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THE IMPACT OF ERGONOMICS ON QUALITY OF LIFE IN THE WORKPLACE

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Abstract: People spend most of their adult lives in the workplace and at work. It is therefore essential to create an environment and working conditions that positively affect their work performance and well-being at work. Ergonomics is the science that studies the relationship between people and the environment that surrounds them on a daily basis. It is not only about achieving optimum work performance, but for companies ergonomics can save costs associated with health problems and physical and psychological illnesses of employees due to poor quality of life in the workplace. Even today, with the implementation of Industry 4.0 and increasing levels of automation and robotization, technological developments are enabling efficient production processes and bringing about changes in human work. With this comes the emergence of new threats to employee well-being and challenging their existing skills and knowledge. It is therefore essential to provide quality workplaces for the workforce that will be work-ing in the changed environment. The aim of this paper is to present how ergonomic rationalisation can be used to influence the quality of life in the workplace so that employees are able to perform optimally at work without negatively impacting on their health.
Keywords: worker, ergonomics, workplace, work condition, rationalization

1. INTRODUCTION

People spend a large part of their lives at work and there is an increased emphasis on productivity, quality and efficiency. Employers should give priority to occupational health and safety, because long-term performance requires healthy employees (Makovička Osvaldová et al., 2021).

Success in any organization, whether it is in the information technology industry or the manufacturing industry, depends on the quality of work and its delivery at the right time and in the right quantity. When considering the overall issue of employee health from top to bottom in any industry that produces any kind of product, new management philosophies and new work techniques such as lean, agile and kit manufacturing must come up. (Krishna Murty Dora et al., 2022).

The work environment is a combination of various conditions such as spatial, material, physical, chemical, microclimatic, physiological, psychological, social and others that affect the work process. If the conditions are inappropriate, they can adversely affect work performance, employee motivation, performance, psychological health, safety and physical health of workers. Examples of unsuitable working environments include workplaces without sufficient daylight, workplaces located underground, at heights, under water or similar (Makovička et al., 2021).
In each enterprise there are different procedures for the performance of work, which require a certain physical fitness of the employee. Employees perform work in different posi-tions or postures, which are determined by the job itself and the parameters of the workplace. Working in one position for a long period of time can have a negative impact on the employee's health and cause musculoskeletal disorders, leading to a reduction in work performance (Makovička Osvaldová et al., 2021).

2. LITERATURE REVIEW

Ergonomics is a field of science whose main goal is to learn about the abilities and limitations of people and to use this knowledge to improve how people interact with products, environments, and systems, whether in work or personal environments. The aim is to optimize workspaces and environments to minimize risks of harm to human health. Ergonomics can be defined as the process of designing and improving workplaces, as well as products and systems, to make work as easy as possible for the people who use them every day. According to Safe Work Australia, the economic cost of work-related injuries and illnesses is estimated at $60 billion. So the aim is to create safe, productive and comfortable work spaces for employees by taking into account human abilities, body size, strength, speed, dexterity, sensory abilities such as sight and hearing, and even a person's attitude when designing work spaces (ergonomics.com, 2014).
The main goal of ergonomics is to optimize the position of people in the work environment so that they can perform at their best and so that their comfort is also ensured. Ergonomic solutions consider people as a priority. The biomechanics of the human body are taken into account and the space is adapted to it. If the principles of ergonomics are not followed in the design of the workspace, spinal and muscular disorders are the most common causes of incapacitation. Ergonomics contributes to human productivity in workplaces and other spaces (zdravypriestor.sk, 2022)
In 2011, ISSA (International Social Security Association) conducted a study and found that every amount invested in improving the working environment returns at least twice as much to society, which means that every €1 invested in prevention per employee per year has an economic return of approximately €2. Positive effects have been noted in the reduction of sick days of employees and also in the well-being of employees, leading to higher productivity, efficiency and quality of work. Very important areas evaluated by ISSA were the increase in employee motivation and satisfaction and the improvement of the company's image (Bräunig a Kohstall, 2011).
Companies in developed countries use ergonomic programmes to increase the efficiency of their employees. These programmes are integrated into overall company processes and take into account occupational health and safety. Employers must be aware of the immediate hazards to the health and life of employees that may result from negative physical, chemical, biological and social factors in the company environment. Occupational health processes are aimed at the prevention and treatment of accidents,

occupational and work-related diseases, and the subsequent return of employees to the workplace. Ergonomics and ergo-nomics programs are based on the integration of these processes, and their application helps to protect the health of employees and brings economic benefits. Today, in Slovakia, responsibility for occupational health and safety is the job of safety engineers. In the past, company doctors' clinics were key to the integration of ergonomics into company processes, and their abolition has significantly affected working conditions. (Hatiar, 2008).

