Industrial engineering, ergonomics, musculoskeletal disorders

Michaela BODINGEROVÁ*

4 APPLICATION OF ERGONOMICS FOR THE PREVENTION OF MUSCULOSKELETAL DISORDERS IN INDUSTRY

Abstract

The relationship between humans and the work environment is a closely intertwined area that is the subject of research in many sectors, such as industry, healthcare, and ergonomics. In fact, people spend up to about half of their lives in the work environment, during which time they are exposed to a variety of factors such as physical, chemical, psychosocial, and many others, all of which may pose a risk of damage to their health to some degree.

4.1. INTRODUCTION

The relationship between humans and the work environment is a closely intertwined area that is the subject of research in many sectors, such as industry, healthcare, and ergonomics. In fact, people spend up to about half of their lives in the work environment, during which time they are exposed to a variety of factors such as physical, chemical, psychosocial, and many others, all of which may pose a risk of damage to their health to some degree.

4.2. WORK-RELATED DISEASES IN INDUSTRY

Within Europe, data on the development and prevalence of newly diagnosed occupational diseases and reported occupational hazards by type of disease, sex, age groups, region, location of the organization, and many other factors are particularly relevant in this area. In the Slovak Republic, for example, the National Centre for Health Information collects such data. The report entitled "Occupational diseases or threats of occupational disease in the Slovak Republic 2022" presents the results of a statistical survey conducted by the Ministry of Health of the Slovak Republic, with data collection and subsequent processing carried out by the National Centre for Health Information, hereinafter referred to as NCZI. The data for the statistical survey were submitted to

* Ing., Department of Industrial Engineering, University of Žilina, michaela.bodingerova@fstroj.uniza.sk

the NCZI by health care providers from the fields of clinical occupational medicine and clinical toxicology, as well as occupational medicine and dermatovenerology. [1]

The report in question further shows that in 2022, based on the survey of the statistical office, there were 2,603,900 workers registered in the territory of the Slovak Republic. In the same year, 525 newly recognized occupational diseases were reported by healthcare providers. The number of cases thus increased by 102 compared to 2021, which represents a year-on-year increase of 24.1%. [1]

In 2022, the rate of newly recognized occupational diseases was 20.2 cases per 100,000 workers in that year. Thus, compared to the previous year 2021 (16.5 cases per 100,000 workers), the rate of newly recognized occupational diseases increased by 22.0%. The report also has information on the gender distribution of these cases. In the current year, the number of newly diagnosed occupational diseases was higher among women (329 cases, representing 62.7% of the total number of cases and 26.9 cases per 100,000 women workers). Compared to 2021, when there were 267 cases in women, the number of new cases of occupational diseases in women has thus increased by 23.2%. [1]

In the case of men, there were 196 cases (37.3% of the total number of cases and 14.2 cases per 100,000 working men). Thus, the number of new cases of occupational diseases in men increased by up to 25.6% year-on-year compared to 2021 (156 cases). In 2022, as in the previous year, one case of occupational disease was also reported. [1]

A much larger change is expected for 2022 in the most frequently reported occupational disease. Whereas in 2021, the most frequently reported occupational disease was illness from prolonged, excessive strain and unilateral strain on the limbs, or, for example, vibration sickness and hearing impairment caused by noise exceeding permissible levels. In 2022, the most reported occupational diseases were infectious diseases and parasitic diseases, excluding tropical infectious and parasitic diseases and communicable diseases. from animals to humans (252 cases). Disease from prolonged, excessive, and unilateral strain on the limbs – diseases of the bones, joints, tendons, and nerves of the limbs (164 cases) thus took second place. [1]

As in the previous year, vibration-related diseases – diseases of the bones, joints, muscles, blood vessels, and nerves of the limbs caused by vibration (44 cases) and hearing impairment caused by excessive noise (14 cases) were also ranked second. Another difference compared with the previous year was external allergic alveolitis and its consequences caused by inhalation of organic dust (farmer's lung disease – a total of 14 cases). [1]

It should also be added that the COVID-19 pandemic will continue to be a major contributor to occupational diseases in 2022. The NCZI records a total of 233 people who have been diagnosed with an occupational disease as a result of COVID-19. [1]

