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ERGONOMIC WORKSTATION DESIGN IN AUTOMOTIVE CAR SEATS PRODUCTION

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Abstract

Musculoskeletal disorders are one of the most common work-related illnesses. At the European level, they affect the health of millions of workers, and, at the same time, the employers themselves pay high costs for their compensation. According to the data from the automotive industry, the costs of introducing ergonomic controls at the initial stage of production design are significantly lower than the costs of compensating musculoskeletal disorders. Along with the implementation of ergonomic controls at an early stage, the risks of developing work-related musculoskeletal disorders are reduced or eliminated.

The need for a scientific research approach in the implementation of ergonomic controls is imposed as one of the most significant ways to deal with musculoskeletal disorders and to improve safety, wellbeing, and effectiveness of employees.

This paper analyzes the ergonomic risks among employees in the automotive car seats production as well as the control mechanisms that can reduce or eliminate the occurrence of work-related musculoskeletal disorders (MSDs).

Key words: *Work-related musculoskeletal disorders, Carpal Tunnel Syndrome, Ergonomics risk factors, Engineering and Administrative control measures*

INTRODUCTION

Despite the rapid development of sewing technologies, the prevalence of work-related musculoskeletal disorders (WMSDs) is still high due to unbalanced workloads, inadequate workplace design, aging of the working population, and a number of other factors [1,2].

Musculoskeletal disorders (MSDs) are a wide range of inflammatory and degenerative changes that affect joints, ligaments, muscles, nerves, tendons, and the corresponding blood vessels. The most important element leading to the creation of musculoskeletal disorders is the balance between the local soft tissue fatigue and the individual's ability to recover from this fatigue. If an adequate supply of blood flow to the soft tissues is maintained during the performance of work activities, that metabolic balance can be maintained and excessive fatigue can be prevented. The relationship between work and the human factor is one of the key elements for this critical balance [3]. Ergonomics risk factors have a negative impact on maintaining this balance and increase the possibility that individuals will develop MSDs.

Most prevalent ergonomic risk factors in the workplace are:

- High degree of repetition
- Force (use of strong efforts)
- Prolonged or repeated awkward posture.

Work-related musculoskeletal disorders can be prevented or reduced by systematically reducing these ergonomic risk factors. The goal is to identify ergonomic risk factors, quantify them, and consequently make measurable improvements in the workplace, ensuring that work and tasks are within the employee's ability and limits [4]. The best approach to this is to establish ergonomics as an

ongoing process of identifying risks and reducing those risks based on a comprehensive Ergonomic Program.

A factory for the production of car seats in Romania was selected as a part of this study. The research at this organization was conducted through a range of analytical methods such as Musculoskeletal Discomfort Questionnaire, to analyze health status and ergonomic risks of a certain population working on sewing operations, trend of work-related illnesses in this organization, ergonomic assessments of the design of sewing workplaces, as well as assessments of ergonomic exposure of the employees in the sewing process.

Among the most significant causes of WMSDs in the automotive car seats production are awkward postures of the joints of the upper limbs and neck accompanied by repetitive movements for a prolonged period without recovery time, use of excessive force when sewing multilayer seams, sewing leather covers as well as prolonged static posture [1, 2].

The data obtained from this research identifies the opportunities to improve the design of workstations and opportunities to optimize human well-being and overall system efficiency through the implementation of engineering and administrative control measures.

MATERIAL AND METHODS

Data trend analysis for the reported MSDs in this paper was done with advanced software solutions for reporting, tracking, analyzing, and managing work-related illnesses. The classification of occupational injuries is designed according to OSHA Injury and Illness Recordkeeping and Reporting [7]. For evaluation of the occupational illnesses the defined Key Performance Indicator has been analyzed.

For the purpose of this paper, Musculoskeletal Discomfort questionnaires (combination Modified Nordic, Cornell and MSDs Severity and Frequency Questionnaire) were conducted [8,9,10]. The purpose of the survey was to assess the work experience of a group of sewing operators with regard to musculoskeletal discomfort during the past seven days and 12 months. The participants in the survey were 140 employees from 3 shifts and 3 projects, of which 95% were women. The survey participants worked between 1 and 5 years and more than 5 years on a different sewing operations.

For the assessment of the design of workstations, tools, equipment and processes, an appropriate design check list was used. The check list itself is intended for a standing working position and is adjustable in terms of anthropometric data for the population being analyzed [11,12]. Identified improvement opportunities that mainly reflect a physical characteristic of the work station also required further analysis with a validated ergonomic risk analysis tool.

