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Current Trends in Ergonomic Innovations for Continuous Improvement in Different Work Fields

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Abstract: Due to the constant technological evolution and social changes in industry, it is indispensable for ergonomics to adapt and effectively integrate new technologies. This review article aims to provide a detailed analysis of the latest developments in ergonomics, examining how the field is responding to the evolving needs of various industry sectors. For instance, in the medical field, 3D scanning and modeling technologies have been used to create prostheses; in design, pictograms have been developed to help agricultural workers in Africa work more efficiently; and in the workplace, artificial vision has been employed to study and reduce musculoskeletal disorders and fatigue among construction company employees. Additionally, areas of opportunity are identified where ergonomics could have a significant impact, such as its application in studies of e-sports players. A total of 50 articles were reviewed and categorized in terms of ergonomics evolution, innovations in design, technology, work, health, and areas of opportunity. This literature review will serve as a guide for researchers in planning future projects.

Keywords: **ergonomics, innovation, computer vision, design thinking, augmented reality.**

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1. Introduction

Ergonomics is a discipline of great relevance for workers as it focuses on improving the quality of life in the workplace. This interdisciplinary field incorporates elements of design, evaluation, system configuration, products, and environments. Its primary objective is to ensure that all elements in the workspace are adjusted to people's abilities, needs, and limitations to maximize individuals' efficiency, safety, and well-being.

The fundamentals of ergonomics are based on a deep understanding of the interaction between human beings and their environment, finding ways to adapt the environment to its inhabitants to promote optimal performance and reduce injury risks or health problems in the workplace. Thus, ergonomics plays a critical role in work settings, resulting in several benefits, such as user well-being and comfort, injury prevention, increased efficiency and productivity, minimization of errors, cost savings, and regulatory compliance, among other things. Notably, ergonomics not only brings advantages to workers but can also positively impact the profitability and competitiveness of companies. In this sense, given the constant technological evolution and social changes in industry, it is essential to maintain both the well-being of workers and the competitiveness of companies. In this context, ergonomics has also had to adapt to these transformations by integrating technologies into work processes.

Moreover, digital transformation has necessitated the design of environments that facilitate worker interaction with advanced technologies, such as automation, artificial intelligence, and virtual reality. Additionally, the importance of inclusive ergonomic approaches that adapt to workers' needs and contribute to sustainability and the environment is worth noting.

This review article aims to provide an overview of the most recent advances in ergonomics, examining how this discipline has evolved to meet the changing needs of industry. By highlighting how experts in this field have introduced new software and methods to address ergonomic challenges, this work will serve as a valuable resource for professionals and students planning future projects.

2. Evolution of Ergonomics

Ergonomics is a discipline that has undergone significant changes throughout its history as it developed and transformed itself to adapt to the changing needs of society and the work environment. The term "ergonomics" was first used in 1857. Wojciech Jastrzebowski postulated that it was a derivation of the Greek ergon (work) and nomos (laws). Therefore, ergonomics is the science that regulates work (de Winter & Hancock, 2021; Salvendy & Karwowski, 2021).

However, it was not until 1949 that the term "ergonomics" resurfaced with a more precise and modern definition. The English psychologist Hywel Murrell reintroduced the word "ergonomics" during a meeting at the headquarters of the British Royal Navy (Salvendy & Karwowski, 2021). This meeting laid the foundations for the formation of the first ergonomics society in the world, the Ergonomics Research Society in the United Kingdom. Thus, ergonomics emerged as a scientific discipline in the late 1940s in response to the increasing complexity of technological systems. This complexity was especially evident in the military sector, where the physical and cognitive demands of the human operator were extremely high (Torres & Rodríguez, 2021).

The Human Factors and Ergonomics Society (HFES) was established in the United States in 1957. The International Ergonomics Association (IEA) was created in 1961, and the Société d'Ergonomie de Langue Française (SELF) was founded in 1963. More than 50 ergonomics societies have been organized worldwide, forming an integral membership in the IEA (Torres & Rodríguez, 2021).

According to Soares (2016), in Latin America, ergonomics took its first steps in Brazil during the 1960s (Soares, 2006). There are different companies and research institutions in several countries in the Americas. Proof of this is the increase in Latin American ergonomists participating in international congresses supported by the IEA.

2.1 Innovations in Ergonomic Design

Ergonomics is related to numerous disciplines and plays a fundamental role in which design is crucial. For instance, in architecture, significant innovations have been made to create sustainable and accessible cities for everyone. Consequently, as highlighted in an article, the design of cities is inherently a human responsibility (Aceves-González & Rey-Galindo, 2021). In response to this problem, blueprints were explored for public transportation in Guadalajara, Mexico, that considered ergonomics and inclusive design. These methods facilitate communication with users, identifying their needs according to diverse abilities to create a more inclusive public transportation service that benefits young and older adults (Aceves-González & Rey-Galindo, 2021). A similar study explores the possibility of using neuro-improved reality to enhance communication between customers and suppliers, combining digital and physical aspects (Hilken et al., 2022).