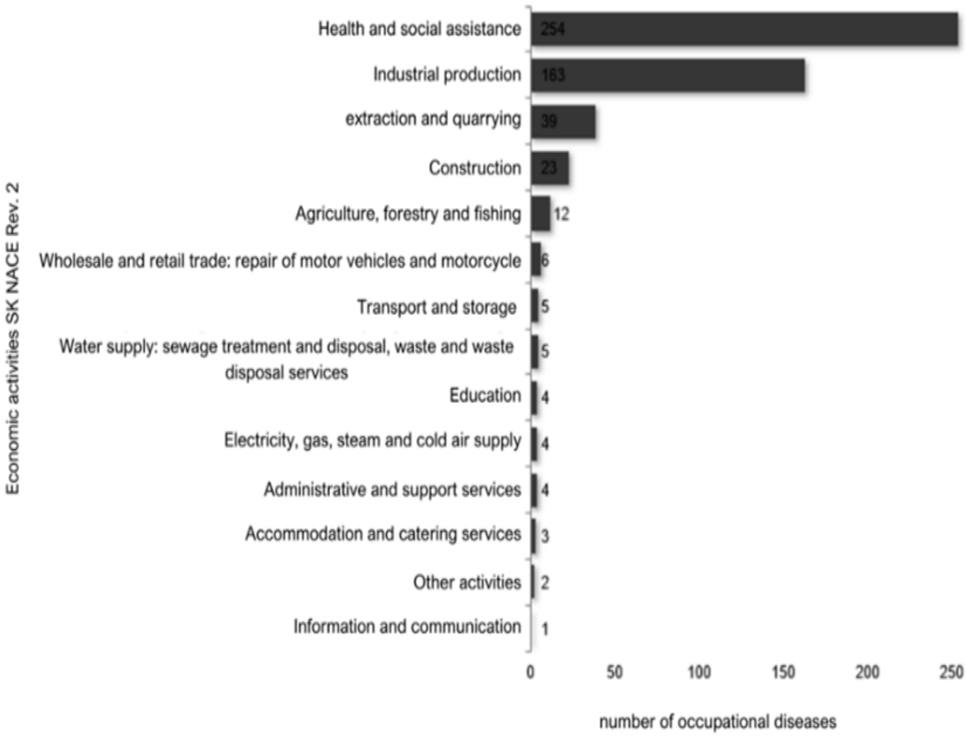

Fig. 4.1. Economic activities with the highest number of newly recognised occupational diseases 2022 [1]

While in 2019, the highest incidence of occupational diseases was reported mainly in the health sector, in 2022, reports were also added from the social assistance sector. Thus, the highest incidence of occupational diseases in 2022, according to the classification of economic activities, was in the health sector and social assistance, with a total of 254 new cases, accounting for 48.4% of all reported occupational diseases. Of this number, 242 new cases were reported in the health sector, representing an increase of up to 48.5% compared to 2021 (163 cases). Next were manufacturing (163 cases), mining and quarrying (39 cases), construction (23 cases), and agriculture, forestry, and fishing (a total of 12 cases). [1]

In fig. 4.1., the evolution of the number of occupational diseases at risk of occupational disease is shown for the period 2001 – 2022. From the graph, it can be deduced that the evolution of occupational diseases has an upward trend from 2020 onwards, which is mainly due to the events of recent years, which have significantly affected and continue to affect the overall functioning of society. [1]

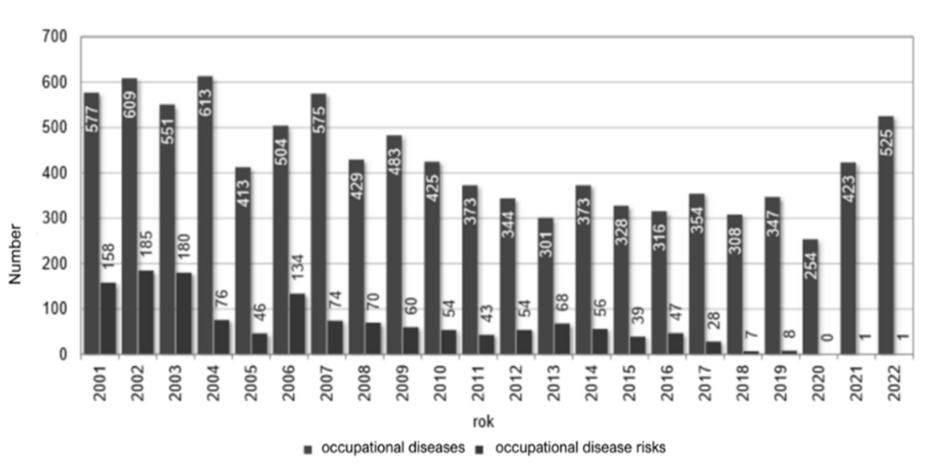

Fig. 4.2. Trends in the number of occupational diseases and risks of occupational diseases 2001 – 2022 [1]

The next graph (Fig. 4.2.) also shows the number of newly diagnosed occupational diseases for 2022, broken down by age group. The graph unmistakably demonstrates that the COVID-19 pandemic, which was known to have a significant impact on vulnerable groups or older workers between the ages of 40 and 60, was also the main cause of occupational diseases in 2022. [2]

The most widespread work-related diseases or occupational diseases are the so-called musculoskeletal disorders, which are the result of ergonomically unsuitable working conditions. They are often referred to as cumulative disorders, as they are mostly caused by repeated exposure to high or low loads over a long period of time. They affect bones, joints, tendons, muscles, and blood vessels. They can arise from a variety of work activities, but their common denominator is prolonged, excessive, and unilateral loading of the limbs. [2]

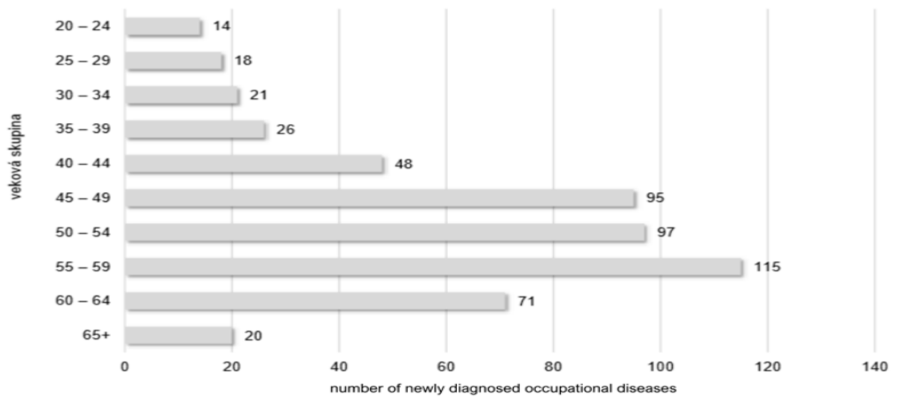

Fig. 4.3. Number of newly diagnosed occupational diseases by age group 2022 [2]

Musculoskeletal disorders are among the most common medical indications in workplaces throughout the European Union. Musculoskeletal disorders (MSDs) occur in workers across all sectors and occupations. As a result, they have a negative impact not only on the employees themselves but also on businesses, particularly financially. Due to the massive impact of the indications on individual industries, the European Health and Safety Agency (OSHA) has conducted a study to provide an accurate picture of MSDs. The study analyzes data from European Union surveys, administrative data, or national sources. [3]