The RULA method was used for rapid assessment of the upper extremities. This tool is intended to assess employees' exposure to ergonomic risk factors associated with the occurrence of upper extremity musculoskeletal disorders. The tool considers the demands of biomechanical and postural loads during work tasks (neck, trunk and upper limbs) [13]. For the purpose of the research the Tumeke computer application was used that creates 3D models of human activity from 2D video and calculates joint positions, repetitive movements and duration of exposure to risk. Deep learning methods detect body parts and joints (semantic key point tracking) to analyze human motion in real-time or periodic snapshots [5].

For the quantification of the implemented improvements re-evaluation was made with Musculoskeletal Discomfort questionnaires of employees working in workstations with improved design and established engineering and administrative measures, and ergonomic risk assessment of upper limbs RULA with Tumeke app.

The analysis and comparative method was applied for the effects of the improved design and the established administrative and engineering measures.

RESULTS AND DISCUSSION

Work related musculoskeletal disorders data from 2019 to 2023 in one of the leading automotive seat cover manufacturing companies, presented in Figure 1 indicate continued growth. Even 71% of the total number of musculoskeletal disorders belongs to the Carpal Tunnel Syndrome. This paper will analyze the data from a production site where the most considerable number of registered musculoskeletal disorders were recorded.

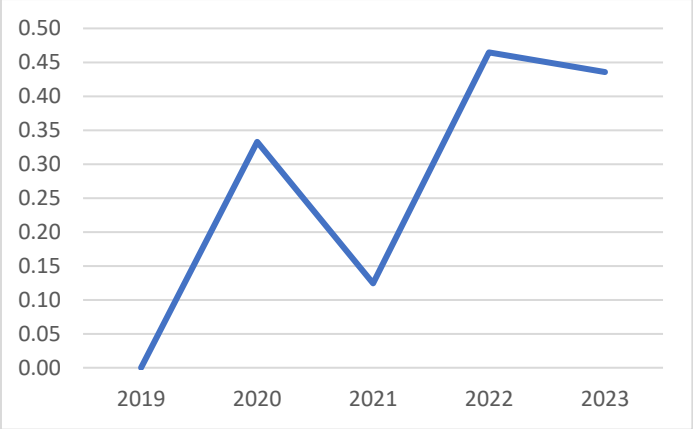

Figure 1. Total Recordable Illness Rate

Based on the results of the questionnaire, even 87% of the participants reported pain, soreness, and discomfort in the last 12 months. Regarding the frequency of the experienced pain and discomfort related to work, only 5% answered that they always feel pain and discomfort. A significantly higher percentage of the surveyed employees 31% experienced often work-related pain and discomfort and in the further work this group/population will be subject to in-depth further analysis. Sometimes a feeling of discomfort was answered by 39% of the respondents, while 17% of the employees answered that they never experienced any discomfort.

According to the data shown in Figure 2, the most affected body parts are: neck, shoulders, forearms, wrists and ankle feet. The largest number of employees with frequent pain and discomfort work on the FB operation (sewing the front back parts of the car seat cover).

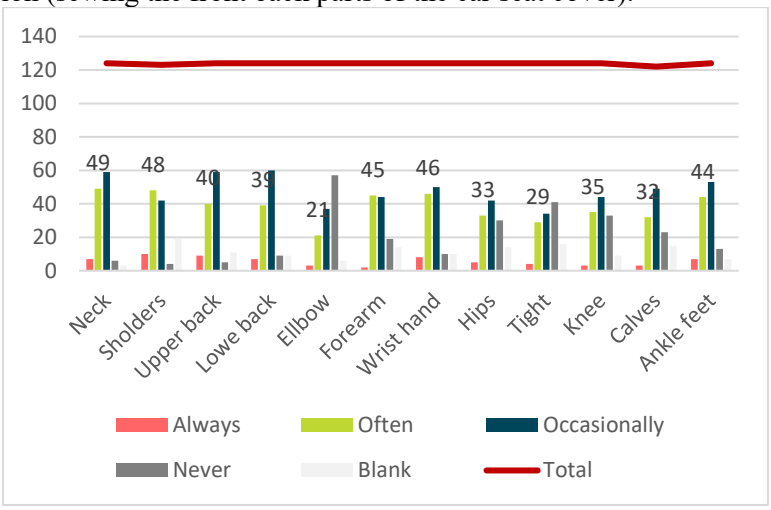

Figure 2. Numerical display of the affected body parts and frequency of pain and discomfort

In terms of workplace design, sewing activities for the production of seat covers are performed in the so-called sewing cells that contain 40 to 60 sewing machines. The sewing process takes place in standing position, which is associated with certain risks. The results of the workplace design assessment are presented in Table 1.

