innovations. These advancements empower physicians by enhancing their diagnostic, treatment, and surgical skills. Furthermore, AR plays a pivotal role in the training processes within medical fields (Guo et al., 2021).

DISCUSSION AND CONCLUSION

The workplace landscape is profoundly shaped by technology. This review highlights a growing emphasis on innovative technologies, particularly in wireless communication. Drones, for example, deliver more comprehensive data than traditional health and safety systems. New factors to consider in industrial safety evaluations include worker interactions and traffic patterns.

Although some mobile devices were initially viewed as mere toys their importance in industrial applications cannot be denied. Over time, these tools gain acceptance due to their efficiency and ease of task automation.

There's a rich repository of literature detailing both commercial and academic technological innovations. Many prototypes, designed by engineering students, often exhibit limitations when implemented in occupational safety due to their cost-effective nature.

In response to RQ1, manufacturing heavily relies on technological solutions to optimize working conditions. Regarding RQ2, most articles focused on wireless devices enhancing worker safety by monitoring posture. Keywords from reviewed articles, such as artificial intelligence, virtual reality, and big data, reflect the spectrum of technological advancements. RQ3 highlights the myriad benefits these devices offer, from enhanced safety measures to effective training modules. Lastly, addressing RQ4, while these technologies offer numerous advantages, they are not without challenges, such as integration issues and worker reliance.

The introduction of electronic monitors in workspaces offers multiple safety advantages. They can detect safety breaches, alerting both employees and supervisors. Additionally, they can provide crucial data to further refine safety measures.

However, the financial aspect of these technological solutions cannot be ignored. Costs related to acquisition, training, maintenance, and updates need thorough assessment. Exploring funding avenues and understanding long-term cost benefits can be ways to mitigate these challenges.

In the realm of occupational safety, technology has birthed various specialized tools across different sectors. The future goal should be to consolidate these tools, enhancing their versatility while ensuring user comfort. Presently, most technological contributions to health are confined to monitoring and information dissemination. For safety, these tools enable swift risk communication and quicker medical response times. Future research should delve into the efficacy of these solutions. This review, therefore, serves as a comprehensive guide to current technological interventions for workplace health and safety.

REFERENCES

Ahmad, Z., Patle, D., & Rangaiah, G. (2016). Operator training simulator for biodiesel synthesis from waste cooking oil. Process Safety and Environmental Protection, 99, 55–68.

Alsadik, B., & Khalaf, Y. H. (2022). Potential Use of Drone Ultra-High-Definition Videos for Detailed 3D City Modeling. ISPRS International Journal of Geo-Information, 11(1), 34.

Álvarez, E., Cubero-Atieza, A., Ruiz-Martinez, P., Vaquero-Abellán, M., Redel, M., & Aparicio-Martinez, P. (2020). Bibliometric Study of Technology and Occupational Health in Healthcare Sector: A Worldwide Trend to the Future. Environmental Research and Public Health, 17, 6732.

Araguillin, J. X., Escarabay, K. E., Trujillo, M. F., & Rosales, A. (2018). Mobile Application for Ergonomic Analysis of the Sitting Posture of the Torso. In Proceedings of the International Conference on Information Systems and Computer Science (INCISCOS), pp. 42–48.

Ariza, A., & Baltao, J. (2015). Ergonomic evaluation and design of a mobile application for maternal and infant health for smartphone users among lower-income class Filipinos. In Proceedings of the 6th International Conference on Applied Human Factors and Ergonomics (AHFE 2015) and the Affiliated Conferences, Volume 3, pp. 266–275.

Bastani, K., Kim, S., Kong, Z., Nussbaum, M. A., & Huang, W. (2016). Online classification and sensor selection optimization with applications to human material handling tasks using wearable sensing technologies. Biomechatronics, 46, 485–497.

Beverly, E., Hommema, L., Coates, K., Duncan, G., Gable, B., Gutman, T., Love, M., Love, C., Pershing, M., Stevens, N., & A tranquil virtual reality experience to reduce subjective stress among COVID-19 frontline healthcare workers. PLoS ONE, 17, e0262703.

Bottani, E., & Vignali, G. (2019). Augmented reality technology in the manufacturing industry: A review of the last decade. IISE Transactions, 51(3), 284–310.

Carrillo, R., Moscoso, M., Taype, A., Ruiz, A., & Bernabe, A. (2018). The use of unmanned aerial vehicles for health purposes: A systematic review of experimental studies. Global Health, Epidemiology and Genomics, 3, e13.

