EVALUATION OF PHYSICAL BURDENS OF OPERATORS USING ERGONOMICS

PETRA MARKOVA, VANESSA PRAJOVA

Slovak University of Technology in Bratislava, Faculty of Materials Science and Technology in Trnava, Institute of Industrial Engineering and Management,Slovakia,

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petra.markova@stuba.sk

The article describes the experience from assessing the load of the upper limbs during the horning operation, which is one of the more difficult manual manipulations. Several analytical methods were used to obtain complex analytical data. They were used to identify deficiencies in work activity causing loading of the upper limbs, which in the form of increased effort affect employees' work performance in the monitored work activity. The excessive workload of workers has a significant impact not only on the decline in performance but also on the development of difficulties caused by the cumulative effect of risk factors (work and work environment) and, last but not least, on the increase in accidents and occupational diseases. A comprehensive assessment of work activity based on various methods serves as a basis for ergonomic rationalization of work activity to reconcile the demands of work activity with operators' physical possibilities and abilities.

KEYWORDS

work, work activity, load, difficulties, ergonomics, work performance, employee,

1 INTRODUCTION

Man is an intelligent being capable of work, the creation of tangible and intangible goods. Work is a purposeful activity aimed at creating some benefit. The set of tasks performed from input to output is called a workflow. The goal of ergonomics is to improve work and the entire work process. To improve the work process also means to strengthen its factors.

We can divide the work according to different areas. In terms of mental and physical demands, we assume that the workload can affect the psychological and physical side. Both of these burdens can be divided according to the degree of action on [Slamkova et al., 2010]:

- optimal load,
- light load,
- unacceptable burden.

The load on the human body is caused by more or less every single work activity. Physical load, together with mental and sensory loads, which are part of the total workload, contributes to the entire workload of the human body during work activities. Evaluation of whole physical load represents the load on the muscles of the upper and lower limbs, large muscle groups and local muscle load, i.e., loading of small muscle groups, such as the arm and forearm muscles. Frequent work activities include working with objects or loads [Turekova et al., 2014].

In industrial production, most occupational diseases are reported, where people suffer from the most common upper limb pain and infectious diseases. It mainly affects working people between the ages of 50 and 59, with a slight shift to older age groups. [Solc et al., 2012].

In the company, it is essential to assess the physical activity during the performed activity and determine whether it does not exceed the physiological possibilities of workers and whether it cannot cause damage to health. These are the main factors related to human equipment and performance capacity. In the assessed workplace, we must focus on [Ockajova et al., 2013]:

- spatial dimensions and layout of the workplace;
- working positions;
- tools and instruments used;
- location of controls;
- handling of loads and conditions for handling;
- frequency of use of force;
- rest and work regime;
- total physical activity;
- rotation of changes, etc.

The physical workload is focused on the workload of the musculoskeletal, respiratory and cardiovascular systems, which impacts metabolism and thermoregulation. Excessive overloading of the musculoskeletal system is when there is an imbalance in the individual's constitution and overall muscular capacity and the demands on physical fitness that result from the assigned work tasks.

During muscle work, we recognize two forms:

- dynamic muscle load - change in muscle length while maintaining the tension (alternation of anxiety and muscle relaxation, alternating involvement of muscle groups);
- static muscle load - muscle length remains, but tension increases (isometric muscle contraction, which increases tension) - much more stressful [Fiserova, 2010].

During heavy static work, the muscles must ensure the supply of oxygen and nutrients; the removal of metabolites is not ensured (accumulation of lactic acid). This causes pain and fatigue in the strained muscles. These are mainly the following positions: raised arms for a long time, pushing and pulling heavy loads, standing in one place or tilting the head.

The physical load is directly affected by the position in which the work is performed. The same job in different situations can provoke a different reaction in the form of human effort to complete it. Muscle strength can be increased by choosing a position in which the muscles work with the giant arm of the levers. For example, a bent leg has three times the treading force of a stretched leg; a half-open hand has much more energy than a closed leg, and so on. [Dulina, 2000].

From the point of view of ergonomics, one of the most monitored areas is the working position, as by choosing an unsuitable working position we can seriously damage our health.