Table 1. Workstations design assessment results

Workplace design requirements	Identified opportunities for improvement of workplace design	Priority
Working space depth (from the first physical barrier in front of the operator to the first physical barrier behind the operator): ≥ 89 cm.	Insufficient space due to closely installed sewing tables in sewing cells. The site tables and holders in cells further narrow the space around the operator.	3
Is there a formal rotation/break schedule?	The breaks/stretching schedule not defined according to the recommended administrative measures from ergonomic assessments.	3
Does the workstation design prevent workers from picking up parts from the back to complete tasks?	There are workstations where employees bend their entire torso to reach the required component to complete the task.	3
The workstation design does not require the operator to twist ≥ 15°	While taking components for the sewing operation, employees twist laterally more than the allowed limits.	2
The workstations are equipped with adequate ergo matt?	The workstations equipped with individual ergo matts to stand on during sewing. The placement of the metal foot pedal is under the ergo matt and not allowing operators to stand on the soft and shock-absorbing ergo matt surface.	2
Is the height of the workstation adjustable to the operator and does it function properly?	The sewing worktables are height-adjustable to the needs of operators. Due to missing front extensions of the tables it is hard for operators to maintain the correct position. Bent spine and awkward neck positions during the sewing process.	1
All forward reaches for: - manual work - parts for work - tools are ≤ 46 cm. from the first physical barrier of the workstation	Forward reaches for taking materials for sewing are beyond the limits due to the distance of the material storage shelves above the sewing machine. Materials stored in higher layers require an additional forward stretch.	2
All lateral reaches for: - manual work - parts for work - tools are ≤ 46 cm from the center line from where the operator performs the work	Retrieving the semi-finished products from the previous machine as well as placing the sewn parts laterally with stretching beyond the limits due to the distance of the material storage shelves.	2
Arm height while: - performing work tasks -manipulating parts (retrieval of parts, workflow, etc.) - taking and using tools - pushing and pulling - activation of manual controls or buttons should be in the range of 81.5 - 112 cm from the floor/platform	Retrieving the semi-finished products from the previous machine as well as placing the sewn parts laterally with stretching beyond the limits due to the distance of the material storage shelves.	1
Squeeze/grip force applied to fold, grasp, pull, push, or hold: ≤ 26.7 N.	The measured pinch and grip forces applied in the final operations, especially when sewing leather covers, are greater than the recommended values.	1
Are all control screens, visual controls, visual aids, etc. on overall height: 142.5 - 152.5 cm from the floor/platform	Visual aids for working instructions are placed at inappropriate heights and reading distances.	1
Is glare minimized by screen protectors or positioning of lighting?	Glare on laminated work instructions attached to brackets in the sewing workstations.	4

For the identified opportunities for design improvements of the workstations, an action plan was developed based on the ranked priority (priority number 1 is higher than priority number 4). For certain deviations from workstation design requirements, additional assessment of the risk level with a suitable ergonomic tool were required.

The Rapid Upper Limb Assessment (RULA) ergonomic tool was used to assess the risk of work-related musculoskeletal disorders. Participants were selected based on exclusion and inclusion criteria. Only women older than 25 years of age with a normal BMI and with at least 5 years of work experience were included in the analyses. The work tasks that were observed and analyzed were selected through structured interviews with company health and safety representatives and in relation to ergonomically challenging work activities that in the past contributed to the occurrence of musculoskeletal diseases as well as based on the data obtained from the conducted survey. The results of the Rapid Upper Limb Assessment (RULA) ergonomic tool, conducted through the Tumeke application, are shown in Table 2.