Chen, D., Cai, Y., Qian, X., Ansari, R., Xu, W., Chu, K. C., Huang, M. C., & Bring Gait Lab to Everyday Life: Gait Analysis in Terms of Activities of Daily Living. IEEE Internet of Things Journal, 7, 1298–1312.

Chen, M., Ma, Y., Song, J., Lai, C.-F., & Hu, B. (2016). Smart Clothing: Connecting Human with Clouds and Big Data for Sustainable Health Monitoring. Mobile Networks and Applications, 21, 825–845.

Chihming, W., Zexin, J., Songqing, H., & Zhongwei, Y. (2020). Investigation on the Eye-tracking Technology in Hazard Identification of Building Construction Engineering. Proceedings of the 2nd IEEE International Conference on Architecture, Construction, Environment and Hydraulics, 25–27 Aralık 2020, Hsinchu, Tayvan.

Choi, B., Hwang, S., & Lee, S. (2017). What drives construction workers' acceptance of wearable technologies in the workplace? Indoor localization and wearable health devices for occupational safety and health. Automation in Construction, 84, 31–41.

Claesson, A., Fredman, D., Svensson, L., Ringh, M., Hollenberg, J., Nordberg, P., Rosenqvist, M., Djarv, T., Österberg, S., Lennartsson, J., et al. (2016). Unmanned aerial vehicles (drones) in out-of-hospital-cardiac arrest. Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine, 24, 124.

Cochrane, C., Hertleer, C., & Schwarz-Pfeiffer, A. (2016). Smart Textiles and Their Applications. In Smart Textiles (s. 9–32). Woodhead Publishing.

De Fazio, R., Dinoi, L. M., De Vittorio, M., & Visconti, P. (2022). A Sensor-Based Drone for Pollutants Detection in Eco-Friendly Cities: Hardware Design and Data Analysis Application. Electronics, 11(1), 52.

Dhayaneshwar, K., Karthik, M., & Sharmila, B. (2017). Complete First Aid App. International Journal of Trendy Research in Engineering and Technology (IJTRET), 1, 3.

Dhinakaran, V., Gokhulabalan, B., Rahul Kumar, A., & Ravichandran, M. (2020). Advancement in materials for industrial safety helmets. Materials Today Proceedings, 27, 777–782.

Dillane, D., & Jo Anne, G. (2020). Comparison between OSHA-NIOSH Heat Safety Tool app and WBGT monitor to assess heat stress risk in agriculture. Journal of Occupational and Environmental Hygiene, 17, 181–192.

Duraisamy, J. (2020). Design and Analysis of Remotely Amphibious Drone. International Journal of Innovative Technology and Exploring Engineering, 9, 284–287.

Eriksen, M. B., & Frandsen, T. F. (2018). The impact of patient, intervention, comparison, outcome (PICO) as a search strategy tool on literature search quality: A systematic review. Journal of the Medical Library Association, 106(4), 420–431.

Ferrone, A., Napier, C., Menon, C., & Wearable technology to increase self-awareness of low back pain: A survey of technology needs among health care workers. Sensors, 21, 8412.

Flor, O., & Acosta-Vargas, P. (2023). Innovative Technologies for Safety and Health Occupational [Dataset]. Mendeley Data, V1. https://data.mendeley.com/datasets/gsm53nrgvb/1

Flores, E., & Da Silva, C. (2017). Innovation in the Workplace—Reinvigorating the Culture of Safety and Occupational Health: Contributions from a Literature Review. Engineering Science and Technology, an International Journal, 20, 372–380.

Fritzsche, L., Galibarov, P., Gärtner, C., Bornmann, J., Damsgaard, M., Wall, R., & Assessing the efficiency of exoskeletons in physical strain reduction by biomechanical simulation with AnyBody Modeling System. Wearable Technologies, 2, e6.

Gan, Y., Liu, S., & Zhu, W. (2011). Studies and Application of Heavy Equipment Fault Diagnosis System. Advanced Materials Research, 225, 399–402.

Godoy, J. C., Campos, I. J., Pérez, L. M., & Muñoz, L. R. (2018). Nonanthropomorphic exoskeleton with legs based on eight-bar linkages. International Journal of Advanced Robotic Systems, 15.

Google Play. (2023). Workers Health. https://play.google.com/store/apps/details?id=org.dreamonkey.workers_health.app&gl=US (Erişim tarihi: 20 Ocak 2023).