Innovative solutions have also been implemented in everyday clothing, which does not accommodate all body types and special needs. A case in point is the creation of inclusive pants with elastic waistbands, Velcro fasteners, and magnetic snaps, eliminating back pockets and adding them below the knee (Cho et al., 2022). These adaptations significantly benefit people with special needs. The study results show that people with or without special needs are willing to purchase garments with slight differences from conventional ones (Cho et al., 2022). Also, "health textiles" have been added to prevent pressure injuries (Salgueiro-Oliveira et al., 2023).

Furthermore, the integration of ventilation systems into apparel has been shown to reduce heat stress in hot environments, supporting its recommendation for continuous use in such environments (Zhao et al., 2023). Likewise, Digital Human Modeling (DHM) has enabled the manufacture of inclusive clothing, providing comfort and customization for various body types (Donmezer et al., 2023). A similar study used 3D scanning to improve the quality of sportswear and allow it to be tailored to the needs of athletes (Vleugels et al., 2022).

A further study on improvements in clothing was carried out to achieve thermoregulation in construction workers. Through active garments, it was found that there was a reduction in skin temperature of up to 2.7 °C. In addition, these new creations allow a personalized fit for the user through artificial intelligence techniques (Dąbrowska et al., 2024). Several studies have improved the reduction of thermal stress caused by clothing for various users (Table 1).

Table 1. Studies related to mitigating thermal stress in occupational environments.

Summary	Reference
Methods that mitigate stress from high temperatures in occupational environments.	Morris et al. (2020)
Study on the impact of high temperatures on the manufacturing sector.	Somanathan et al. (2021)
Improvement in occupational heat assessment methods.	Gao et al. (2017)
Design of a portable cooling garment based on thermoelectric engineering.	Xu et al. (2022)
Design of a liquid cooling vest.	Hou et al. (2019)

In addition to clothing redesigns, a study aimed to automate the 3D scanning procedure to assess the quality of fabrics used in footwear by employing a robotic arm to scan different items, surfaces, and other materials (Pancu et al., 2024).

An article on design-related cognitive ergonomics explores its application in agriculture, specifically in areas of Africa with low literacy levels. The study in Uganda focused on creating pictograms to guide and instruct farmers. It was found that many farmers needed help understanding information in foreign languages, which hindered their work. Initially, only 40% of pictograms were correctly understood. However, after receiving user feedback and making improvements, 70% acceptance was achieved, highlighting the importance of user-centered design and suggesting the application of pictograms in other sectors with limited resources (Kisaalita & Sempiira, 2022).

Medicine is a field that undergoes continuous research. For instance, one prominent issue that hospitals encounter is the heavy workload and specialized duties performed by paramedics in the confined space of an ambulance. An ergonomic review of the interior of a type II cabin was conducted to improve this issue using an anthropometric analysis to enhance the working conditions of paramedics and reduce the risk of injury. The design thinking methodology was used to identify the discomforts that paramedics experience in various areas of the body. It was found that the ambulance furniture was designed for the patient's needs without considering the paramedic. Therefore, solutions such as a stretcher lift and swivel seats were proposed to improve ergonomics. The aim was to reduce effort, correct poor posture, and optimize space in the ambulance (Mejía Martínez, 2022). In addition, the possibility of designing stretchers and electric wheelchairs that allow people with disabilities to move independently and reduce back pain and injuries among caregivers assisting in transfers has been studied (Satpute et al., 2023).

Over the past decade, manufacturers have dedicated their efforts to creating vehicles that are not only environmentally friendly but also ensure the safety and comfort of both drivers and passengers. An article published by the University of Cambridge proposes a cockpit for autonomous vehicles. This design proposed displaying essential information to avoid distractions and allow the driver to regain control when necessary. The data would be provided by road conditions, driver memory, and communication via loudspeakers, screens, and other means. The main objective is to adapt the cabs to the driver's needs and improve the existing systems based on simulation models (Figure 1). It should be noted that this proposal does not consider human factors such as lack of attention to the road or user fatigue (Iuskevich et al., 2020).

In addition, symbols have been incorporated into electronic dashboards in new vehicles; however, it is essential to evaluate their effectiveness. For this reason, a study was carried out that surveyed 204 young participants to determine their ability to recognize the symbols on these dashboards. The survey results revealed the need for improved road safety education, especially regarding understanding the symbols used on dashboards to indicate safety status. In addition, a recommendation was made to redesign these symbols (Manojlovic et al., 2023).

Another means of transport that has undergone several modifications over time is the bicycle, which is well known for promoting sustainable transportation, improving personal health, and reducing carbon emissions. A recent study has incorporated tools such as a hub dynamo, USB chargers, batteries, and solar panels to produce and store energy through their use. This allows users to charge their batteries and power devices connected to a USB cable. In addition to integrating these tools, this ergonomic design allows cyclists to replace the batteries easily when needed (Velázquez et al., 2024).

In training, a smart wearable gadget has been created to identify and rectify improper squat positions. This exercise can lead to a significant risk of injury from poor posture and improper equipment use (Figure 2). Therefore, the device, which uses sensors, alerts the user when it detects poor knee posture and records this information on a computer for further analysis and studies (Arciniega-Rocha et al., 2023).