Local muscle load represents a one-sided excessive and long-term load of still the same muscles, which ultimately leads to various diseases of joints, muscles, bones, nerves, tendons, attachments, where the risk of damage to health arises mainly from these activities:

- multiple repetitive movements and high muscular strength, especially in unusual or extreme positions
- other factors (distribution of force expended over time, duration of energy, distribution and period of breaks, time to recovery),
- the influence of other associated factors, such as poor gripping of work tools, exposure to vibration, adverse climatic conditions, inappropriate personal work habits, insufficient training [Fiserova, 2010].

Physical and physical stress is primarily affected by the extent and activity of muscles associated with energy consumption.

Physiological studies, which are focused on the examination and subsequent evaluation of the functions of the human body during and after work, are the primary tool in the physiology of yield. [Kovac et al., 2010]. In practice, the most common and most sophisticated methods of physiological examination are [Kovac et al., 2010]:

- Pulse frequency tests;
- Blood pressure testing;
- Measuring the magnitude of energy conversion;
- Muscle strength tests;
- Muscle endurance tests;
- Pneumography;
- Electromyography (EMG);
- Electroencephalography (EEG);
- Electrodermatometry (EDM).

In response to the impacts of functional job specialisations, changes in the structuring of work began to be adopted, which were to increase the organisation's efficiency and employees' activity and job satisfaction. Methods of designing workplaces that take these needs into account include:

- rotation of work tasks - temporary transfers of employees within one profession. This reduces the monotony of work, facilitates excessive specialization.
- grouping of work tasks - integration of work activities, which reduces the repeatability of functions during the change.
- combining functions and specializations - an extension of the original profession by parts of additional activities. The result is the creation of preconditions for qualification growth and mutual substitutability. Unilateral burdens on employees are minimized.
- autonomous working groups - work tasks are focused on smaller working groups. The members of the group are independent and responsible for the decisions made - the growth of motivation. The application of autonomous groups initially represents an increased cost for the company, especially for the training of employees. Still, at the same time, it brings an increase in employee satisfaction and thus an increase in the results achieved. [Kachnakova et al, 2008]

According to Sukalova [2010], workplace design is influenced mainly by the nature of work activity, workplace equipment, workplace mobility, organization of work at the workplace, the connection of the worker with the workplace (spatial, functional reference) and working position.

Economic effects are also an essential benefit of ergonomic solutions for workplaces, as it is the application of ergonomic requirements that can increase employees' work performance. [Sukalova, 2010]

Software products make it possible to create virtual models of individual workplaces corresponding to their actual characteristics. After adding a person to this model, space will be created to consider the requirements of future employees even before the actual workplace is put into operation. Workplace changes on a virtual model are significantly less time-consuming and costly than changes implemented in an actual workplace.

To create a correct ergonomic design of the workplace, not only average human models are used. The workspace must be adapted to the whole group of workers who will work at the workplace. Software products make it possible to take into account a wide range of anthropometric dimensions of employees to create the correct workplace design. [Tabakova et al., 2008]

With the advent of new technologies, the nature of work has also changed: while high demands were placed on the worker's physical load and skills in the manual work phase, the automation phase requires mental resilience and professionalism. Ergonomic creation of the workplace and working environment monitors the optimization of human-machine-environment relationships. It is a suitable choice, construction and arrangement of controls and tell-tales, a suitable spatial solution, which will ensure a convenient working position and minimize the static load. [Ruzicka et al., 2008]

Musculoskeletal disorders are the most common work-related illness in Europe. These are mainly diseases affecting muscles, joints, tendons, ligaments, nerves, bones and the circulatory system. It can say that they have wide-ranging societal consequences: social, health, economic. They are the most frequent cause of occupational diseases in EU countries. [Sukalova, 2010]

Occupational hazards, mainly due to unsuitable working conditions, lead to accidents at work and occupational diseases. These significantly affect all sectors of the economy. For the employee, they mean personal suffering and loss or a decrease in income. [Sagova, 2011]