The rapid development of information technology and artificial intelligence (AI) technologies, especially machine learning (ML), has greatly impacted research, industry and society. The use of ML techniques for risk assessment and injury prevention represents a new trend in ergonomic research. According to the Bureau of Labor Statistics (BLS), more than 30% of DAFW days (days away from work) in the U.S. private sector are caused by musculoskeletal disorders (MSDs), i.e., ergonomic injuries that occur when the body uses muscles, tendons, and ligaments, and result in an average of 12 days of disability. Ergonomics, as an important part of engineering, and thus particularly for manufacturing, is attracting increasing interest from ML research. The revolutionary and paradigmatic change due to Industry 4.0 has accelerated such a trend and generated many opportunities for inovation and many new challenges. These opportunities and challenges have greatly expanded the scope of traditional ergonomics research. Therefore, there is a need here to review recent progress and developments in ML applications for the study of ergonomy in manufacturing and to provide strategic insights into visions and directions for future research and practice (Lee et al., 2021).

Musculoskeletal disorders (MSDs), often caused by working in non-ergonomic conditions, are the most important category of work-related diseases. Different methods exist to investigate ergonomics through various postural assessment techniques, e.g. Rapid Entire Body Assessment (REBA), which are mostly performed through survey-based observations. As a consequence, the measurement of operator ergonomics is time-consuming and is only carried out sporadically, often only after problems have arisen. Furthermore, as the ergonomist has to assign a score to the activity performed, the evaluation of ergonomics is subjective. These problems can be solved by continuous and automated ergonomic load monitoring methods that provide direct feedback to operators. In order to monito monitor the operator without interfering with the task being performed, a vision-based ergonomics monitoring system is developed. Here, ergonomic properties (e.g. joint angles) are estimated based on multiple video streams, which are used to calculate an objective ergonomic score using a standard ergonomics assessment technique. Although cognitive operator support systems (i.e., digital work instructions) for manual assembly environments are widely used, they typically do not include ergonomics information (Claeys et al., 2022).

The most common ergonomic injuries that arise from non-ergonomic solutions at work are (recursosdeautoayuda.com, 2022):

- carpal tunnel syndrome (it is caused by pressure on the meridian nerve, which runs from the shoulder to the hands);
- ganglion cysts (a sign is a lump under the skin usually on the wrist often caused by overuse of the joint, leading to inflammation);
- Raynaud's disease (a sign is numbness in certain areas of the body due to restricted blood supply);

- tendonitis (a sign is pain or swelling of the joints due to repetitive and uncomfortable positions);
- lower back problems (which can result from prolonged sitting in uncomfortable positions, lifting, bending and twisting);
- other musculoskeletal disorders (MSD).

The impact of psychosocial risks on MSD risk is often very significant, but workplace risk management practices focus mainly on biomechanical risks, as do the risk assessment methods used by ergonomists. Translating research evidence into more effective workplace practices requires a more comprehensive risk management framework that incorporates both types of hazards. In this context, we evaluate the validity of different MSD risk assessment methods for different purposes, focusing in particular on the requirements for routine workplace risk management. These include selecting assessment methods that are fit-for-purpose, prioritising the hazards that most affect risk, and control measures as high up the risk control hierarchy as possible. Occupationalists could facilitate more effective workplace risk management by promoting: awareness of the need for change; improved guidance from OSH regulatory bodies; research into issues related to workplace management of MSDs; and professional development programmes on the topic for occupational therapists and other OSH professionals (Macdonald a Oakman, 2022).

A person at work has to perceive his environment and its stimuli, receive information and commands from his superiors, transmit information to other persons, decide what actions are appropriate or not in a given situation, carry out his tasks, etc. An example is the position an employee adopts at work, which may have psychological effects and influence his level of alertness. The application of cognitive ergonomics is used to predict and avoid so-called human errors (sainte-anastasie.org, 2023).