In another study, a robot called Luna EMG was developed for knee injuries. This robot allows rehabilitation through the active and passive evaluation of the sense of the position of the knee joints (Oleksy et al., 2022).

Another common cardio-related exercise is running, for which an analysis test called KeepRunning has been created. This test aims to provide indicators to runners to improve their technique and prevent possible injuries, recognizing variations according to each person's individual characteristics (Rodríguez et al., 2023).

Moreover, an oscillating hydraulic trainer (Figure 3) has been designed to strengthen and prevent neck injuries. After subjecting the device to various tests and comparing it with traditional instruments used to exercise the neck, researchers concluded that it offers a more

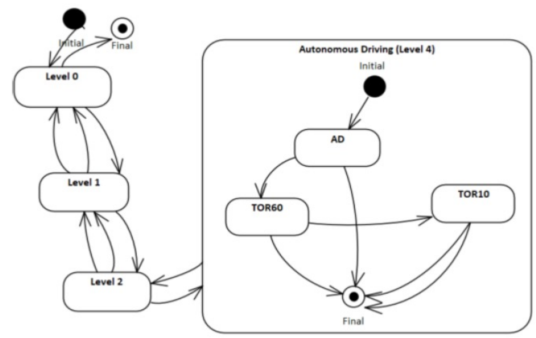


Figure 1. The events sequence of the car is shown through a state machine diagram with adaptive automation.

Note. © Iuskevich et al. (2020). CC BY-NC-ND 4.0

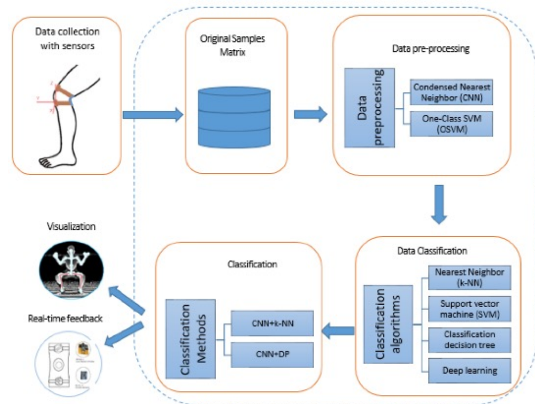


Figure 2. System scheme of a smart wearable for preventing injuries in amateur athletes in squats exercise.

Note. Arciniega-Rocha et al. 2023 © CC BY 4.0 DEED.

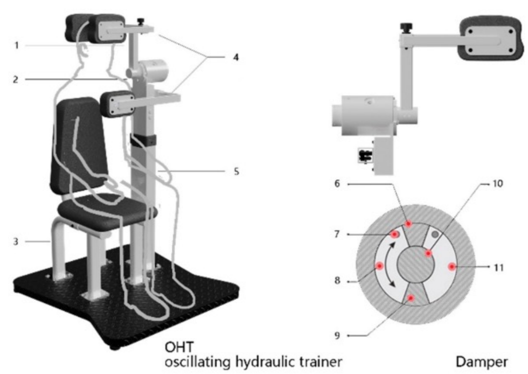


Figure 3. Oscillating hydraulic trainer and functional structure of the damper. 1—Swing arm; 2—Oscillatory hydraulic damping device; 3—Support base; 4—Adjustment mechanism; 5—Electric height adjustment support post; 6—Fixed blade; 7—Throttle valve; 8—Cavity A; 9—Rotating blade; 10—Rotating axis; 11—Cavity B.

Note. © Yang et al. (2023). © CC BY-NC-ND 4.0

effective, safe, and beneficial strength training alternative for neck well-being (Yang et al., 2023).

Another study focused on the upper extremities and neck aimed to identify the optimal type of pillow. The materials used in pillows were found to influence the comfort and support of the spine significantly. Although the best pillow choice may vary depending on the user's needs, postures, and sleeping preferences, pillows with goose feathers were found to offer greater head comfort and better shoulder support (Türkmen et al., 2023).

An innovative inspection device was developed in the aeronautical industry. The central focus of this study was to develop an ergonomic handle for the inspection device to prevent musculoskeletal disorders and provide excellent stability during inspection tasks (Figure 4). This design was based on user feedback after using three different types of handles, significantly improving the efficacy and usability of the new device (Colim et al., 2023).

A recent innovative ergonomic design involves creating a footrest equipped with an accordion blower to mitigate the negative effects of long periods of sitting (Figure 5). The effectiveness of this safety cushion was evaluated using simulation software (CATIA), and the results obtained through the RULA method revealed an acceptable index regarding seated working postures (Mistarihi et al., 2023).