2 METHODOLOGY

The article elaborates on the analysis of the evaluation of the total physical and local muscle load, working positions, and manual handling of loads at selected workplaces of mining - the research performed by several methods to obtain a comprehensive view of the practical problem in the workplace. Selected operations were assessed from the point of view of local muscle load of the upper limbs by the method of integrated electromyography with the EMG Holter analyzer. A digital sensitometer used to measure the physical load of specific muscle groups in the form of force expended to perform the work operation. A video recording of everyday work activities processed using the EMGhVideo Viewer software accurately determined the number of movements during work. The assessment of total physical activity consisted of full-heart monitoring of heart rate and determination of energy expenditure at work. The evaluation of working positions and work with loads was carried out by direct observation, weighing loads, and detailed analysis of photo documentation, video recordings, and working time frames. In addition to direct measurements, ergonomic analysis was carried out at workplaces using the Nordic Questionnaire to detect risk factors at work, deficiencies in working conditions and their severity expressed by the intensity of workers' difficulties. In addition, used Humantech software to confirm the results of the ergonomic analysis, which points to the potential risks associated with the work performed in regular work activities. To conclude, confronted the data obtained with the legislative regulations applicable to the issue [Vyhlaska 542/2007 MZSR Z.z.]. The results of research by foreign authors were also an essential source for the evaluation of outputs.

3 RESULTS

Assessment of work activity - hogring performed in 3 basic levels. It was necessary to evaluate the physical load of employees, determine the local static load of the upper limbs of the monitored operators, assess working positions, and evaluate the handling of gears and the overall course of work at the monitored workplace. The ergonomic analysis was attended by 15 employees working on a work shift. The ergonomic analysis was focused on a comprehensive assessment of work and the effects of risk factors of working conditions at the workplace. The examined employees were men, which ensured the homogeneity of the monitored sample. Two employees were selected by random selection of a contracted occupational health service, fully trained, healthy, physically fit, and employed from the group of employees who participated in the ergonomic analysis. They both worked in a job position for more than one year. These are representatives of the age group of 50-59 years, in which, according to the literature, the most occupational diseases reported, and people most often suffer from upper limb pain. From the point of view of their physical structure, 57-year-old men, right-handers, 182 cm and 70 kg tall, designated as the EMG1 operator, and 156 cm and 57 kg for the EMG2 operator. Both have BMI values in the normal weight range.

The measurements took place in actual conditions during the ongoing work shift. Employees performed all the activities they encounter in their daily work. Within the organization of work activities, due to the physical demands of work activities, workers rotate. Due to the complexity of the performed measurements, two operators took turns at the monitored workplaces. However, the results converted into a labour standard, i.e. a situation in which three workers take turns at a given workplace as usual.

The primary working position of the evaluated employees is standing without the possibility of changing it, which is given by the layout of the workplace. During work, large muscle groups of the lower limbs, torso, shoulder girdle and small muscles of both hands and forearms are exposed. The employee's work activity is homogeneous throughout the work shift and is performed at the same workplace.
Compounding was observed during the evaluation - working movements of the wrists / palmar, ulnar and radial flexion, extension, rotational movements without the occurrence of extreme joint positions. As shown in Table 1.

Worker	Average full-force effort (% F_{max})				Number of working movements of small muscles of the hands and forearms	
	Dominant hand		Non-dominant hand		Dominant hand	Non-dominant hand
	Extensors	Flexory	Extensors	Flexory		
EMG 1	9,5	13,9	4,3	12,1	17000	13600
EMG 2	4,5	12,8	12,8	11,8	15470	10200
Priemer	7,0	13,4	8,5	12,0	16235	11900

Table 1. Evaluation of exerted force and frequency of working hand movements [Herceg, 2020]

It was necessary to assess the exertion of the force of the upper limbs during work and the frequency of working movements of the limbs. The average full-force labour of the evaluated employees was 13.4 % F_{max} for the muscle group of flexors of the dominant upper limb and 12.0 % F_{max} for the muscle group of flexors of the non-dominant upper limb. The numbers of working movements for the average values of the dominant hand from the point of view of exerting flexor force exceeded, which indicates excessive hand strain when exerting the energy of small muscle groups of the forearm and writing for a work shift. The measurement of the physical activity of employees performed during hogring. Specifically, an EMG1 employee used a manual hogring machine to hogring the seat cover. The work activity consisted of removing the seat's seat foam and the body from the hopper, placing them on the work table, where the employee uses a hogring weapon to grab the seat cover on the foam. Part of the hogring process is manual stretching and adjustment of the seat cover, representing a physical burden for the employee's upper limbs. The whole process ends by turning the seat on the pneumatic turntable by depressing the foot pedal and then connecting the side parts of the cover with Velcro. The employee places the finished part on the secondary work surface, where other operations performed. The second monitored employee worked at a neighbouring workstation, where the work is similar to that of an EMG employee 1.