Table 2. Results of the Rapid Upper Limb Assessment (RULA) ergonomic tool

RULA Results	Level of risk	Recommendation	Total number
7/7	High Risk	Investigation and changes are needed immediately	23
7/6	High Risk	Investigation and changes are needed immediately	10
6/6	High Risk	Investigation and changes are needed immediately	7
5/7	High Risk	Investigation and changes are needed immediately	6
5/6	Medium Risk	Investigation and changes are needed immediately	4

The results indicate a significantly elevated risk from:

- upper arms in a position between 45^0 and 90^0 when taking pieces from the upper shelf.
- shoulders raised and rotated when turning part of a cover or sewing plastic components.
- forearms at an angle greater than 100^0 and moved sideways across the midline of the body when guiding material and long components through the sewing machine as well as when turning the cover in the direction of sewing.
- wrists bent up-down more than 15^0 and left-right across the midline of the wrist when guiding multi-layered pieces of cover.
- neck bent more than 20^0 due to the unadjusted height and width of the worktable.
- torso position between 20^0 and 60^0 due to the unadjusted height and width of the worktable and during assembling large covers.
- repetitive movements when assembling many elements of the cover itself (repeated several times per minute).

According to the hierarchy of controls, the priority is to eliminate the identified risk. If this is not possible, an engineering control should be applied to reduce the level of risk. If the risk remains unchanged, then an administrative control must be reviewed and implemented.

These principles were also used in implementing ergonomic improvements, starting with engineering controls such as: design change of the upper shelf forward and bringing the components closer to the work envelope, i.e., within the reach of the employees; design change of the upper shelf in height to reduce the angle of the upper arm when retrieving components at the same time limiting quantities of materials on the upper shelf; effective use of anti-fatigue matt, placing it above the sewing foot pedal; tilting the work table at an angle to take advantage of gravity when sewing heavy leather covers; resetting sewing machines to optimum speed. The remaining risk that could not be reduced with engineering controls was reduced with the following administrative controls: conducted trainings through videos on correct working techniques for continuous sewing; height adjustment control of the sewing tables, introducing breaks and stretching exercises during shift; ergonomically based rotation: creating a rotation schedule in 8 to 12 workstations where the operator can rotate every hour in a standardized and organized way, where the workstations use different body parts and different movements; education by a Doctor of Occupational Medicine; dynamometric measurement of grip

strength at regular time intervals; introduction of a successful test for rapid diagnosis of the carpal tunnel syndrome; introduction of physiotherapeutic treatments for employees who feel work related discomfort; physiotherapy treatments including manual massages as well as electrostimulation and chiropractic.

To verify the implemented ergonomic improvements after 6 months of the implemented controls, repeated Musculoskeletal Discomfort Questionnaires were conducted of a group of employees from the same projects.

The result of the survey of 110 participants shows a 25% reduction in discomfort, while 51% of employees have a positive opinion about the improvements in their workplace.

To quantify the reduction of the level of risk a RULA ergonomic assessment using Tumeke application was repeated. The improvements are visible from the results:

Table 3. Quantify the reduction of the level of risk a RULA ergonomic assessment

RULA Results	Level of risk	Recommendation	Total number
5/6	Medium Risk	Investigation and changes are needed soon	28
4/5	Medium Risk	Investigation and changes are needed soon	51
3/4	Minor Risk	Investigation and changes are possible	19
6/7	High Risk	Investigation and changes are needed immediately	12

CONCLUSION

An increased occurrence of work related musculoskeletal disorders has been identified among sewing operators in automotive seat cover production. The findings have revealed that cumulative exposure to ergonomic risks such as awkward body posture, especially neck and wrist, prolonged standing, use of excessive force, repetitive movements without adequate recovery time, are the main contributors to the increased MSD risk level. The high risk results obtained from the conducted ergonomic assessments imposed the need for a systematic reduction of ergonomic risk factors in order to prevent or reduce the occurrence of work-related musculoskeletal disorders.

Through the implementation of engineering controls on the identified risks and opportunities for improvement, interventions were made in the design of workplaces in the arms of forward and side reach in working envelope, inclination of working table for better wrist angle, standing on anti-fatigue matts, sewing speed optimization and software tools for work balance optimization. From administrative controls stretching exercises were introduced, ergonomically based rotation, training for continuous sewing, training for adjusting the work table to an appropriate height, and a range of other activities. The education of the ergonomic improvement teams regarding the general principles of ergonomic design, the understanding of the limits of muscle loads as well as the risks and causes of musculoskeletal diseases, also made a significant contribution to this improvement project.

The overall result of this paper indicates that the implemented engineering and administrative control measures, based on the obtained risk levels from ergonomic re-assessments, are having a positive impact in reducing MSDs risk level among sewing operators in automotive seat cover production.

For the ergonomic improvement process to be successful, employers must commit fully to integrating ergonomics into the organization. Along with the implementation of ergonomic controls at an early stage, the risks of developing work-related musculoskeletal disorders can be reduced or eliminated.

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