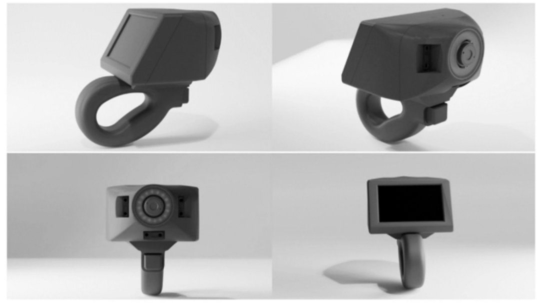
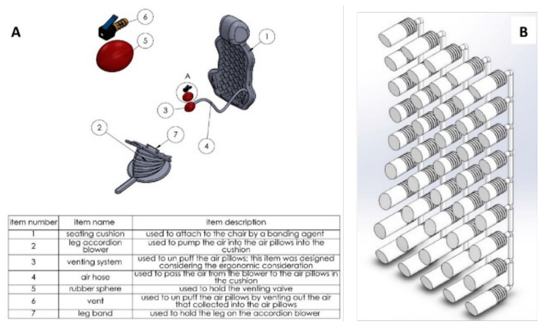


Figure 4. Final design of the user-centered inspection device for the aircraft manufacturing industry.

Note. © Colim, A. et al. (2023). © CC BY 4.0 DEED



item number	item name	item description
1	seating cushion	used to attach to the chair by a banding agent
2	leg accordion blower	used to pump the air into the air pillows into the cushion
3	venting system	used to un puff the air pillows; this item was designed considering the ergonomic consideration
4	air hose	used to pass the air from the blower to the air pillows in the cushion
5	rubber sphere	used to hold the venting valve
6	vent	used to un puff the air pillows by venting out the air that collected into the air pillows
7	leg band	used to hold the leg on the accordion blower

Figure 5. A) Parts of the manual blowing system using the accordion blower. B) Design of the air cell system mimics the human spine.

Note. © Mistarihi, M.Z. et al. (2023). CC BY 4.0 DEED

2.2 Ergonomic Innovations at Work

Ergonomics, applicable at various stages of daily life, can be adjusted to multiple work environments involving the interaction between a process and the human operator. The central purpose of ergonomics lies in adapting machines to the operator, generating a beneficial relationship between the individual, the environment, and the activities performed, all to guarantee the worker's physical and mental safety.

In a tertiary hospital in Ecuador, three of its key areas were evaluated: Emergencies, Neurology, and Traumatology, where auxiliary staff were found to suffer from pain in the back and extremities due to activities such as handling patients and heavy equipment. Through the OWAS method, it was identified that the leading cause of physical strain was incorrect posture. The study showed that the mobilization of patients is the leading cause of musculoskeletal disorders in health personnel, affecting the lumbar-dorsal spine and neck. Emphasis is placed on improving working conditions through training in patient mobilization techniques and using ergonomic devices to reduce the physical burden and discomfort of health personnel (Correa et al., 2019).

Because adequate lighting significantly impacts employee performance and well-being, ergonomics addresses lighting quality in the workplace. A study published in the journal ACE investigated the impact of daylight simulation in a lab in Norway, where a space called the "Garden" was designed with furniture, plants, and a natural lighting system on the ceiling. The results revealed that the simulation of natural light improved the mood of the volunteers, generating feelings of relaxation, security, and happiness. In addition, the presence of plants in the environment contributed to creating a more natural atmosphere, highlighting the importance of exploring further advantages and disadvantages of natural light in work environments (Martins et al., 2023).

Therefore, ergonomics encompasses a wide range of aspects that impact the well-being and health of workers in different work environments. For example, another study simulated forests to reduce stress and improve patients' moods. After a gaming session in a virtual reality forest, the participants in this study subsequently showed lower stress levels (Mohamad Yahaya et al., 2023). In this sense, companies are invited to apply the smart office concept, in which users feel satisfied and have an improved interaction between their physical and social environment (Tuzcuoğlu et al., 2022). In addition, emphasis has been placed on considering various factors such as design, distribution, orientation, and location of the workplace to contribute to the psychological satisfaction of the worker (Kwon & Remøy, 2020).

Ergonomics improves working conditions in various settings, including construction, where 30% of workplace injuries in the U.S. occur. Advanced engineering informatics uses machine learning to identify awkward postures and prevent musculoskeletal disorders (Zhao & Obonyo, 2021). Likewise, the European Conference on Computing in Construction automated the assessment of postures with the Rapid Entire Body Assessment (REBA) method using artificial vision (MV) technology (Massiris Fernández et al., 2020). Similar research was carried out through an artificial intelligence program supported by the Intelligent Vision-Based Method (SVBM), which is a resource that facilitates the deduction, analysis, and training of the human posture when lifting loads manually in the construction sector (Purushothaman & Gedara, 2023).

The relationship between ergonomics and handcart handling was studied, highlighting the influence of psychological factors and pain on work performance (Petrovic et al., 2022). Another study of wearable devices explored the possibility of using bracelets to create a machine-learning algorithm to determine the risk of a job task. The bracelet is intended to automate the evaluation of the Job Strain Index (JSI) (Concha-Pérez et al., 2023). Moreover, using portable devices to measure and mitigate risks in the construction sector led to the conclusion that it is possible to prevent accidents such as slips, falls, and trips, among others. However, it is emphasized that such devices have little use in developing countries due to the costs of these analyses (Ibrahim et al., 2023). These approaches highlight the importance of ergonomics in occupational safety and well-being in various sectors.