In 2017, EU-OSHA launched a four-year research activity on work-related musculoskeletal disorders, which concluded at the end of 2020. This research activity is linked to EU-OSHA's Healthy Workplaces 2020 – 2022 campaigns, which focuses on MSDs. The aim of this activity is to promote and support the prevention of MSDs and the management of work-related chronic MSDs in the workplace. This is achieved by identifying, raising awareness, and providing guidance on good practices for national authorities, employers, and organizations at the sectoral level. [4]

Use existing research and new data to improve understanding of the root causes of MSDS in different sectors and occupations:

- Identify successful initiatives to prevent and manage MSDs and promote them to the public.
- Stimulate debate on the promotion of preventive measures at the national level among policymakers and occupational safety and health (OSH) professionals.
- Promote the successful long-term reintegration of workers with MSDs through the identification of effective systems and measures.
- Research tasks include a literature review, data collection and analysis, case studies and identification of best practices, practical tools, and materials for training, and raising awareness. [4]

The data and evidence presented in this report confirm that MSDS are multifactorial. Prevention of and access to MSDS will therefore need to focus on exposure to physical, psychosocial, and organizational risk factors, while considering socio-demographic factors such as age. and gender. ESENER provides some insight into the prevention of work-related MSDs: Many employees who benefit from preventive measures work in large companies with 250 or more employees. The availability of preventive measures increases with enterprise size, which means that micro and small enterprises need additional policy attention. [4]

European Agency for Safety and Health at Work (EU-OSHA) Investing in preventive measures is particularly beneficial because they are proving to be effective. Workers in countries and sectors where more preventive measures are in place are less likely to report complaints to the MSDS. [4]

The percentage of workers reporting back pain falls from 51% (for workers in countries and sectors with an average of one to three precautionary measures) to 31% (for workers in countries and sectors with an average of five to six precautionary measures) from 1.5% (for workers in countries and sectors with an average of one to three precautionary measures). The prevalence of MSDs in the lower limbs shows a comparable trend. [4]

There is considerable variation between the EU-28 Member States in the proportion of enterprises that have policies to support employees in returning to work after long-term sickness absence. A large proportion of employees in the UK (97%), Sweden (95%), Finland (93%), and the Netherlands (92%) work in enterprises where support is provided to help employees return to work after long-term sickness absence. In Lithuania (19%) and Estonia (27%), these percentages are significantly lower than the EU-28 average (73%). These percentages are most likely also indicative of the changes that workers with MSDs benefit from return-to-work measures in their country. [3]

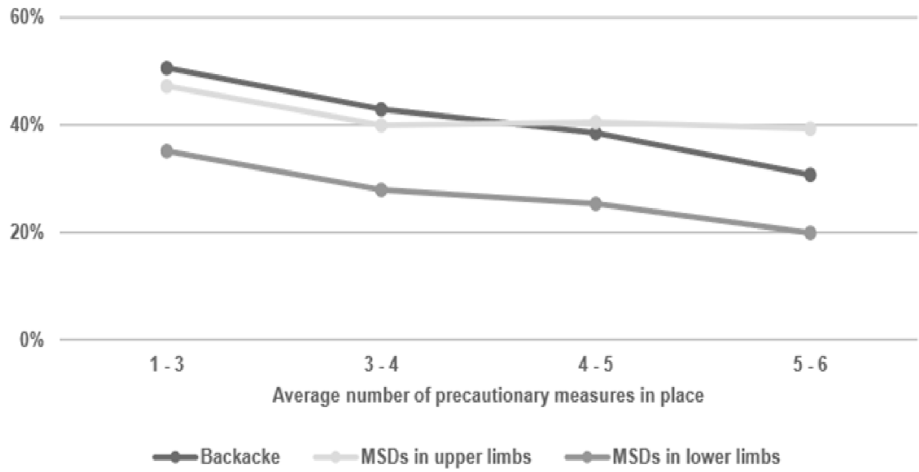

Fig. 4.4. Percentage of workers having MSDs in back, upper limbs and lower limbs, by average number of precautionary measures in place, EU-28 2015 [3]

MSDs often occur in combination with other health problems. Between 2010 and 2015, around three quarters of all workers in the European Union reported having had a health problem in the past year (Fig. 4.5.). In four out of five cases, these health problems involved MSDs, and, often, MSD-related health problems occurred in combination with other health problems. [3]

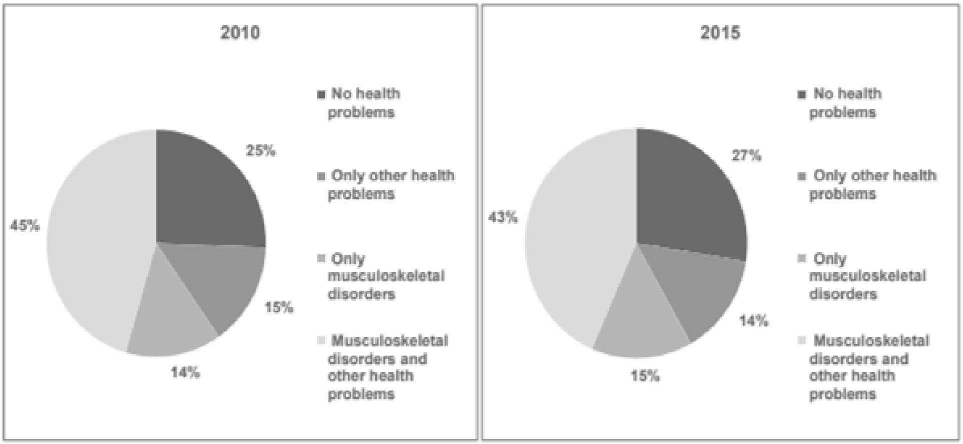

Fig. 4.5. percentage of workers with and without different types of health problems during the past 12 months, EU-28, 2010 and 2015 [5]

