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REDUCTION OF MANUAL HANDLING WITH LOADS AND ACTIVITIES CAUSING MUSCULOSCELETAL DISORDERS IN A SELECTED WORKPLACE

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Abstract

The main aim of the article is to present the results from the research project which was focused on the minimisation of ergonomic risk to the musculoskeletal system. The research was conducted in a company whose core business includes the production; converting and sales of packaging materials. The first section of the article is focused on the theoretical basis of software support in ergonomics. In the second section, the authors' deal with analysis of the current situation in the selected workplace (production of printing forms for rotogravure and flexoprinting) by anthropometric measurements and research conducted in the form of a questionnaire survey. The third part is focused on the presentation of the newly created simulation model in the virtual environment of Tecnomatix Jack software. The final section of the article describes the proposed solutions (organisational and technical).

Key words

Ergonomics, manual handling, physical load, simulation

INTRODUCTION

The evaluation of physical load for the process of manual handling is still in many cases an omitted activity, and enterprises realise its importance only to a minimal extent. Therefore, it is necessary to focus on the minimisation of musculoskeletal disorders (MSDs). The MSDs risk when completing a manual handling task is determined by comparing the force; required to execute the task to estimate the maximum force that would be safe for this person to exert in similar circumstances. For a lifting task; the actual weight that must be lifted is compared to the recommended weight limit for that situation. For pulling; the force required to pull an object can be measured with a force gauge and compared to the recommended maximum pulling forces that can be safely exerted under various circumstances.

There are several tools and methods that can be used to address these issues on two levels. The two levels are defined as primary analysis and expert analysis. Primary analysis uses the basic concepts and practices, whereas expert analysis involves external enterprises; research and educational institutions.

Manual handling and manual work with loads are integral parts of everyday work activities in the selected workplace. The reduction of manual handling with loads and activities causing musculoskeletal disorders can be achieved only by detailed analysis and the proposal of an optimal solution.)

OBJECTIVES AND METHODS

The main objective of the project was to prepare a proposed solution for the reduction of manual handling with loads and activities causing musculoskeletal disorders.

The methods that were used for the purpose of the project are as follows:

- Anthropometric measures – the basic scientific method; which was used for a detailed assessment of the workplace from the perspective of adjustments to the individual abilities and capabilities of employees;
- The completion of a questionnaire (Modified Nordic Questionnaire) – to monitor the effects of selected factors upon the creation of MSDs;
- Statistical evaluation of the measured data – selection of statistically significant factors (evaluated characters) from statistically insignificant;
- The creation and evaluation of a simulation model in a virtual environment – allowing the modelling and simulation of the behaviour of a biomechanical human body model with the objective to improve ergonomics; whether in relation to the working environment; tools; work activities; creation and modification of the virtual environment; sizing and positioning of the biomechanical model of a human and the creation of a simulation of work tasks.)

ACHIEVED RESULTS

From an ergonomic point of view a detailed analysis was performed to improve the current status. Important data from the analysis and summary are presented below.

Anthropometric measures

As a first step, anthropometric measurements of basic human parameters were made. The anthropometric measures were carried out using the method devised by Martin and Saller (1957) [4]. We performed the measurements on the side of each individual's preferred dominant hand. The anthropometric parameters were measured in the reference position (standing upright – the measured person had his heels and spine against the back wall [basis dorsalis] and head was in the so called Frankfurt horizontal). The results from anthropometric measurements subsequently served as the basis for creating a biomechanical model of a human in a virtual environment and for processing of data for assessing the impact of the unmodifiable risk factors and their direct effect on the creation of MSDs.

Questionnaire survey

A questionnaire survey was used to determine the level of ergonomic implementation. The initial analysis served to obtain data which was then discussed with representatives from the company and which enabled the evaluation of the epidemiologic system EPI Info for the selection of statistically significant factors from statistically insignificant. By using this statistical evaluation, we were able to define the problematic areas from the perspective of ergonomics. From the output, a database was created. The database served as a basis for the creation of the proposed solutions. The questionnaire was distributed to individuals at the selected workplace, and the Modified Nordic Questionnaire typology was chosen. Data collection was carried out on a sample of 26 employees. The total return of completed questionnaires was 25 – 95.16 %. Prior to the commencement of the survey questionnaire we explained to the employees the purpose of ergonomic analysis and the method of data collection).