3. EXPERIMENTAL

The paper is based on the results of an analysis of local muscle load assessment and model-based measurement of upper limb muscle forces exerted by two workers at selected workplaces of air-conditioning unit production. The changes in electromyographic potentials of flexors (flexors of the wrist, fingers and hand) and extensors (extensors of the fingers and hand) of the forearm muscles of both upper limbs were evaluated using EMG Holter. The analysis was performed using multiple methods to obtain a com- prehensive view of the workplace problem under study. At the beginning of the measurements, the value of the maximum muscle force (Fmax) of the studied muscle groups was recorded, which, when further processed, represented a reference value for the calculation of the percentage of muscle force exerted (% Fmax) during the work activity. In parallel with the measurement, a detailed time-lapse assessment of the temporal characteristics of the work and a video-recording were processed. The video footage was used to accurately count the movements of the workers in each position. Evaluation of the measurements was done by using an EMG program and by counting the number of movements from the video recordings. The types of products produced and the nature of the activity were determined by the production on the day of measurement from observations of employees of the same occupation and laterality (right or left-handed) working on the analyzed line. Measurements were taken during the morning and afternoon shifts. Measurements were made on the basis of the work of each operator, according to the positions performed by the operator. In the preparation of the paper, basic thought processes such as analysis, synthesis, abstraction, concretization, deduction, analogy, comparison, etc. were used. In addition to direct measurements, an ergonomic analysis using the Nordic Questionnaire was realized at the workplaces to reveal the risk factors operating at the workplaces, the deficiencies in the working conditions and to find out their severity as expressed by the intensity of the workers' difficulties. To draw conclusions, the data obtained were confronted with the legislative regulations applicable to the issue. Published research results of foreign authors were also an important source for the evaluation of the outcomes.

3. RESULTS AND DISCUSSION

Based on the results from the local muscle load measurements of the PZS on the line, it was found to consist of 13 workstations. Each workstation position is manned by 1 operator. The line was designed so that the entire air conditioner manufacturing process could be performed by 1 worker, however, due to the workers not being proficient in all positions they perform either one or a few positions. Integrated electromyography, which is one of the most accurate methods of measuring local muscle strain, was used for the measurement. The line is predominantly worked by women. According to the measurement data and the Decree of the Ministry of Health of the Slovak Republic No. 542/2007 Coll., 5 workstations are unsatisfactory, in terms of a greater number of movements within the imposed muscle forces of the extensors and flexors of the forearm. The higher number of movements may be a consequence of high employee fluctuation and insufficient training of employees who have been working in their position for a shorter period of time, as experienced employees have been found to comply with the limit values for the forces exerted and the number of movements. We illustrate the solution of the shortcomings of the non-compliant stations with the example of the implementation of ergonomic measures at 1 of them, namely WS50/WS60.

As shown in Table 1 for the right upper extremity (RUE), the whole-shift value of the exerted extensor muscle forces for Employee 1 was exceeded by the frequency of movements per shift, and for Employee 2, in addition to the frequency of movements I, the exerted force of flexor I involvement of the forearm extensors was slightly exceeded.

Table 1.
Values obtained from WS50/WS60 measurements

staff	PHK %F_{max}		Number of moves per shift PHK	LHK %F_{max}		Number of moves per shift LHK
	Extensores	Flex-ores		Extensores	Flexores	
1	9.71	9.91	27000	11.07	8.39	24750
2	10.73	10.77	25650	10.98	7.62	23400

Source: (Horný, 2023)

The limit for 10% Fmax is 19 800 movements/shift. This indicates that the average number of movements for PHK exceeds the permissible limits of the number of movements for the measured muscle forces of both the extensors and flexors of the forearm. The value was exceeded for Employee 1 by 7200 movements/shift and for Employee 2 by 5850 movements/shift. For the left upper limb (LUL), the value of the exerted forces of the extensors and flexors was 11.02 Fmax and 8.00 Fmax, respectively. The limiting throw-

force at 11% Fmax was 18,100 movements/shift and at 8% Fmax was 24,300 movements/shift. Consequently, the average number of movements exceeds the permissible limits of the number of movements for the measured muscle forces of the forearm extensors of the LHK and does not exceed the permissible limits of the number of movements for the measured muscle forces of the flexors of the forearm of the LHK.
From the ergonomic point of view, the identified shortcomings can be remedied in terms of technical but also organisational measures. The purpose of organisational measures is to design adjustments to the employees' working regime and the organisation of work in order to prevent adverse effects of work and the working environment on the health of employees and to improve the quality of their working life. Due to the exceeding of the limit values of movements under the action of flexor and extensor forces according to the Decree of the Ministry of Health of the Slovak Republic No 542/2007 Coll. at the workstation concerned, it is possible to introduce rotation in ½ shifts as a measure. The implementation of the measure will improve the quality of work and reduce the risk level of the workplace, thus fulfilling the objectives of ergonomics, i.e. a positive impact on the health and well-being of the employee and, at the same time, elimination of the costs associated with the classification of the workplace in risk level 3 in terms of health and safety risks. An employee in such a workplace is entitled to supplementary pension insurance, overtime pay, wage compensation for difficulty in performing work, additional leave, convalescence and reduced weekly working hours. At the same time, the employer does not have the possibility to order overtime work.
Tables 2 and 3 show the WS50/WS60 workstation rotation alternatives for the two operators working at the analyzed station. When applying the rotation after ½ work shift in combination with any of the designed positions, they are able to work in such a way that the limit values of movements under the action of flexor and extensor forces according to the Decree of the Ministry of Health of the Slovak Republic No. 542/2007 Coll. are not exceeded.