The 2020 – 22 campaign focuses on the prevention of work-related musculoskeletal disorders (MSDs). MSDs remain one of the most prevalent types of work-related health problems in Europe. Postural risks, exposure to repetitive movements or fatiguing or painful postures, carrying or moving heavy loads – all these very common workplace risk factors can cause MSDs. Given how prevalent work-related MSDs are, it is clear that more needs to be done to raise awareness of how they can be prevented. [5]

The campaign comprehensively addresses the causes of this persistent problem. It aims to disseminate high-quality information on the subject, promote an integrated approach to managing the problem, and offer practical tools and solutions that can help at the workplace. [5]

It should not be forgotten that working conditions are created not only by the working environment but also by the way the work is carried out. It is therefore the task of every company to create working conditions that enable workers to carry out their work without harming their health. [5]

4.3. ERGONOMICS AS A TOOL FOR MITIGATING WORK-RELATED DISEASES IN INDUSTRY

One of the possible solutions is ergonomics, which can effectively contribute to solving the problem of work-related diseases such as musculoskeletal disorders. [2]

The role of ergonomics is not only to reduce the consequences of workload for people, but also to make every day work more human or more adapted to the needs of each person. [6]

Ergonomics is concerned with the overall understanding of the interactions between humans and other elements of a system, with the goal of optimizing not only better conditions for workers but also better system performance. Ergonomics has a social goal as well as an economic goal and thus takes into account both the physical and psychological aspects of the human being. It also seeks solutions in both the technical and organizational fields. Aspects of performance may include, among others, production volume, lead time, production flexibility, quality level, and operating costs. [7]

Workers were initially assessed from a purely economic point of view. However, over the years, workers have also experienced disadvantages in carrying out their assigned tasks. The industrial work environment is often characterized by monotonous and repetitive tasks. The manual activities required, such as maintaining static working positions, lifting, carrying, pushing, pulling loads, or handling low loads, place physical strain on the body and can lead to work-related illnesses. As a result, there is a high prevalence of directly work-related musculoskeletal disorders among workers in industrial production processes. In addition, the economic impact of such diseases is considerable. [8]

In the article 'Harmonizing ergonomics and economics of assembly lines using collaborative robots and exoskeletons', they also mention in the fact sheet that work-related musculoskeletal disorders led to a loss of output of up to EUR 6.57 billion (wages) in Germany in 2017 and also to a loss of gross value added of EUR 11.15 billion (productivity) in the manufacturing sectors. [8]

In situations like this, the emphasis today is on a high level of economic prevention. For example, in view of the trend towards an aging workforce, it is therefore likely, particularly in developed countries, that the importance of ergonomic aspects in manual production may continue to increase in the future. [8]

However, the design and operation of ergonomically advantageous assemblies require the inclusion of measures to reduce the risk of musculoskeletal disorders, and these are further conditioned by financial investments such as the use of additional workers or technical aids. In recent years, however, innovative technologies have emerged on the market that can complement or fully replace manual labour in industry. [8]

The effective selection and inclusion of these resources in manual assembly lines, for example, can be useful not only to reduce the risk of worker breakdowns but also to improve the economic position of the company. [8]

Weckenborg et al. point out, however, that human factor consideration is still underrepresented among contributions towards future production and logistics systems and that the quantitative economic benefits of human factor consideration are not well understood. The authors also point out that the interconnection between economic and ergonomic criteria in industrial production is a relevant subject for future research. [8]

For example, the cooperation of workers with advanced robotics technologies such as robots, sorting stations, robotic arms, crate lifters, AVG trolleys, or exoskeletons is current. The advantages of manual and automated production can thus be realized in the production system in a combined way, with both economic and ergonomic benefits. In recent years, it has been seen how technologies from the field of robotics are meeting a significantly increasing market demand and are being successfully implemented in industrial practice. [8]

An important challenge in the design of common workplaces for workers and technologies such as robotic arms, among many others, is the evaluation of their capabilities. The division of tasks between humans and robots can make many tasks automated. Technology can also be used to replace workers when it comes to tasks with a particularly high workload, but in many other ways, the worker is still an indispensable component, for example, in manual inspection. [8]

The exoskeleton technology mentioned above, for example, can only be used as an adjunct to the worker. The exoskeleton is a term derived from the term for the external skeleton of animals, the exoskeleton. It is a device attached to the human body that can be classified as active or passive. The main benefit of this device is that it can greatly reduce the biomechanical stress on workers. [9]

Active exoskeletons are supported by actuators (a device that moves or controls a mechanism) and require sensors and an energy source, while passive exoskeletons are associated with energy storage and restitution, usually by springs. Active exoskeletons use batteries or electrical cable connections to operate sensors and actuators. Active exoskeletons are further divided into two types, namely static and dynamic:

- Static exoskeletons: actuators must be constantly switched on for the device to keep its shape.
- Dynamic exoskeletons: the actuators do not have to be on all the time, and the device can be many times more energy efficient.