In the following three tables we can see the selected results from the conducted analysis.

Tab. 1 Occurrence of MSDs

MSDs	**Frequency**	**%**	**95 % Confidence limit**
With MSDs	**23**	92.00	73.97 % - 99.02 %
Without MSDs	2	8.00	0.98 % - 26.03 %
Total	25	**100.00 %**	

Tab. 2 Visit to a doctor in the last year as a consequence of MSDs

Visit to a doctor in the last year	**Frequency**	**%**	**95 % Confidence limit**
Visit to a doctor was needed	9	36.00	17.97 % - 57.48 %
Visit to a doctor wasn´t needed	16	64.00	42.52 % - 82.03 %
Total	25	**100.00 %**	

The results from Tab. 1 show that 92.00 % of employees had a problem with MSDs. From Tab. 2 we can see that 36.00 % of employees had to visit a doctor because of occurrence of MSDs.

Tab. 3 Localisation of MSDs according to intensity

Localisation of MSDs	**Men in the selected workplace** (n = 25)	
	% with symptoms	**% visit of doctor**
Neck	32.00 %	8.00 %
Spine (*Thoracic region*)	32.00 %	0.00 %
Back (*Lumbar - sacrum region*)	84.00 %	24.00 %
Shoulders	32.00 %	4.00 %
Elbows	24.00 %	4.00 %
Hands/Wrists	48.00 %	8.00 %
Hips/femur	16.00 %	0.00 %
Knees	52.00 %	4.00 %
Ankles/Feet	36.00 %	4.00 %

The results shown in Tab. 3 indicate that 84% of respondents had problems in the Lumbar – sacrum region and 32 % had problems in the Thoracic region. The results from Tab. 3 show that most respondents had to visit a doctor as a consequence of problems with the Lumbar – sacrum region.

We can see in Tab. 4 that repetitive work (Monotonous); a high working pace and handling of heavy material; have the largest impact upon difficulties with the musculoskeletal systems of the respondents. A case control group was used for the evaluation of modifiable factors of work and the work environment. The frequency of exposition between groups with difficulties and disorders related to the work and without them was compared. Then the Odds ratio (OR); respectively the proportion of probability was calculated. The results from the questionnaire survey demonstrated the need for corrective measures in relation to minimising the above-defined factors.

Tab. 4 Evaluation of the total negative influence of modifiable factors of work and the work environment

MODIFIABLE FACTORS OF WORKING CONDITIONS	**Epidemiologic indicators**		**Statistic significance of differences**	**(%) of risk**
	Odds Ratio (OR)	**95 % confidential limits for (OR)**		
Repetitive work (Monotonous)	–	–	–	92.00 %
High work pace	–	–	–	92.00 %
Handling small objects	–	–	–	56.00 %
Insufficient breaks(Time for relaxation)	–	–	–	68.00 %
Forced working positions	–	–	–	84.00 %
Long persistence in the working position	–	–	–	88.00 %
Excessive bending forward and rotating trunk	–	–	–	88.00 %
Working at the limit of physical and psychical possibilities	–	–	–	84.00 %
Work above head level	–	–	–	60.00 %
Microclimatic conditions	–	–	–	80.00 %
Work after injury and during sickness	–	–	–	76.00 %
Handling heavy materials (weight of load)	–	–	–	92.00 %
Quality of work organisation	–	–	–	80.00 %
Quality of tools	–	–	–	84.00 %
Quality of instructions and training	–	–	–	72.00 %

SIMULATION MODEL

For the purpose of the project, the Tecnomatix Process Simulate and Tecnomatix Jack 8.2 were used to create the work environment; machinery and tools. In Process Simulate, basic cad objects were created including stands for cylinders, cylinders, adapter for cylinders, pneumatic wrench, hammer, “finalization hook”, and machines for the chemical processing of cylinders, which are shown on Fig. 1.