Table 2.
Rotation proposal - staff member 1

Position	PHK $\%F_{max}$		Number of movements per shift PHK	LHK $\%F_{max}$		Number of movements per shift LHK
	Extensores	Flexores		Extensores	Flexores	
WS50/WS60	9.71	9.91	27000	11.07	8.39	24750
WS70	7.46	6.46	15300	7.49	5.89	11250
Balancing device	6.57	5.33	9900	6.54	5.08	8640
Rear cover installation	9.57	9.82	12060	11.12	8.30	12150

Source: (Horný, 2023)

The rotation of work activates muscle groups and changes the attention span of employees. It is the change in attention that is important, because doing one job all the time leads to monotony, which causes a decrease in efficiency and an increase in making mistakes. Other negative effects of monotonous work can be e.g. work aversion, drowsiness, anxiety, depression, irritability, etc. Another advantage of rotation may be the interchangeability of employees in case of sickness. A disadvantage of rotation may be the employee's reluctance to change his/her position or to learn to perform a new job.

Table 3.
Rotation proposal - staff member 2

Position	PHK %F_{max}		Number of movements per shift PHK	LHK %F_{max}		Number of movements per shift LHK
	Extensores	Flexores		Extensores	Flexores	
WS50/WS60	10.73	10,77	25650	10.98	7.62	23400
WS70	10.14	9.40	12600	7.84	6.28	10350
Balancing device	11.03	10.91	10485	11.19	7.88	9000
Rear cover installation	10.20	9.95	10035	8.20	6.39	12060

Source: (Horný, 2023)

If rotation is not used as a tool to reduce local muscle strain, adding 1 extra employee to each non-compliant workstation may be a suitable alternative. However, this proposal increases labor costs, training time, etc. However, adding an employee would solve the problem created at the non-compliant workstations and could theoretically increase labour productivity as long as there is no downtime due to waiting for semi-finished products at the upcoming workstations. The advantage of adding a worker is the elimination of identified deficiencies at the workstations. The disadvantage is precisely the increase in wage costs, the acquisition of the missing workers for these positions and the training of the new employees to perform these activities.
Another solution would be to divide the assembly stations into WS 50/WS 51 and WS 60. The rotation design serves to eliminate the main problem of the line. It can be stated that employee rotation is not a costly but time consuming tool due to the training of employees in multiple positions. Employees would have to perform 2 positions per shift. The proposal of retraining would help to solve the problem of significant differences in measured values between two employees in the same position. These differences may be related to inadequate training of employees in the work procedure.
As confirmed by the European Occupational Health Survey, the most common work-related health problems are back pain, affecting 46% of employees, and neck, shoulder and upper limb pain, affecting 43% of employees. Between 2007 and 2013, the percentage of workers reporting musculoskeletal disorders increased from 59% to 62%. The occurrence of such conditions often cannot be reduced to a single cause and prevention can only be successful if the occupational aspect of the cause is reduced. For work-related health problems, it is estimated that the number of days lost due to illness is 1.6 to 2.2 times higher than the number of days of temporary disability due to injury. One tentative explanation is that these disorders develop gradually over time. Longer-term impairments and chronic diseases increase with age. Due to demographic changes, especially in developed countries, the importance of topics such as occupational health and safety for the labour market policy will increase significantly in the future (Rusu et al., 2021). It is therefore essential to provide quality workplaces for the workforce. One option is to influence the quality of life in the workplace through ergonomic rationalization so that

employees are able to perform optimally at work without negatively impacting their health status.

5. SUMMARY AND CONCLUSION

Every work activity is more or less taxing for the human organism. The physical load, together with the psychological and sensory load within the total workload, constitutes the total load on the human body during work activity. The aim of ergonomics is to improve work and the whole work process (Marková and Prajová, 2021).

Based on the analysis of the local muscle load assessment and the model-based measurement of upper limb muscle forces, it was possible to suggest improvements in the quality of workplace life for workers through ergonomic rationalization. Organizational measures were applied to achieve the goal. In addition to these measures, technical measures can also be applied to improve the quality of workplaces in the future.