The work of employees is standardized. During the 8-hour work shift, 170 front seats must be produced at each workplace. This standard was observed during the measurement of the physical load of the monitored employees and the required number of seats was produced at both monitored workplaces.

When assessing the frequency of the need to exert force during work operations above 60 % F_{max}, as shown in Table 2, the limit values were observed. According to Vyhlášky 542/2007 Zb. z. work operations with an applied force above 60% F_{max} for predominantly dynamic work are permissible a maximum of 600 times per change. Work operations with the need to use force above 70 % F_{max} in mostly dynamic work did not occur at the monitored workplaces.

	Limb	Extensors/ Flexors	Power over 60% F_{max}	Power over 70% F_{max}
Production operator	Dominant	E	3	0
		F	236	0
	Non-dominant	E	7	0
		F	391	0

Table 2. Evaluation of the use of force during work operations [Herceg, 2020]

The working position of employees is directly dependent on the layout of the place of work and the height of the handling planes. From the perspective of ergonomics, it is optimistic that the desks of employees on which the monitored work activity takes place are height-adjustable. During the physical activity assessment, the occurrence of unacceptable positions of the upper limbs mainly related to the manual application of the cover to the seat foam. This is the biggest problem of the whole monitored work operation, as the operator has to exert force on its implementation and at the same time performs it in an unacceptable position of the limbs and as Table 3 shows during almost a quarter of the work change.

Worker	Time in unacceptable position hand / change / min.		Time in conditionally acceptable hand / change / min position.	
	Dominant	Non-dominant	Dominant	Non-dominant
EMG1	17	26	119	125
EMG2	11	20	122	140

Table 3. Time spent in a conditionally acceptable limb position [Herceg, 2020]

To assess the total physical load, full-change monitoring of the heart rate of both operators and determination of energy expenditure at work was performed. The results are shown in Table 4. For workloads, the average pulse rate during a career should not exceed 100 pulses per minute for employees, while in the short term, the maximum pulse rate for employees over 40 may rise to 130 beats per minute, which must not exceed. The permissible stress limit for dynamic work was not exceeded during pulse frequency monitoring. Also, the permissible load (expressed by energy expenditure) during emotional work for the muscles of the upper limbs and torso in men was in the norm as the limit value is 5.8 MJ.

Worker	Pulse frequency		Average energy expenditure in $kJ.min^{-1}$		
	Calm	Average	Minute	Changing	MJ
EMG1	70	93	9,66	4 636	4,6
EMG2	72	97	10,5	5 040	5,0

Table 4. Total physical activity during the monitored work shift

In the ergonomic analysis using the Nordic Questionnaire (NQ), the localization of difficulties in the body parts of the whole group of employees found, where employees themselves subjectively expressed in which specific body parts they feel the most challenges. Their intensity expressed by visiting a doctor precisely because of these difficulties. As the results in Table 5 show, more than half of the employees experience the most significant challenges in hands and wrists, in the shoulders and the legs, because they already forced to visit a doctor.

Location of difficulties	Operators at selected stations	
	% Difficulties	% Visits to the doctor
Neck	26,67	6,67
Upper back	6,67	0,00
Lower back, crosses	13,33	0,00
Shoulder	46,67	6,67
Elbows	26,67	6,67
Hands and wrists	66,67	6,67
Hips and thighs	6,67	0,00
Knees	6,67	0,00
Ankles and feet	33,33	0,00

Table 5. Occurrence and intensity of PPS in body parts of employees by sex [Herceg, 2020]

From the data evaluated in the questionnaire, it is clear that the work is physically demanding for operators. The application of ergonomic principles in monitored workplaces is not sufficient, as workers feel the adverse impact of environmental factors to a greater or lesser extent. This is even though the physical and muscular load measurements were in order from the point of view of the legislation. Nevertheless, if we consider the subjective opinion of the exposed employees in Figure 1, it is possible to observe workplace deficiencies. Employees who identified working conditions as highly burdensome most hampered by long-term work in the same working position, excessive forward bends and torso dials, and the quality of training and education, which corresponds to the nature of the work performed.