Passive exoskeletons can be used for the following purposes namely:

- Weight redistribution: springs and locking mechanisms redirect the weight of the object around the user and into the ground.
- Energy capture: exoskeletons with spring clutches at the ankles have been shown to improve walking efficiency, while exoskeletons with spring dynamos at the knees can be used to charge a battery.
- Damping: some spring-loaded passive exoskeletons have been designed as shock absorbers or vibration reducers.
- Locking: some passive exoskeletons are designed to be unobtrusive until locked in place, allowing the user to sit or crouch in the same position for extended periods of time. [10]

Originally designed for the military, exoskeletons are now being used in the medical, agricultural, and industrial sectors. When it comes to the aforementioned collaborative robots, identifying the tasks that a worker with an exoskeleton can realistically perform is key. Manufacturers of industrial exoskeletons describe a wide range of applications. An overview of available exoskeletons for industrial applications and also the body parts they can control or future use cases is given by Voilque et al. in "Industrial Exoskeleton Technology: Classification, Structural Analysis, and Structural Complexity Indicator. [11]

Weckenborg et al. also point to the successful introduction of industrial exoskeletons, particularly by car manufacturers, who report a reduction in biomechanical stress of up to 20 – 30% and a subsequent reduction in morbidity of up to 75% when the technology is introduced. Overall, the new technologies can reduce the biomechanical burden on workers and improve the economic operation of the industry. [8]

Fig. 4.6. Use of industrial exoskeleton [12]

A laboratory study entitled A passive back exoskeleton supporting symmetric and asymmetric lifting in stoop and squat posture reduces trunk and hip extensor muscle activity and adjusts body posture. A laboratory study published in the journal Applied Ergonomics by authors T. Luger, M. Bär, R. Seibt, P. Rimmele, M.A. Rieger, and B. Steinhilber discusses the use of passive exoskeletons in repetitive lifting with different lifting styles. The study confirmed that hip extensor activity decreased when wearing the exoskeleton. Wearing the exoskeleton also resulted in slightly modified working postures depending on different lifting styles and orientations. However, the authors caution against the need for further studies to include participants of different ages and sexes or people with low back pain. Also, consideration should be given to the constant evolution that exoskeleton technology is currently undergoing. This study, therefore, does not offer a definite conclusion. [12]

The development of future technologies that will not only increase safety in the workplace and also bring increased ergonomic comfort to workers is now abundant. In the following section we will briefly mention some of the technologies used in Slovakia, namely:

- Item sorters: this is a fully automated system of sorting items, which greatly reduces the muscle load of the worker, who does not have to manipulate items in crates and tediously search for them.

- Pallet movers are robotic arms that eliminate the need to use forklifts to transport pallets.
- Crate lifters: these are machines that automatically lift crates and place them on conveyors.
- AGV trucks are similar to robotic units; these are robotic support vehicles. Automatically guided carts move around the workplace, moving items closer to employees. The benefit is not only the time saved on moving but also the handling of loads, which includes carrying or pushing crates and trolleys. The trolleys are equipped with sensors and follow predetermined routes. In this case, the risk of injury or collision between the worker and the trolley is reduced or even eliminated.
- Robotic sorters are smaller robotic arms that have eliminated duplicate tasks such as lifting and stacking goods or turning in the company's logistics processes. They also give workers the space to perform better and focus on tasks that technology can't. [13]

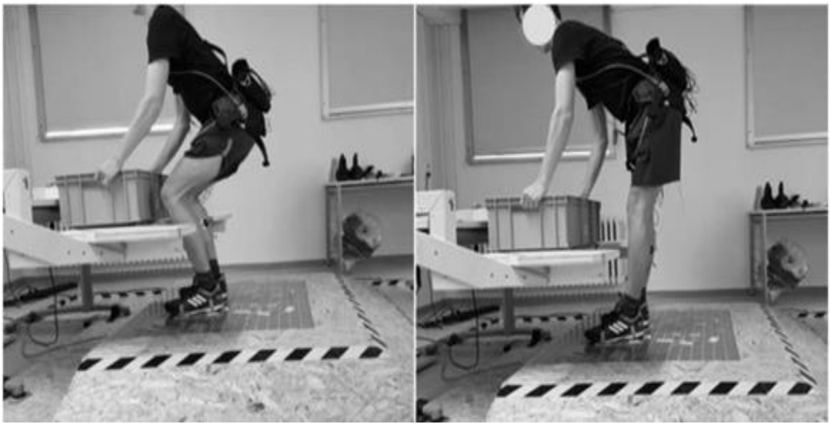

Fig. 4.7. A simulated dynamic lifting task with an exoskeleton using a squatting (left) or prone (right) lifting technique [13]

However, it should be noted that once digital technologies are introduced into the workplace, specialist supervision is required to ensure ongoing security. These specialists not only supervise safety during the start-up period but also provide employees with comprehensive training on how to work with the introduced technology. [13]

Another technology that is often integrated into logistics processes lately is the technology of unmanned aerial vehicles (UAVs), which have a wide range of applications. The way they are used, and their characteristics allow the use of UAV technology in various sectors ranging from transport, armed forces, emergency services, agriculture, manufacturing, the aforementioned logistics, and many other areas. [14]

UAV technology has also been used in logistics processes, for example in Slovakia, France, and other parts of Europe. In Slovakia, this technology was used for the first time in August 2021, thanks to the cooperation of two companies. A company dedicated to unmanned and autonomous aircraft and a company focused on logistics in the automotive industry. [15]

The company, which is dedicated to autonomous and unmanned technology, created special control software that made it possible to move with UAV technology in warehouse spaces. The software was tested in a model environment, and the first trials in a real warehouse space took place in September 2021. [15]

A company that focuses on logistics was thus able to use the technology in the context of a stock inventory for a client in the automotive industry. Unmanned aerial vehicles (UAVs) are thus providing inventory for approximately one-third of the 10,000 m^2 facility. The investment is expected to return to the client in approximately 17 months. However, early on in the project, one of the benefits for the client of automated inventory was a significant speed-up in the process. [15]