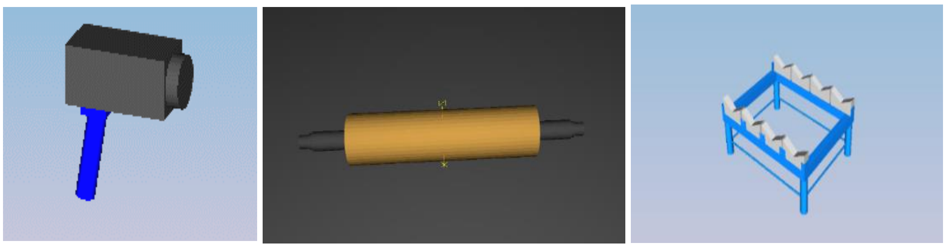

Fig. 1 *Example of created tools and elements for the selected workplace (source: own)*

In the virtual environment of Tecnomatix Jack 8.2, the work environment that is shown in Fig. 2 was created.

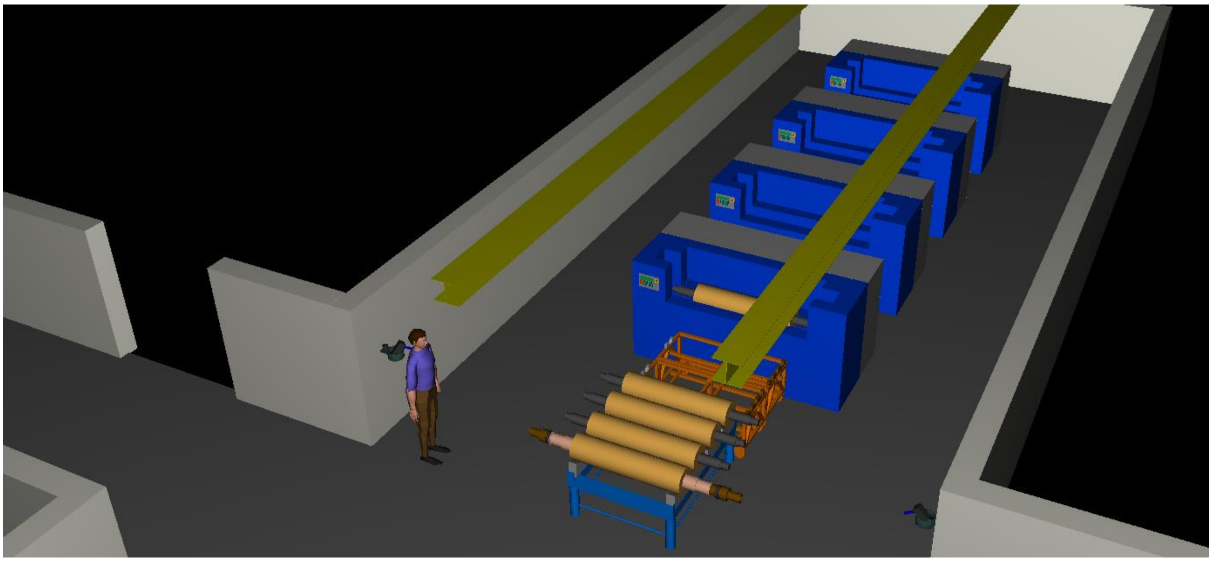

Fig. 2 *Work environment in virtual reality (source: own)*

PROPOSED SOLUTION

The solutions were based on results from the conducted analysis and focused on the following areas:

- Elimination of excessive bending forward and rotation of the trunk;
- Elimination of incorrect manipulation with the pneumatic wrench;
- Minimisation of walking distance;
- Creation of visual standards for employees.

Organizational solution

For elimination of the current inappropriate work habits of employees we proposed the application of the following adjustments for lifting and putting a load on the floor:

- Stand up with the load as close to your body as possible;
- Stand up with the load directly;
- Find the equilibrium point and keep your legs slightly bent;
- Squat down, legs bent at the knees;
- Hold spine in an upright position;
- Breathe and hold breath;
- Draw down abdomen;
- Get into the straight position through the legs with upright spine;
- Lift smoothly and keep the lifting under control.

Inappropriate and appropriate manipulation with a load is shown in Fig. 3 with illustration of the loads effect upon the spine.