In computer keyboard use, it is crucial to recognize that conventional standing or sitting positions are not optimally adjusted to avoid work-related musculoskeletal disorders (WMSDs). Regardless of the user's position, the wrists and forearms are not correctly aligned, which can lead to health problems in office workers (Eghujovbo, 2023). Research demonstrated that the keyboard should be placed at negative angles ranging from -5° to -10° to avoid interfering with the natural position of the wrist, thus preventing musculoskeletal disorders such as carpal tunnel syndrome (Eghujovbo, 2023). However, this proper inclination is more challenging to achieve in the case of laptops. Therefore, using a scapular brace is proposed to improve ergonomics when using laptops, thus addressing the specific challenges of this type of device (Leung et al., 2023).

The military industry is another field where ergonomic analysis is used to seek innovation. One study examined the impact of loading on the gait biomechanics of military men and women. This analysis revealed that the burdens assigned to soldiers do lead to musculoskeletal disorders. Therefore, although the equipment that soldiers carry is essential, it is recommended that the load be reduced and steps be taken to distribute it more effectively so that it does not affect the body's natural gait (Parret, 2023). A similar study was carried out with police officers to identify how the load affects gait spatially and temporally. Despite not finding very significant changes in spatial parameters, it was determined that there may be a difference in walking times with a higher load weight (Kasović et al., 2024).

Innovations to enhance firefighters' comfort and safety have been investigated. A study examined the impact of a nanotube cooling vest on the health and comfort of firefighters during firefighting scenarios, concluding that this new vest, compared to traditional ones, has beneficial effects on workers' breathing and thermal comfort (Villaveces, 2023). In addition, firefighter footwear was designed to guarantee user protection while being lighter, easier to remove, and resistant to adverse conditions. The result was intelligent personal protective equipment (PPE) with enhanced features of sustainability, comfort, and strength (Tomaskova & Krajňák, 2023). Another study regarding PPE for firefighters investigated whether the measurements on the gloves were ideal for interacting comfortably and safely with other elements in their environment. Through a 3D scan, the conclusion was that the gloves did not fit appropriately on participants' hands, particularly in the distance between the fingers and the glove (Szkudlarek et al., 2023). Souza et al. investigated the possibility of replacing the lead used in radiation protection suits to make them lighter and more comfortable for the wearer. Various tests, including X-rays and Monte Carlo simulations, concluded that a combination of barium sulfate, magnesium, and silicone rubber meets the requirements to be applied in radiation-protective garments (Souza et al., 2023).

In a study by Zakeri et al., cognitive ergonomics was used to study the workload of factory employees collaborating with robots (Zakeri et al., 2023). The article analyzed the impact of task complexity, robot work speed, and workload on human worker stress, underscoring the usefulness of cognitive ergonomics in work environments. On the other hand, a similar study was conducted to evaluate the cognitive workload of human beings when collaborating with robots in industry, proposing two scenarios: one in which workers assembled objects individually and another in which they worked with the assistance of a robot. This study concluded that productivity levels were significantly higher in a collaborative environment (Caiazzo et al., 2023). However, another study found that workers, when performing their tasks with the help of a mechanical arm, improved human speed and comfort but compromised the speed and accuracy achieved (Sharkawy, 2023). In addition, it has been shown that mistrust, expectation of effort, and computer anxiety could may influence how operators collaborate with a robot (Molitor & Renkema, 2022). Therefore, a skin-like touch sector system and proximity sensors are being developed to provide robots with a sense of touch to perform safe and efficient operations (Giovinazzo et al., 2024). Other studies (Table 2) have analyzed the use of interfaces and reliance on robots to improve workers' environments and reduce mental stress.

It is common for production systems to be based on the assembly line concept; for this purpose, an adaptive assembly system was developed, adapting to workers' anthropometric measurements, reducing the risk of injury and the adverse effects on their health and safety (Bortolini et al., 2023).

In this sense, efforts have also been made to adapt the work environment to the needs of older workers in a company. A research study used Motion Capture Systems (MoCap) and virtual reality to analyze how companies can use this technology to guarantee an ergonomic work environment for their aging population (Alves et al., 2023). Another study developed a Quick-Change Design (QCD) for manufacturers. QCD helps manufacturers discover how their products can be tailored to customers' needs while prioritizing technical solutions and encouraging them to build machines that are easier to use and configure (Braglia et al., 2023). Another strategy to protect the integrity of employees and equipment in industrial firms involve using drones. Their application would be of considerable assistance for tasks such as inspecting dangerous or inaccessible areas to identify gas leaks or inventory counts in warehouses (Maghazei & Netland, 2020).

Table 2. Studies related to working with robots and interface creation.