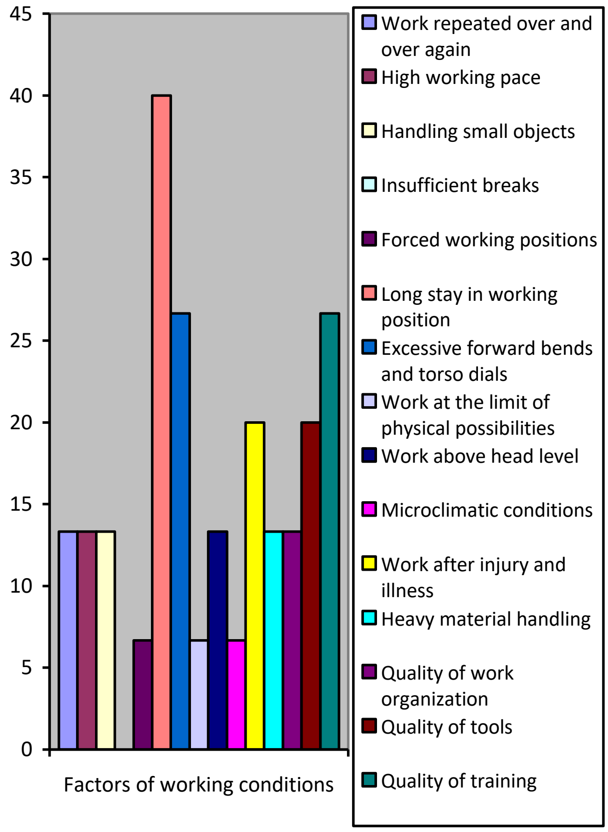


Figure1. Factors of working conditions indicated by a high degree of load [according to Herceg, 2020]

The evaluation of working positions and work with loads was carried out by direct observation, weighing loads, and detailed analysis of photo documentation, video recordings, and working time frames. This data also served as input data for the Humantech software, which used to quantify the risks associated with work performed in regular work activities. At the same time, the software review served to verify the results of the ergonomic analysis carried out through the NQ questionnaire. To assess the work activity using the Humantech software, a video analysis prepared to cover the entire work activity from the gripping of the material to complete the whole operation and insert the finished product into the rack. The video presented the input data of the complete analysis to determine the type of movements of the operator and determine the length of individual operations and determine the frequency of occurrence of a given direction. As we can see in Figure 2, entrees these individual movements into the software with the determination of the duration or the number of repetitions.

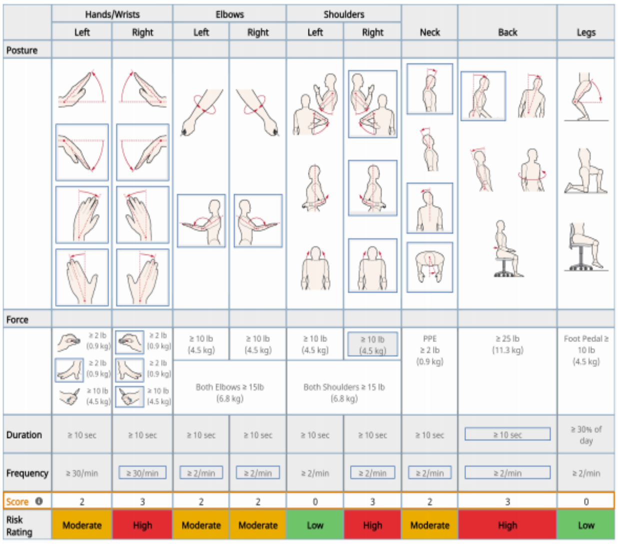
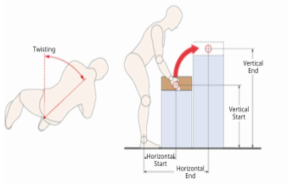


Figure 2. Determining the type, occurrence and repetition of individual movements [Herceg, 2020]

The second part of the analysis using Humantech software (Figure 3) focused on lifting objects. In this case, it is a hogring weapon used to connect the seat cover with the foam. Approximately 20 hogrings must use during one operation, which means pressing the shutter button 20 times with the index finger of the right hand.