EU employment policy priorities aim to increase employment rates, prolong working lives, increase female participation, develop productivity and innovation, and adapt to the digital challenges posed by today's labour market. The success of these policies depends not only on changes in the external labour market, but also on the development of good working conditions and quality of work (Národný inšpektorát práce, 2023).

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REFERENCES

Bräunig, D., Kohstall, T., 2011. *The return on prevention: Calculating the costs and benefits of investments in occupational safety and health in companies. Summary of results*, International Social Securty Association. [online]. [cit. 2023-04-19]. Dostupné na internete: < https://ww1.issa.int/node/25672 >

Claeys, A., Hoedt S., Domken C., Aghezzaf E. H.,, Claeys D., Cottyn J., 2022. *Methodology to integrate ergonomics information in contextualized digital work instructions*, In Procedia CIRP [online]. 2022, Roč. 106, s. 168–173. ISSN 22128271, DOI:10.1016/j.procir.2022.02.173

Dohrmann consulting. 2014. What is Ergonomics?. [online]. [cit. 2023-04-19]. Dostupné na internete: < https://www.ergonomics.com.au/what-is-ergonomics/ >

Hatiar, K. 2008. *Moderná ergonómia,* In: Produktivita a inovácie. Roč. 9(6), 22-24. ISSN 1335-5961.

Horný, M. 2023. *Návrh riešenia ergonomickej racionalizácie na linke PSA v podniku MAHLE Behr Senica s.r.o*. Diplomová práca, Školiteľ: Marková, P., MTF-16684-91444

Krishna Murty Dora, H., Siva Rama Krishna L., Ravinder Reddy P., 2022. *Enhancement of safety and productivity all the way through function of ergonomics principles – A case study*, In Materials Today: Proceedings [online], S2214785322025949, ISSN 22147853, DOI: 10.1016/j.matpr.2022.04.444

Lee, S., Liu L., Radwin R., Li J., 2021. *Machine Learning in Manufacturing Ergonomics: Recent Advances, Challenges, and Opportunities*, In IEEE Robotics and Automation

Letters [online], 6(3), 5745–5752, ISSN 2377-3766, 2377-3774, DOI: 10.1109/LRA.2021.3084881

Macdonald, W., Oakman J., 2022. *The problem with "ergonomics injuries": What can ergonomists do*? In Applied Ergonomics [online], 103, 103774, ISSN 00036870, DOI: 10.1016/j.apergo.2022.103774

Makovička Osvaldova, L., Sventeková E., Malý S., Dlugoš I., 2021. *A Review of Relevant Regulations, Requirements and Assessment Methods Concerning Physical Load in Workplaces in the Slovak Republic,* In Safety [online], 7(1), 23, ISSN 2313-576X, DOI: 10.3390/safety7010023

Marková, P., Prajová, V., 2021. *Evaluation of physical burdens of operators using ergonomics,* In MM Science Journal [online], 4, 4872–4878, ISSN 18031269, 18050476, DOI: 10.17973/MMSJ.2021_10_2021016

Národný inšpektorát práce. 2023. [online]. [cit. 2023-04-19]. Dostupné na internete: <https://www.ip.gov.sk/eurofound-vytvoril-suhrnny-prehlad-europskych-pracovnych-podmienok/>

Recursosdeautoayuda. 2022. Čo je to ergonómia: vlastnosti a typy. [online]. [cit. 2022-20-10]. Dostupné na internete: < https://www.recursosdeautoayuda.com/sk/ergonomia/ >

Rusu, C., Constantinescu C., Marinescu S., 2021. *A generic hybrid Human/Exoskeleton Digital Model towards Digital Transformation of Exoskeletonsintegrated workplaces*, Procedia CIRP [online], 104, 1787–1790, ISSN 22128271, DOI: 10.1016/j.procir.2021.11.301

Sainte-Anastasie.org. 2023. *Définition et exemples d'ergonomie cognitive*, [online]. [cit. 2023-04-19]. Dostupné na internete: < https://www.sainte-anastasie.org/articles/ psicologa-cognitiva/ergonoma-cognitivadefinicin-y-ejemplos.htm>

Vyhláška č. 542/2007 Zb. Ministerstva zdravotníctva Slovenskej republiky zo 16. augusta 2007 o o podrobnostiach o ochrane zdravia pred fyzickou záťažou pri práci, psychickou pracovnou záťažou a senzorickou záťažou pri práci

Zdravý priestor. 2022. *Optimalizácia prostredia z ergonomického hľadiska*, [online]. [cit. 2023-04-15]. Dostupné na internete: < https://zdravypriestor.sk/sluzby/optimalizacia-prostredia-z-ergonomickeho-hladiska/ >