Summary	Reference
Use of musculoskeletal simulators to estimate compressive forces and slices in joints.	(Nail-Ulloa et al., 2024)
Assessment of low back pain among U.S. workers via the National Health Interview Survey (NHIS)	(Luckhaupt et al., 2019)
Design of an experiment to assess the mental stress of workers using different user interfaces for a manufacturing system.	(Dörner et al., 2024)
Evaluation of different cognitive ergonomics variables in human-robot collaborative systems.	(Gualtieri et al., 2022)
Use of graphic information to reduce workers' anxiety when collaborating with a robot.	(Eimontaite et al., 2019)
Importance of considering ergonomics and human factors in the design of collaborative environments between robots and humans.	(Cardoso et al., 2021)
New model for evaluating joint overload in workers.	(Lorenzini et al., 2019)
Task assignment framework for robots and workers based on ergonomic considerations.	(Makrini et al., 2019)
Risk assessment through the use of sensors in collaborative environments.	(Ranavolo et al., 2020)
Creating reconfigurable workspaces for humans and robots.	(Kim et al., 2019)
Robotic system for order picking.	(D'Souza et al., 2020)
Development of a design methodology to create collaborative environments between humans and robots.	(Khalid et al., 2016)

In addition, it has been demonstrated that using the Lean Six Sigma methodology improves the design of manufacturing spaces to make them adaptable and comfortable for users (Trubetskaya et al., 2023). An example of the aforementioned is the creation and adaptation of the Integral Ergonomics-Value Stream Mapping (Ergo-VSM) methodology to reduce psychosocial risk factors, improve productivity, and create more ergonomic working conditions (Domínguez-Alfaro et al., 2023).

In agriculture, fruit pickers' working conditions can affect product quality. In this sense, a study determined that the picker's discomfort causes an increase in pressure while cutting the fruit, which reduces the firmness and characteristic shape of the fruit (Komarnicki & Kuta, 2021). A similar study was conducted, evaluating the relationship between the quality of tomatoes and the postures adopted by the picker; it was found that poor postures significantly affect the level of physical load when performing this task (Kuta et al., 2023). Moreover, the workload of tractor operators was studied using electromyography, finding that operators suffer from muscle fatigue due to intense muscle contractions. The authors concluded that it is possible to quantify workload and fatigue in the lower extremities through ergonomic transducers (Hota et al., 2023). Also, the safety of tractor operators can be enhanced by implementing a support system to facilitate the use of a rollover protection structure (Gattamelata et al., 2023).

In the agricultural sector, the diversification of dairy farms is considered. A questionnaire called ERGOROM was applied, and it was identified that manual work and awkward postures cause musculoskeletal pain in various body areas. Therefore, it is recommended that ergonomic adaptations be made to the dairy production area (Buisseret et al., 2024). In 2024, Kapse explored the use of artificial intelligence to identify the unfavorable postures of farmers during their work, integrating computer vision techniques for ergonomic evaluations (Kapse et al., 2024).

2.3 Ergonomic Innovations in the Healthcare Area

Innovations in ergonomics were applied to produce a prosthesis for a young woman who lost her forearm and right hand in an accident. Through detailed anthropometric analyses, a prosthesis was designed with ecological and lightweight materials that would fit perfectly the young woman's arm, providing her mobility. The manufacturing process was carried out through computer programs and 3D scanning technologies to determine the user's needs, CAD modeling to design the prosthesis, and a 3D printer to obtain the final product (Estrada Apolo, 2020). Another study made a prototype to add a tactile feedback system to improve grip accuracy and implant usefulness (Peternell et al., 2023). This project shows how innovations in ergonomics and technology can improve the quality of life for people with disabilities.

Ergonomics is constantly dedicated to analyzing the field of health in which professionals experience various injuries caused by non-ergonomic conditions in their work environment. Consequently, research has been carried out in recent years, and different proposals have been developed to improve the experience of health personnel without neglecting patients' needs.

One ergonomics application focused on the limbs of doctors when performing sutures and the effect of muscle-strengthening exercises on the health of their fingers, hands, wrists, and forearms. This research concluded that regularly performing exercises to build and strengthen muscle endurance could help healthcare professionals prevent muscle pain and fatigue (Schaffhausen, 2023). Another way to improve the working conditions of health personnel is to adapt surgeons' protective eyewear to the size and shape of their faces (Figure 6). Based on 3D-printed eyewear, the protective glasses reduce the field of vision (FOV) to provide greater comfort (Singh et al., 2023).

An additional instance relevant to the healthcare sector is a study examining the advantages of vibrational treatment (WBV) in children diagnosed with cerebral palsy. After conducting a comprehensive systematic review, significant changes were observed in gait speed, stride length, and clinically relevant improvements in the musculoskeletal system. These findings suggest that vibrational therapy should be considered an effective adjunct to conventional physiotherapy in treating this medical condition (Pulay et al., 2023). A similar study was conducted to prevent phantom pain (PLP) in people who have lost a limb through the application of a whole-body cryostimulation (WBC) cycle. It is essential to mention that this study was conducted on a former athlete; therefore, evaluating this method broadly is still necessary. However, the results show improved pain, tingling, and quality of life (Piterà et al., 2024).