Task	Results: RWL (kg)	Results: LI	Inputs: Weight (kg)	Horizontal (cm) Start	Horizontal (cm) End	Vertical (cm) Start	Vertical (cm) End	Twisting (degrees) Start	Twisting (degrees) End	Grip	Duration (hours)	Frequency (lifts/min)
Lifting the weapon from the basic position	13.4	0.1	1.27	0.0	25	35	120.0	0.0	15	Good	8	0.5



Inputs	NIOSH Input Limits	Optimal Input Values
Horizontal	min. 0 cm, max. 63 cm	0 - 25 cm
Vertical	min. 0, max. 178 cm	75 cm
Twisting	min. 0°, max. ± 135°	0°
Duration	1 - 8 hours	1 hour
Frequency	0.2 - 15 lifts/min	0.2 lifts/min (1 lift every 5 min)

Figure 3. Lifting a load from the basic position [Herceg, 2020]

The third step was to enter the operation of storing the finished product on the shelf in the software (Figure 4). Based on the entered data, the software calculated the initial and the inertial forces required and the relocation of the product and evaluated the whole operation as low risk.

Task	Initial Force: Rec. kg	Initial Force: Accep. kg	Initial Force: Risk	Sustained Force: Rec. kg	Sustained Force: Accep. kg	Sustained Force: Risk	Force: Initial kg	Force: Sustained kg	Hand Height cm	Distance m	Frequency
Lifting foam from the box	22.0	25.0	Low	13.0	18.0	Low	2.0	1.0	Forearm (89 cm)	2.1 m	Every 2 Minutes

Low – Within strength capabilities of 75% of female population. Within ergonomic guidelines.

Figure 4. Storing the finished product on the shelf [Herceg, 2020]

Analysis using Humantech software confirmed the increased load on the operator's body in the cruciate area, right shoulder and hand area, as shown in Figure 5. The unacceptable burden is also in the wrist and neck areas. Thus, the findings of the ergonomic analysis confirmed by the Nordic Questionnaire, where the employees themselves indicated in which body parts they were experiencing difficulties and because of which they forced to see a doctor, which means the intensity of these difficulties. The problem of directly hogring operations also confirmed. The simultaneous work operations for handling work tools and the finished product did not represent an increased burden on the operator's body.

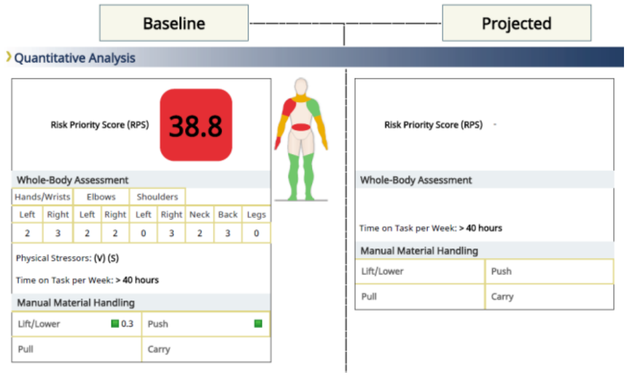


Figure 5. Analysis results using Humantech software [Herceg, 2020]

4 DISCUSSION

When performing work activities, a person burdened with the work itself and various factors of the work environment. These facts affect the physiological and mental functions of his body. We can measure a person's workload by units of an acting factor (e.g., force, heat, noise, etc.). On the other hand, stress represents the effort of the organism to cope with the load and is manifested by a certain response of individual functions of the organism to the action of the load. This is an increased activity of loaded organs or parts of the body during workload and conditioning reactions (accommodation), which ensures or prevents the disruption of homeostasis and damage to the body (e.g., pulse and respiratory rate, oxygen consumption, etc.).