Grabowski, A., & Jankowski, J. (2015). Virtual Reality-based pilot training for underground coal miners. Safety Science, 72, 310–314.

Granger, S., & Turner, N. (2022). Adapting, adopting, and advancing change: A framework for future research in the psychology of occupational safety. Journal of Safety Research, 82, 38–47.

Gualandi, I., Tessarolo, M., Mariani, F., Possanzini, L., Scavetta, E., & Fraboni, B. (2021). Textile chemical sensors based on conductive polymers for the analysis of sweat. Polymers, 13, 894.

Guo, Y., Agrawal, S., Peeta, S., & Benedyk, I. (2021). Safety and health perceptions of location-based augmented reality gaming app and their implications. Accident Analysis & Prevention, 161, 106354.

Hayden, M., Barim, M., Weaver, D., Elliot, K., Flynn, M., Lincoln, J., & Occupational Safety and Health with Technological Developments in Livestock Farms: A Literature Review. International Journal of Environmental Research and Public Health, 19, 16440.

Hemavani, K., & Kumar, V. (2015). Temperature Programmable Suit using Thermoelectric Cooler/Heater. SSRG International Journal of Electronics and Communication Engineering, 2(7).

Hiebert, B., Nouvet, E., Jeyabalan, V., & Donelle, L. (2022). The Application of Drones in Healthcare and Health-Related Services in North America: A Scoping Review. Drones, 4, 30.

Hoang, T., Greuter, S., Taylor, S., Aranda, G., & Mulvany, G. T. (2021). An Evaluation of Virtual Reality for Fear Arousal Safety Training in the Construction Industry. In Proceedings of the 2021 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct) (s. 177–182). IEEE.

Hwang, S., & Lee, S. (2017). Wristband-type wearable health devices to measure construction workers' physical demands. Automation in Construction, 80, 12–21.

INSST. (Çalışma Bakanlığı, Endüstriyel İş Güvenliği ve Sağlık Enstitüsü). (2023). Seguridad y Salud en el Trabajo con Nanomateriales. https://www.insst.es/documents/94886/514312/poster+sst+nanomateriales.pdf/443eb879-268b-4263-83ae-1db72ca11ce9?t=1605801005033 (Erişim tarihi: 10 Ocak 2023).

Jacobs, N., Roberts, B., Reamer, H., Mathis, C., Gaffney, S., & Neitzel, R. (2020). Noise exposures in different community settings measured by traditional dosimeter and smartphone app. Applied Acoustics, 167, 107408.

Jebelli, H., Choi, B., & Lee, S. H. (2019). Application of Wearable Biosensors to Construction Sites. I: Assessing Workers' Stress. Journal of Biosensors and Bioelectronics, 145, 12.

Jebelli, H., Hwang, S., & Lee, S. (2018). EEG-based workers' stress recognition at construction sites. Automation in Construction, 93, 315–324.

Johnsen, S., Bakken, T., Transeth, A., Holmstrøm, S., Merz, M., Grøtli, E. I., Jacobsen, S. R., & Storvold, R. (2020). Safety and security of drones in the oil and gas industry. In Proceedings of the 30th European Safety and Reliability Conference and the 15th Probabilistic Safety Assessment and Management Conference.

Jozef, S., & Ľudmila, B. (2013). Multifunctional fabric with Camouflage Print, Hydrophobic, Self-Cleaning and Antimicrobial Nanofinish. https://www.researchgate.net/publication/289041846_Multifunctional_fabric_with_camouflage_print_hydrophobic_self-cleaning_and_antimicrobial_nanofinish (Erişim tarihi: 12 Mayıs 2023).

Kaiser, M. S., Mahmud, M., Noor, M. B. T., Zenia, N. Z., Al Mamun, S., Mahmud, K. M. A., Azad, S., Aradhya, V. N. M., Stephan, P., Stephan, T., & iWorksafe: Towards Healthy Workplaces During COVID-19 With an Intelligent Phealth App for Industrial Settings. IEEE Access, 9, 13814–13828.

Kelm, A., Meins-Becker, A., & Helmus, M. (2019). Improving Occupational Health and Safety by Using Advanced Technologies and BIM. Proceedings of the International Structural Engineering and Construction, 20–25 Mayıs 2019, Chicago, IL, ABD.

Khairul, A., & Adel, A. (2022). Active Exoskeleton Control Systems: State of the Art. Procedia Engineering, 41, 988–994.