Prior to the deployment of the UAV technology, stock inventory was carried out by staff in a forklift cage. The process was therefore a lengthy but particularly dangerous activity for employees. In addition to the annual inventory, the company conducts a sectoral inventory at a monthly frequency. By changing the process using UAV technology, the inventory can be carried out much more safely and with a relatively significant time savings. In addition, such inventories can be carried out during employee breaks, at night, or on weekends. [15]

The first phase of the process is semi-automatic; the employee has an application for controlling the UAV technology, in which he or she marks the area where he or she wants to carry out the inventory. The UAV then places the worker in a so-called starting position in front of a specific shelf and starts the inventory process. From this point on, the process is fully automated, using the technology to capture the labels of the goods, which are then compared with existing data in the system. [15]

As the process is not continuous, the use of technology is not calculated to save on manpower per se but rather to speed up the process. In fact, the company plans to use the technology in areas where vehicles are stored, which are tens of hectares in size, and inventorying by manpower is extremely time-consuming in such an area. [15]

4.4. EDUCATIONAL AND TRAINING PROGRAMMES IN THE FIELD ERGONOMICS

There is a great scope for future research in the field of ergonomics within education and training programs based on the professional research carried out. In this chapter, we will review scholarly articles and studies that focus on the addressed issue of ergonomics education and training programs. A quasi-experimental study from 2021, entitled an ergonomics educational training program to prevent work-related musculoskeletal disorders for novice and experienced workers in the poultry processing industry: A quasi-experimental study is concerned with assessing the benefits of ergonomics educational training for novice and experienced workers in preventing work-related musculoskeletal disorders. Sociodemographic and occupational questionnaires were used to evaluate the identified variables, such as age, perceived exertion, education, time on the job, musculoskeletal complaints and pain intensity, perceived exertion, and perceived ease or difficulty of receiving ergonomic training. Musculoskeletal complaints in the neck, back, and wrist were reduced by the training. There was also a reduction in occupational biomechanical exposure from baseline to the period immediately after training and 2 months after training in both novice and experienced workers. All workers in this study benefited from ergonomic education training in the short and medium term. However, the success of the training largely depended on the content and approach of the trainer. [16]

Authors P. Rothmore, P. Aylward, J. Oakman, D. Tappin, J. Gray, and J. Karnon focus on Stage of Change (SOC), a method for improving the implementation of ergonomics advice, in a study entitled The Stage of Change Approach for Implementing Ergonomics Advice: Translating Research Into Practice. In the study, the authors use a series of focus groups and a follow-up survey of members of human factors societies in Australia and New Zealand to look at what makes it hard and what makes it easier to follow ergonomics advice and use the SOC approach. The findings of this study suggest that the limited application of a SOC based approach to the prevention of work-related musculoskeletal injuries by ergonomists is due to the absence of an appropriate tool in the ergonomists' repertoire, the need for training in the approach, and their limited access to relevant research findings. [17]

The article Ergonomics assessment methods used by ergonomics professionals, published in 2019 in the professional journal Applied Ergonomics, focuses on an extensive online survey of ergonomics professionals who are certified in the USA, Canada, UK, Australia, and New Zealand. The survey surveyed the use of basic tools relevant to ergonomic practice as well as more specific analytical tools such as observational techniques for assessing postural demands at work and instrumentation for direct measurement of these demands. The data were compared with the 2005 survey, and it was found that the overall use of some ergonomic assessment methods by US ergonomists has increased. There appear to be geographic differences between countries and continents in terms of the use of different methods. Ergonomists were asked about the use of mobile devices and smartphones, and it appears that these technologies are currently in the early stages of adoption, with 24 – 28% of practitioners reporting that they use apps in their ergonomic practice. [18]

A study published in the Journal of Human, Environment, and Health Promotion entitled Can Educational Intervention be Useful in Improvement of Body Posture and Work-Related Musculoskeletal Symptoms? focuses on the impact of educational interventions on correcting posture and reducing work-related musculoskeletal disorders (WMSDs). in assembly line workers. The study was conducted with a total of 63 participants (assembly line workers). Different instruments, such as the demographic questionnaire, the Cornell Musculoskeletal Discomfort Questionnaire (CMDQ), and the Rapid Upper Limb Assessment (RULA), were used for data collection. Data collection was done before the educational intervention and two months after the training. Data analysis was performed using descriptive statistics and the Wilcoxon test. Based on the detailed analysis, the authors of the study found that the educational intervention is an effective solution to reduce the prevalence and frequency of pain but also to reduce the severity and impact of pain on workers' abilities and posture. [19]

The article, Musculoskeletal disorder risk assessment tool use: A Canadian perspective, looks at a large-scale internet survey. Professionals in the field of ergonomics participated in a web-based survey about their awareness, use, and factors influencing the use of ergonomic musculoskeletal disorder (MSD) risk assessment tools. A total of 791 respondents participated in the survey. Based on this survey, it was found that the most used tool in each sector of practice was the NIOSH equation, which assesses activities related to lifting loads. It was also found that all practice sectors except the transportation sector used a similar subset of MSD risk assessment tools, which included RULA, REBA, and psychophysical material handling data. [20]

Table (in fig. 4.8.) of the top MSD risk assessment tools used in each practice sector. In a review article entitled Online office ergonomics training programs: A scoping review examining design and user-related outcomes, authors H. Zerguine, G.N. Healy, A.D. Goode, J. Zischke, A. Abbott, L. Gunning, and V. Johnston conducted a review to assess the design and user-related outcomes of current online office ergonomics training courses that have been tested in the scientific literature and delivered by occupational safety and health (OSH) authorities. The authors systematically searched the databases and websites of OHS bodies based on the identified criteria. Based on the results published in individual articles and websites, eight online training programs were identified in six OSH authorities in Australia (2), the USA (2), and Canada (2). Based on the survey, the authors of the article found that the online office ergonomics training programs tested in the literature focused on user-related outcomes, whereas the OHSA training programs were more comprehensive and met design-related objectives. Therefore, in the future, according to the authors, collaboration between OHS bodies, the scientific community, and end-users should be considered to develop robust evidence-based programs that focus on both design-related and user-related outcomes. [21]