In addition, the body's response to load is manifested by various qualitative and quantitative concomitant manifestations (e.g. muscle action potentials) and subsequent changes (increased body temperature after exercise, decreased body water content and recovery processes) in those organs and functions that are directly affected by a loading factor or other load-related changes in the body. The magnitude of this response is individual in each individual.

All these changes can be an indicator of the magnitude of the stress. They depend on the intensity and duration of the load and the functional fitness of the individual. Therefore, the intensity of stress must be determined and assessed according to the type and magnitude of the response of physiological functions or according to the effects of a given factor on the organism. This is necessary because, unlike the load (the magnitude of which can be measured), there are no units by which the stress of the organism as a whole can be measured or expressed.

Significant interindividual differences in the body's response to stress caused by different levels of fitness of the respective functions in different people. Assessing the focus on the body is a complex task, so it evaluated in a simplified way in practice. Such functional indicators and changes selected that most sensitively reflect the level of stress of the organism under a particular load.

As the survey results in the article suggest, we cannot be satisfied just by finding out the size of the workload of employees with work activities. For a comprehensive assessment of the impact of work and work environment factors on humans, it is necessary to determine the impact of workload on the worker. The assessment of the physical load of workers must be carried out not only for the loaded muscles but also comprehensively from the point of view of working positions and the way of manipulation during work activities and the influence of work environment factors. The workload in humans is highly affected by the monotony of work. Even according to the latest EUROSTAT survey, the repetition of work, together with unsuitable working positions and complex manipulation, were the factors causing the most significant difficulties for employees in connection with the working environment. Work monotony as a cumulative pathogenic factor in the load of small muscle groups of the forearm can cause employees a variety of occupational diseases in the form of enthesopathy, periostitis (tennis elbow, golf elbow,) and other bone damage, nerve palsy (carpal tunnel syndrome). [Luptakova, 2021]

Ignoring the symptoms and late diagnosis and treatment, these diseases are the reason for the loss of employees from the work process and a permanent nature with the need to retrain the employee. The survey found an excessive load on the flexors of employees' hands in combination with excessive force, which are the first indicators for the emergence and development of difficulties causing occupational diseases. Especially in older employees than in our case, it is necessary to pay attention to employees' physical load to avoid its adverse effects, as ergonomics seeks to ensure that employees can work for a long time without adverse effects on their health.

For a comprehensive assessment of the workload, it is necessary to directly measure the effect on the human body to determine the emotional impact of the factors of the work environment on the employees themselves. Employees working in a given workplace are best able to assess its harmful impact concerning occupational exposure. It is good to support the objectivity of the results with one of the software methods for quantifying the risks in the workplace. This will guarantee the complexity of the obtained results of the evaluation of the workload of employees. Suppose employees' workload was assessed only in terms of total physical activity and the local muscular load of the upper limbs or by determining the force exerted. In that case, it could happen that the analysis will not be performed in sufficient depth. It may seem that problems in the workplace are not severe because, from this point of view, values can be measured within the intervals specified by the legislation. However, when we supplement the analysis with quantification of risks and determine the impacts of the workload, we get a complete overview, which will allow us to find the most suitable solution for influencing the workload and, ultimately, the stress on workers.

5 CONCLUSION

The assessment of physical activity during work activities, together with the evaluation of work positions and the method of manipulation at work, and assessing the influence of work environment factors make sense. It becomes essential, especially for a physically demanding job, which we try to limit as much as possible from ergonomics. The best solution would be to automate as much as possible work operations, which, from the perspective of ergonomics, are for a person at risk of developing occupational diseases. The answer to reducing the physical demands of work is the implementation of Industry 4.0, which assumes automation, robotics and intelligent machines to complement human labour. As a result, the nature of labour involvement will change dramatically. It will have to succeed in a much more automated economy with less physical activity along with new forms of skills.

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CONTACTS:

Ing. Petra Markova, PhD.
Slovak University of Technology in Bratislava/Faculty of Science and Technology in Trnava
Ulica Jana Bottu c. 2781/25, Trnava, 917 24, Slovakia
+421 906 068 454, petra.markova@stuba.sk, www.mtf.stuba.sk