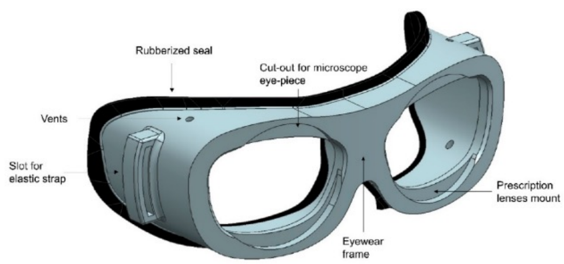


Figure 6. 3D model of personalized eyewear with provision for prescription glasses and slots for microscope eye-piece lens insertion.

A further effort to improve the work environment of health personnel was made through the design of a user interface (UI) that would allow specialists to process calcium images more quickly and efficiently. This interface would decrease their workload while significantly improving data acquisition (Jung et al., 2022).

Due to their length, performing procedures by healthcare professionals results in considerable physical and mental stress. Hence, significant efforts have been made to alleviate the workload, as seen in follicular unit excision surgery involving around 3,000-4,000 grafts. A Bluetooth device with a touch sensor was created to decrease the time and workload per surgery. This device offers an automated operation as it establishes a time interval between perforation movements for transplantation, which decreases the risk of follicular injury and, at the same time, improves ergonomics in the operation (Park, 2023).

In a separate study, an ergonomic handle was developed for a handheld robotic instrument to enhance the endonasal endoscopic surgery procedure at the base of the skull. This new instrument allows the surgeon's hand to retain its natural position and, in the same way, surpasses the conventional tool in performance and efficiency (Dimitrakakis et al., 2022). Monitoring devices have also been proposed to detect health conditions and allow users early diagnosis and treatment. Such devices work through big data, neural networks, and artificial intelligence. However, a recent study emphasizes the need to use smart and sustainable materials that comply with user ergonomic factors (Ghosh et al., 2023). A similar study focused on co-creating a digital platform to provide reliable open-access health information, considering the user's needs and making the content easy to understand, supporting the patient in adherence to treatment and risk minimization (Turk et al., 2022). Additional information for healthcare is available in Table 3.

Table 3. Use of new technologies for healthcare.

Summary	Reference
Evaluation of the usability of an electronic module to record the date and time for taking medication.	(Izzah et al., 2022)
Development of wearable sensors for the timely diagnosis of diseases.	(Luo & Gao, 2021)
Use of nanoenergy nanosystems for smart healthcare.	(Hassani et al., 2020)
Health monitoring through triboelectric nanogenerators.	(Yi et al., 2019)
Feasibility study of glucose sensors that work through body heat.	(Kim et al., 2021)
Use of microfluid sensors for health monitoring.	(Li et al., 2019)

One of the various limitations found in healthcare is the ability to manage client requirements in healthcare projects. Baldauf et al. developed a method to manage customer requirements in healthcare projects using BIM (Building Information Modeling). With this advance, healthcare workers are allowed to have a vast repertoire of requirements and be able to coordinate changes that arise depending on the client more quickly (Baldauf et al., 2021).

2.4 Technology and Ergonomics

Technological advancements bring new ways of working, education, and even sports. These new advancements make it crucial to find a more ergonomic approach so that users can perform their activities efficiently and comfortably.

Astronauts were trained based on an algorithm in virtual reality environments, focusing on acquiring and retaining learning in complex tasks of space missions. This research demonstrates the feasibility of establishing personalized and adaptive training for each astronaut, using virtual reality to automate the training process (Verniani, 2023). Also, student pilots were subjected to simulations of adverse weather conditions during flights to improve their training and prevent accidents. The results show outstanding performance and tracking quality across various devices, supporting the effectiveness of these simulations on student learning (Wang, 2023). Moreover, incorporating innovative technology into pilot helmets helps address pilots' spatial disorientation. These studies reveal that this technology can reduce fatalities associated with spatial disorientation, thus improving aviation safety (Brown IV, 2023).

Another way to continue to apply ergonomics is by creating new assessment methods. For example, the Ergonomics Risk Assessment Methodology in Industry (ERAI) was created based on identifying the level of exposure of the upper body and the feet to identify the physical condition of workers (Ispășoiu et al., 2023). In another study, authors offered an online algorithm aimed at calculating the NIOSH (National Institute for Occupational Safety and Health) Index to facilitate the assessment of ergonomic risks faced by workers. This experiment used inertial motion sensors for workers handling loads of around 10 kg (Leggieri et al., 2024).

2.5 Areas of Opportunity for the Application of Ergonomics

Technological innovations in ergonomics are present in video games, in which thousands of people spend a large part of their time playing daily, giving rise to the birth of the so-called e-sports. These are virtual competitions held on video game consoles or personal computers that have manifested high levels of stress and physical disorders in the hands, arms, shoulders, neck, and back of users. As a result, it is intended to establish protocols for the players' well-being. These protocols include evaluating tools such as keyboards and mice used by players and identifying appropriate postures. Thus, angle adjustment, height-adjustable furniture, and other solutions were proposed to prevent Repetitive Strain Injuries (RSI) (Pierides, 2023).