Khalid, M., & Knightly, E. (2022). Networked Drones for Industrial Emergency Events. Systems & Control Letters. doi:10.1016/j.sysconle.2022.103676

Kilshaw, A., & Jivan, S. (2021). Smartphone apps on burns first aid: A review of the advice. Burns, 47, 171–174.

Kim, J., Kim, N., Kwon, M., & Lee, J. (2017). Attachable Pulse Sensors Integrated with Inorganic Optoelectronic Devices for Monitoring Heart Rates at Various Body Locations. ACS Applied Materials & Interfaces, 9(31), 25700–25705.

Kim, Y., Yun, J., & Oh, T. (2022). Effectiveness Analysis for Smart Construction Safety Technology (SCST) by Test Bed Operation on Small- and Medium-Sized Construction Sites. Environmental Research and Public Health, 19, 5203.

Kinaneva, D., Hristov, G., Raychev, J., & Zahariev, P. (2019). Early Forest Fire Detection Using Drones and Artificial Intelligence. In Proceedings of the 2019 42nd International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO), pp. 1060–1065.

Koźlak, M., Kurzeja, A., & Nawrat, A. (2013). Virtual Reality Technology for Military and Industry Training Programs. In A. Nawrat & Z. Kuś (Eds.), Vision Based Systems for UAV Applications (s. 481). Springer.

Le, Q., Pedro, A., & Park, C. (2015). A Social Virtual Reality-Based Construction Safety Education System for Experiential Learning. Journal of Intelligent & Robotic Systems, 79, 487–506.

Li, J. M., Molinaro, D. D., King, A. S., Mazumdar, A., & Young, A. J. (2022). Design and Validation of a Cable-Driven Asymmetric Back Exosuit. IEEE Transactions on Robotics, 38, 1489–1502.

Liu, P., Chen, A. Y., Huang, Y. N., Han, J. Y., Lai, J. S., Kang, S. C., Wu, T. H., Wen, M. C., & Tsai, M. H. (2014). A review of rotorcraft unmanned aerial vehicle (UAV) developments and applications in civil engineering. Smart Structures and Systems, 13, 1065–1094.

Masoud, G., & Esmaeili, B. (2016). Unmanned Aerial Systems (UAS) for Construction Safety Applications. In Proceedings of the 2016 Construction Research Congress, pp. 2642–2650.

Mayer, S., Lischke, L., & Wozniak, P. (2019). Drones for Search and Rescue. In Proceedings of the iHDI—International Workshop on Human-Drone Interaction, Glasgow, UK, 5 Mayıs 2019.

Mohammed, J., & Mahmud, J. (2020). Selection of a machine learning algorithm for OSHA fatalities. Proceedings of the 2020 IEEE Technology & Engineering Management Conference (TEMSCON), 3–6 Haziran 2020, Novi, MI, ABD.

Nahid, Y. L. (2021). Virtual and augmented reality technologies for emergency management in the built environments: A state-of-the-art review. Journal of Safety Science and Resilience, 2, 1–10.

Nakanishi, M., Taguchi, K.-I., & Okada, Y. (2010). Suggestions on the applicability of visual instructions with see-through head-mounted displays depending on the task. Applied Ergonomics, 42, 146–155.

Nazir, S., & Manca, D. (2014). Immersive Virtual Reality for Training and Decision Making: Preliminary Results of Experiments Performed With a Plant Simulator. SPE Economics & Management, 6, 165–172.

Niehaus, S., Hartwig, M., Rosen, P. H., & Wischniewski, S. (2022). An Occupational Safety and Health Perspective on Human in Control and AI. Frontiers in Artificial Intelligence, 8, 868382.

Nnaji, C., Awolusi, I., Park, J.W., & Albert, A. (2021). Wearable sensing devices: Towards the development of a personalized system for construction safety and health risk mitigation. Sensors, 21, 682.

Nooralishahi, P., Ibarra-Castanedo, C., Deane, S., López, F., Pant, S., Genest, M., Avdelidis, N. P., & Maldague, X. P. V. (2021). Drone-Based Non-Destructive Inspection of Industrial Sites: A Review and Case Studies. Drones, 5, 106.

Ometov, A., Shubina, V., Klus, L., Skibińska, J., Saafi, S., Pascacio, P., Flueratoru, L., Gaibor, D. Q., Chukhno, N., Chukhno, O., ve diğerleri. (2021). A Survey of Wearable Technology: History, State of the Art, and Current Challenges. Computer Networks, 193, 108074.