Sector	Ranked Reported MSD Risk Assessment Tool Use (Tool (% use))				
	1st	2nd	3rd	4th	5th
Construction	NIOSH Lifting Equation (49.5%)	Rapid Upper Limb Assessment (19.3%)	Rapid Entire Body Assessment (17.4%)	Job Content Questionnaire (17.4%)	Baseline Risk Identification of Ergonomic Factors (15.6%)
Forestry/Mining	NIOSH Lifting Equation (51.9%)	Job Content Questionnaire (22.2%)	Rapid Upper Limb Assessment (18.5%)	Body Discomfort Map (18.5%)	Rapid Entire Body Assessment (14.8%)
Healthcare	NIOSH Lifting Equation (77.3%)	Psychophysical Material Handling (47.7%)	Rapid Upper Limb Assessment (34.1%)	Rapid Entire Body Assessment (27.3%)	Biomechanical Model (25.0%)
Manufacturing	NIOSH Lifting Equation (79.6%)	Psychophysical Material Handling (50.5%)	Rapid Upper Limb Assessment (43.0%)	Rapid Entire Body Assessment (37.6%)	Strain Index (34.4%)
Services	NIOSH Lifting Equation (62.4%)	Psychophysical Material Handling (28.0%)	Rapid Upper Limb Assessment (24.8%)	Body Discomfort Map (16.8%)	Rapid Entire Body Assessment (16.0%)
Transportation	NIOSH Lifting Equation (64.0%)	Psychophysical Material Handling (24.0%)	Energy Expenditure Model (24.0%)	Ergo Job Analyzer (24.0%)	Baseline Risk Identification of Ergonomic Factors (24.0%)
Multiple Sectors	NIOSH Lifting Equation (70.4%)	Rapid Upper Limb Assessment (45.7%)	Psychophysical Material Handling (43.2%)	Body Discomfort Map (30.9%)	Strain Index (29.6%)

Fig. 4.8. Ranked reposted MSD Risk Assessment Tool Use [21]

A study titled Occupational Safety and Ergonomics Training of Future Industrial Engineers: A Project-Based Learning Approach, published in the professional journal Procedia Computer Science in 2022, addresses the need for training future industrial engineers. Authors A. Colim,P. Carneiro, J. D. Carvalho, and S. Teixeira draw attention in the article to the development of different skills, including in the field of occupational safety and ergonomics (OSH). The Active Learning Methodology, or Project-Based Learning (PjBL), in which students work in teams to develop projects as a means of building effective professional skills and knowledge, has been applied in the education of the 7th semester of the Integrated master's in industrial engineering and management at the University of Portugal. The aim of this study was to evaluate the impact of PjBL on effective H&S learning based on participants' perceptions. The study involved a document analysis that was conducted with respect to the final technical reports produced by the students during the scholarship semester. In addition, a questionnaire was developed to collect data that was administered to the participants. The sample (n = 64) included undergraduate students who participated in the above PjBL, their teachers, and executives of the companies where the project was developed. The overall perception of the participants showed that the participants of the PjBL attributed a positive rating to this educational methodology in terms of the development of technical and cross-cutting skills. [22]

An article titled Advanced visualization of ergonomic assessment data through industrial augmented reality published in Procedia Computer Science in 2023 discusses improving the working conditions of operators with a human-centered approach. Currently, the primary challenge in industry is to reduce the number of work-related musculoskeletal disorders that result from ergonomically incorrect conditions. Authors A. Evangelista, V. Manghisi, S. Romano, V. Giglio, L. Cipriani, and A. Uva discuss the assessment of postural ergonomic risk using a D-RGB camera (Kinect c2) and an augmented reality (AR) visualization system, using the RULA metric for the evaluation. This approach aims to optimize postural understanding by creating a link between real information (operator) and virtual information (virtual skeleton, RULA score) by providing a simple and immediate user interface for ergonomists. [23]

The area of workers' health from both an economic and ergonomic perspective has been the subject of research for years. The focus on people in the upcoming Industry 5.0 is also reflected in the European Agency for Safety and Health at Work 2020 – 2022 campaign, which focuses on the prevention of work-related musculoskeletal disorders (MSDs). As already mentioned, MSDs continue to be one of the most prevalent types of work-related health problems across Europe. [23]

4.5. CONCLUSION

Postural risks, exposure to repetitive movements or fatiguing or painful postures, carrying or moving heavy loads all these very common workplace risk factors can cause MSDs. Given how prevalent work-related MSDs are, more needs to be done, not least to raise awareness of how they can be prevented. Therefore, the goal of every company is to implement digital technologies that replace physical work and reduce or completely eliminate worker strain. The human being, or worker, is thus replaced only in physical work and handling loads where he adds no value. Conversely, in the actual assessment of the condition of items or other checks, the worker's skills are crucial.

The increasingly active introduction of digital technologies into the industrial sector can largely prevent the development of musculoskeletal disorders in workers, who, for example, do not have to handle loads or perform repetitive movements after the introduction of some of the aforementioned technologies. Load handling has been minimized in some workplaces and even eliminated in others following the adaptation of the technologies.

The use of modern digital technologies and available tools not only makes work more efficient but also improves the quality of work for workers. Therefore, the necessary direction for companies in the future is to continuously improve ergonomics and reduce the physical burden on workers. In addition, current trends suggest that an increasing share of digitization and automation will make logistics processes not only more agile and reliable but also safer.