Another area of opportunity in which ergonomics is applicable is motorcycle use. After an analysis through OpenPose, it was possible to make a 3D reconstruction of the postures that motorcycle users perform during their riding (Figure 7). This analysis concluded the importance of 3D reconstruction for ergonomic analysis, facilitating research into aerodynamic movements and forces used in the motorcycle-rider system (Barberi et al., 2023).

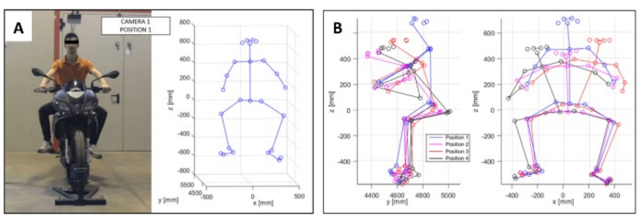


Figure 7. A) Reconstruction of position 1 for Subject 1. B) Comparison of the four positions, from the side and front view for Subject 1.

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Wheelchair basketball (WB), a sport that has gained increasing popularity among people with disabilities, offers an area for improvement for players with shoulder pain. A review article focused on this issue by identifying the underlying causes of this musculoskeletal disorder. This study proposes the need to carry out more in-depth research that considers various influencing factors, such as the characteristics of the wheelchairs used, the training methods, and the implementation of multidisciplinary approaches for the recovery of those affected (Farì et al., 2023).

A cognitive ergonomics analysis was carried out aimed at students participating in distance education. The primary purpose of this research was to examine how physical, mental, and macroergonomic factors affect students' motivation and academic attention. A survey determined that ergonomic and macroergonomic aspects significantly influence motivation and attention, unlike physical factors. In light of these findings, teachers are called upon to consider these factors and develop strategies to counteract their effects on students and to improve their learning process (Gumasing et al., 2023). Also, online educational programs were more attractive to workers, and the importance of tailoring health interventions to them, considering demographic factors, is underlined (Stubelj et al., 2023). In this sense, a study determined that digital simulations using digital human modeling can improve the online teaching of various engineering careers by allowing complex scenarios to be created and planning alternatives proposed (Schlund et al., 2022).

In addition, redesigning university spaces through ergonomics facilitates students' circulation and plays a dynamic role in their design. They serve as flexible meeting areas that promote informal interactions and connect users psychologically and visually, impacting their well-being. These findings conclude that these spaces should be designed considering the users' needs and the diversity of activities performed (Al-Ramahi et al., 2023).

Another area where ergonomics can advance is in Formula 1 competitions. It is well known that this maintenance process has evolved significantly to work collaboratively and reduce time as much as possible. However, a recent study proposes the importance of adding studies of unique variables such as human error. Based on this, it is intended to develop a feedback loop to adjust processes and increase operator reliability and motivation (Martinetti et al., 2021).

It is also important to mention that most companies must align with the Sustainable Development Goals to achieve the goals established in the 2030 Agenda. However, there is still a need to conduct an internal analysis within organizations to identify such areas of opportunity (Hasanain, 2024). In this context, a recent MATLAB Fuzzy Logic Designer study identified the implementation of Sustainable Development Goal (SDG) No. 8, focused on ensuring decent work and sustainable economic growth. This assessment was conducted in a factory producing automotive windshields, revealing that workers experience difficulties maintaining a healthy lifestyle due to injuries and musculoskeletal disorders (Abundes-Recilla et al., 2024).

One study focused on identifying musculoskeletal burdens suffered by supermarket cashiers. Using various evaluation methods, such as REBA, it was determined that checkout workstations must be redesigned to comply with aspects of organizational sustainability (Silva et al., 2024).

In health, ergonomics and new technologies could make inroads in multiple areas of opportunity. For example, various evaluation methods, such as REBA, have shown that checkout machines must be redesigned to avoid the musculoskeletal burdens suffered by supermarket cashiers (Silva et al., 2024). Ergonomics also impacts robotic surgery, where repositioning the screen and other parameters, such as camera controls and exposure, can help reduce surgeons' visual fatigue (Wong & Crowe, 2023).

Conclusions

This review has presented detailed and significant findings on exploring ergonomic trends in various areas of work experience and daily life. Additionally, this study offers relevant practical applications of these ergonomic trends and innovations. The results emphasize the importance of improving workers' job conditions and quality of life, significantly contributing to social welfare.

Advances in ergonomic design open a broad avenue for future research. Therefore, it is essential to expand the integration of emerging technologies, such as augmented reality, and to include factors like sustainability and acceptance by workers and employers. Furthermore, it would be valuable to delve into designing and optimizing personal protective equipment for workers in various fields or investigate the cognitive workload of individuals collaborating with robots in their workspace.

Considering the advancements in ergonomic innovations and new technologies, it is beneficial to continue exploring the potential of virtual reality for training professionals in complex fields. Finally, given the opportunities in the field of ergonomics, it is crucial to continue fostering interdisciplinary collaboration, integrating new technologies, and considering diversity to create healthier environments in both work and daily life.

Conflict of interest

The authors have no conflict of interest to declare.

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