Papathoma-Koehle, M., Promper, C., Bojariu, R., Cica, R., Sik, A., Perge, K., László, P., Czikora, E. B., Dumitrescu, A., Turcus, C., et al. (2016). A common methodology for risk assessment and mapping for south-east Europe: An application for heat wave risk in Romania. Natural Hazards, 82, 89–109.

Park, H., Kim, K., Ghung, H., Jeong, S., Soh, J., Hyun, Y., & Kim, H. (2021). A Worker-Centered Personal Health Record App for Workplace Health Promotion Using National Health Care Data Sets: Design and Development Study. JMIR Public Health and Surveillance, 9, e29184.

Pattarapom, K., Benjamas, S., & Orawit, T. (2018). First Aid Literacy Mobile Application Development. In Proceedings of the 8th International Conference on Information Communication and Management (ICICM '18), pp. 17–21.

Petz, P., Eibensteiner, F., & Langer, J. (2021). Sensor Shirt as Universal Platform for Real-Time Monitoring of Posture and Movements for Occupational Health and Ergonomics. Procedia Computer Science, 180, 200–207.

Poy, H. M., & Duffy, B. (2014). A Cloud-Enabled Building and Fire Emergency Evacuation Application. IEEE Cloud Computing, 1, 40–49.

PRISMA Statement. (2021). PRISMA for Scoping Reviews. http://www.prisma-statement.org/Extensions/ScopingReviews

Proffitt, R. (2023). Virtual Reality—Augmented Rehabilitation Lab. https://healthprofessions.missouri.edu/occupational-therapy/research/faculty-research-labs/virtual-reality-augmented-rehabilitation-lab/ (Erişim tarihi: 22 Ocak 2023).

Rajendran, S., Giridhar, S., Chaudhari, S., & Gupta, P. K. (2021). Technological advancements in occupational health and safety. Measurement and Sensors, 15, 100045.

Ranjan, A., Zhao, Y., & Misra, P. (2016). Opportunities and Challenges in Health Sensing for Extreme Industrial Environment: Perspectives from Underground Mines. IEEE Access, 4, 139181–139195.

Riccò, M., Ranzieri, S., Vezzosi, L., Balzarini, F., & Bragazzi, N. L. (2021). Wearable Exoskeletons on the Workplaces: Knowledge, Attitudes and Perspectives of Health and Safety Managers on the implementation of exoskeleton technology in Northern Italy. Acta Bio Medica, 92, e2021310.

Ricketts, M. (2015). Introduction to Sling Load Tension Calculations. Mitch Ricketts Northeastern State University.

Sadeghi, S., Soltanmohammadlou, N., & Nasirzadeh, F. (2021). Applications of wireless sensor networks to improve occupational safety and health in underground mines. Journal of Safety Research, 83, 8–25.

Schall, M., Sesek, R., & Cavuoto, L. (2018). Barriers to the Adoption of Wearable Sensors in the Workplace: A Survey of Occupational Safety and Health Professionals. Human Factors, 60, 351–362.

Simpson, L., Maharaj, M. M., & Mobbs, R. J. (2019). The role of wearables in spinal posture analysis: A systematic review. BMC Musculoskeletal Disorders, 20, 55.

Spies, C., Khalaf, A., & Hamam, Y. (2017). Development of a first aid smartphone app for use by untrained healthcare workers. African Journal of Information and Communication, 20, 31–47.

Sun, C., Buchholz, B., Quinn, M., Punnett, L., Galligan, C., & Gore, R. (2018). Ergonomic evaluation of slide boards used by home care aides to assist client transfers. Ergonomics, 61, 913–922.

Tamers, S. L., Streit, J., Pana-Cryan, R., Ray, T., Syron, L., Flynn, M. A., Castillo, D., Roth, G., Geraci, C., Guerin, R., ve diğerleri. (2020). Envisioning the future of work to safeguard the safety, health, and well-being of the workforce: A perspective from the CDC's National Institute for Occupational Safety and Health. American Journal of Industrial Medicine, 63, 1065–1084.

Tarique, I., Briscoe, D. R., & Schuler, R. S. (2022). International Human Resource Management: Policies and Practices for Multinational Enterprises (6. baskı). Routledge.