REFERENCES

[1] NCZI: *CHOROBY Z POVOLANIA ALEBO OHROZENIA CHOROBOU Z POVOLANIA.* [online]. 2023. Available on the internet:https://www.nczisk.sk/Statisticke_vystupy/Tematicke_statistic ke_vystupy/Choroby_povolania_alebo_ohrozenia_chorobou_povolania/Pages/default.aspx

[2] HATIAROVÁ K.: *Návrh skríningovej metódy na vyhľadávanie rizikových pracovníkov z hľadiska vzniku syndrómu karpálneho tunela*. [online]. 2007. Available on the internet: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwiaydH6tryBAxUc2gIHHe2nDHsQFnoECBAQAQ&url=http%3A%2F%2Fverejnezdravotnictvo.szu.sk%2FSK%2F2007%2F2007-4%2Fhatiarova.htm&usg=AOvVaw06acOKGpHATdIuDHJa96QO&opi=89978449

[3] European Agency for Safety and Health at Work: *Work-related musculoskeletal disorders: prevalence, costs, and demographics in the EU.* [online]. 2019. ISSN: 1831-9343. Available on the internet: https://osha.europa.eu/en/publications/msds-facts-and-figures-overview-prevalence-costs-and-demographics-msds-europe

[4] European Agency for Safety and Health at Work: *Research on work-related MSDs.* [online]. 2023. Avaliable on the internet: https://osha.europa.eu/en/themes/musculoskeletal-disorders/

[5] Agency for Safety and Health at Work: *Healthy Workplaces Campaigns*. [online]. 2023. Available on the internet: https://osha.europa.eu/en/campaigns-and-awards

[6] DULINA L. and col.: *Ergonomics and the Musculoskeletal Disorders in the Work of Nurses.* [online]. 2019. Available on the internet: https://www.google.com/url?sa=

[7] DUL J. NEUMANN P.: *Ergonomics contributions to company strategies.* [online]. 2009. Available on the internet: https://www.sciencedirect.com/science

[8] WECKENBORG CH., THIES CH., SPENGLER T.: *Harmonizing ergonomics and economics of assembly lines using collaborative robots and exoskeletons.* [online]. 2022. Available on the internet: https://www.sciencedirect.com/

[9] PROCHÁDZKA J.: *Exoskeleton - o vonkajšej kostre snívajú vojaci aj hendikepovaní.* [online]. 2016. Available on the internet: https://www.techbox.sk/exoskeleton-vonkajsej-kostre-snivaju-vojaci-aj-hendikepovani

[10] MARINOV B.: *Types And Classifications of Exoskeletons.* [online]. 2015. Available on the internet: https://exoskeletonreport.com/2015/08/types-and-classifications-of-exoskeletons/

[11] VOILQUÉ A. and col.: *Industrial Exoskeleton Technology: Classification, Structural Analysis, and Structural Complexity Indicatort.* [online]. 2019. Available on the internet: https://ieeexplore.ieee.org/abstract/document/8719395

[12] LUGER T.: *A passice back exoskeleton supporting symmetric and asymetric lifting in stoop and squat posture reduces trunk and hip extensor muscle activity and adjust body posture- A laboratory study.* [online]. 2021. Available on the internet: https://www.sciencedirect.com/science/

[13] Amazon Newsroom: *Amazon predstavuje európske inovačné laboratórium. Bude vyvíjať nové technológie, ktoré zvyšujú bezpečnosť a spokojnosť zamestnancov.* [online]. 2023 Available on the internet: https://amazon-news.sk/Tlacove-spravy/

[14] ASATECH: *Svet Dopravy 02/2022*. [online]. 2022. ISSN: 1338-9629. Available on the internet: https://www.google.com/url?s

[15] ATP Journal: *Drony a mobilná robotika majú svoje miesto už aj v logistike.* [online]. 2022. Available on the internet: https://www.atpjournal.sk/rubriky/

[16] DENADAI M. and col.: *An ergonomics educational training program to prevent work-related musculoskeletal disorders to novice and experienced workers in the poultry processing industry: A quasi-experimental study.* [online]. 2021. Available on the internet: https://www.sciencedirect.com/science/article/pii/S0003687020301848

[17] ROTHMORE P. and col.: *The stage of change approach for implementing ergonomics advice –Translating research into practice.* [online]. 2017.Available on the internet: https://www.sciencedirect.com/science

[18] LOWE B. and col.: *Ergonomics assessment methods used by ergonomics professionals.* [online]. 2017. Available on the internet: https://www.sciencedirect.com/science/article

[19] SAMADI H. and col.: *Can Educational Intervention be Useful in Improvement of Body Posture and Work-Related Musculoskeletal Symptoms?* [online]. 2018. Available on the internet: https://www.researchgate.net/publication

[20] BELIVEAU P. and col.: *Musculoskeletal disorder risk assessment tool use: A Canadian perspective.* [online]. 2018. Available on the internet: https://www.sciencedirect.com/ science/

[21] ZERGUINE H. and col.: *Online office ergonomics training programs: A scoping review examining design and user-related outcomes.* [online]. 2023. Available on the internet: https://www.sciencedirect.com/science/article/pii/S0925753522003393

[22] COLIM A. and col.: *Occupational Safety & Ergonomics training of Future Industrial Engineers: a Project-Based Learning Approach.* [online]. 2023. Available on the internet: https://www.sciencedirect.com/science/article/pii/S1877050922008572

[23] EVANGELISTA A. and col.: *Advanced visualization of ergonomic assessment data through industrial Augmented Reality.* [online]. 2023. Available on the internet: https://www.sciencedirect.com/science/article/pii/S1877050922024310