Tender, M., Fuller, P., Vaughan, A., Long, M., Couto, J., Damien, P., Chow, V., Silva, F., Reis, F., & Reis, R. (2022). Lessons from implementation of Key Technological Developments to improve occupational safety and health processes in a complex UK-based construction project. IOP Conference Series: Earth and Environmental Science, 1101, 092016.

Thygerson, S., West, J., Rassbach, A., & Thygerson, A. (2012). iPhone Apps for First Aid: A Content Analysis. Journal of Consumer Health on the Internet, 16, 213–225.

Ulhaq, A., Born, J., Khan, A., Gomes, D. P. S., Chakraborty, S., & Paul, M. (2020). COVID-19 Control by Computer Vision Approaches: A Survey. IEEE Access, 8, 179437–179456.

Valero, E., Sivanathan, A., Bosché, F., Abdel-Wahab, M. (2016). Musculoskeletal disorders in construction: A review and a novel system for activity tracking with body area network. Applied Ergonomics, 54, 120–130.

Vukicevic, A., Macužic, I., Milicevic, V., & Shamina, L. (2021). Digital Training and Advanced Learning in Occupational Safety and Health Based on Modern and Affordable Technologies. Sustainability, 13, 13641.

Wahidi, S., Pribadi, T., Rajasa, W., & Arif, M. (2022). Virtual Reality Based Application for Safety Training at Shipyards. IOP Conference Series: Earth and Environmental Science, 972, 012025.

Wang, P., Zhang, X., Xing, S., Liu, T., & Zhang, C. (2019). Development and application of lifting and leveling system for space station. Journal of Physics: Conference Series, 1314, 012092.

Wang, Z., Wu, X., Zhang, Y., Chen, C., Liu, S., Liu, Y., Peng, A., & Ma, Y. (2021). A Semi-active Exoskeleton Based on EMGs Reduces Muscle Fatigue When Squatting. Frontiers in Neurorobotics, 15, 625479.

Xu, J., Lu, W., Wu, L., Lou, J., & Li, X. (2022). Balancing privacy and occupational safety and health in construction: A blockchain-enabled P-OSH deployment framework. Safety Science, 154, 105860.

Xu, Z., & Zheng, N. (2020). Incorporating Virtual Reality Technology in Safety Training Solution for Construction Site of Urban Cities. Sustainability, 13, 243.

Yang, L., Lu, K., Diaz-Olivares, J. A., Seoane, F., Lindecrantz, K., Forsman, M., Abtahi, F., & Eklund, J. A. E. (2018). Towards Smart Work Clothing for Automatic Risk Assessment of Physical Workload. IEEE Access, 6, 40059–40072.

Yeung, A. W. K., Tosevska, A., Klager, E., Eibensteiner, F., Laxar, D., Stoyanov, J., Glisic, M., Zeiner, S., Kulnik, S. T., Crutzen, R., & Virtual and Augmented Reality Applications in Medicine: Analysis of the Scientific Literature. Journal of Medical Internet Research, 2, e25499.

Yeung, S. S. Y., Trappenburg, M. C., Meskers, C. G. M., Maier, A. B., & Reijnierse, E. M. (2020). The use of a portable metabolic monitoring device for measuring RMR in healthy adults. British Journal of Nutrition, 124, 1229–1240.

Zhang, M., Ghodrati, N., Poshdar, M., Seet, B., & Yongchareon, S. (2023). A construction accident prevention system based on the Internet of Things (IoT). Safety Science, 159, 106012.

Zhao, D., & Lucas, J. (2015). Virtual reality simulation for construction safety promotion. International Journal of Injury Control and Safety Promotion, 22, 57–67.

Zhao, W., Lun, R., Gordon, C., Fofana, A. B., Espy, D. D., Reinthal, M. A., Ekelman, B., Goodman, G. D., Niederriter, J. E., & Luo, X. (2017). A Human-Centered Activity Tracking System: Toward a Healthier Workplace. IEEE Transactions on Human-Machine Systems, 47, 343–355.

Zsofkovits, M., Cheng, S., Walder, F., & Heidenberger, K. (2012). Smartphone-Based Coordination Support for the Austrian Medical First Responder System. In Proceedings of the Third International Conference on Emerging Intelligent Data and Web Technologies, pp. 155–162.

Zwęgliński, T. (2020). The Use of Drones in Disaster Aerial Needs Reconnaissance and Damage Assessment—Three-Dimensional Modeling and Orthophoto Map Study. Sustainability, 12, 6080.