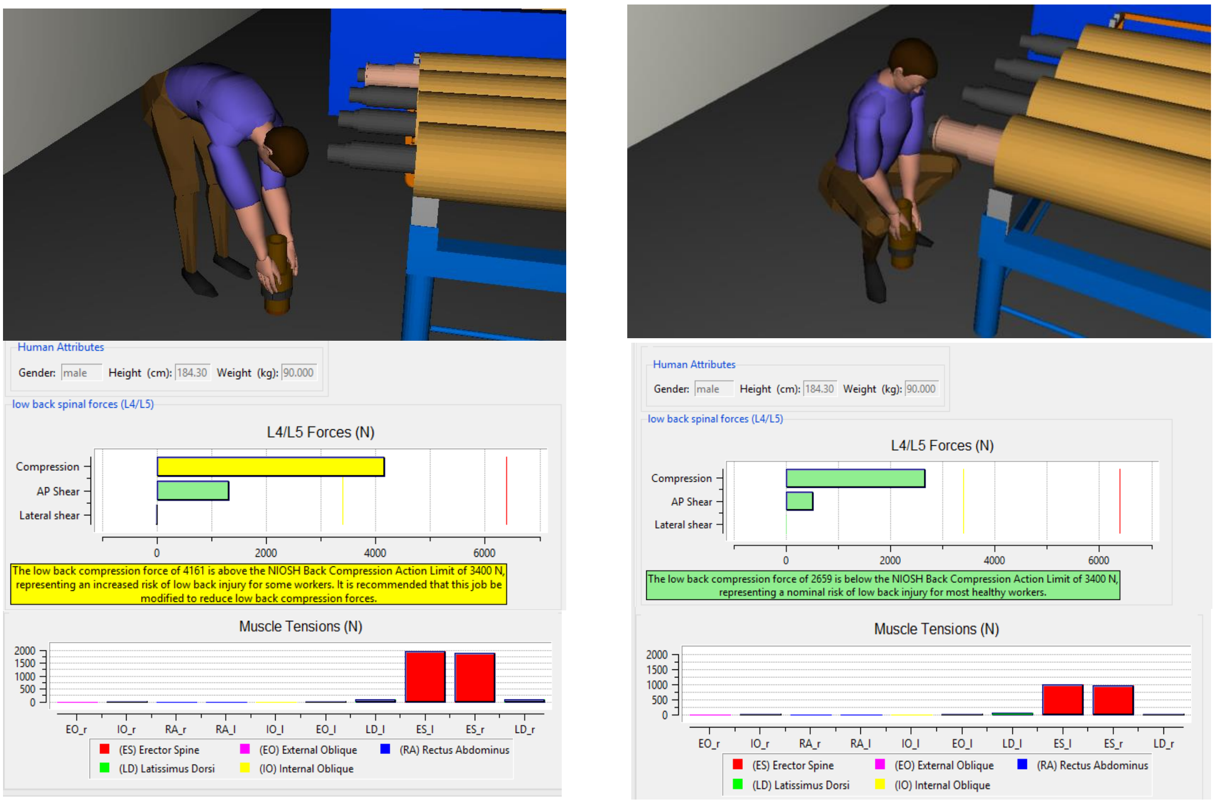

Fig. 3 *Definition of appropriate work posture during the manipulation with load (source: own)*

The overall effect of correctly executed manual handling will result in minimising the effect of compression and shear forces acting on the L4/L5 vertebral joint and also to decrease the muscle activity level of the erector spinae. Reduction of compression and shear forces between vertebral joints can be approximately 1502 N, which means a decrease of 37 %. The activity level of erector spinae can be reduced by 1000 N, which means a decrease of 50 %.

Technical solution

The proposed technical solution was achieved in two stages. The first stage was represented by changing of the pneumatic wrench position, which was a distance 2.8 m from the stands for storing cylinders. The location of the pneumatic wrench caused excessive walking and it represented a restriction for the workplace.

Another technical solution for the minimisation of manual handling with activities causing MSDs was the creation of a manipulation truck from a light alloy (Fig. 4) with basic dimensions 87x45x65 cm (the height was finally set to 87 after consultation with the plant manager).

The construction of the manipulation truck had two basic effects:

- Reduction of the burden of manual handling - removing the need for improper handling of loads; respectively eliminating the need for forward bending;
- Creation of a defined location for adapters as well as for the hammer and “finalization hook”, which were placed away from cylinders on to the table, rack or another truck.

Lastly, the technical solution focusing on the elimination of manual handling with load was to increase the size of the stands for cylinders by 13 cm, as can be seen at Fig. 4.

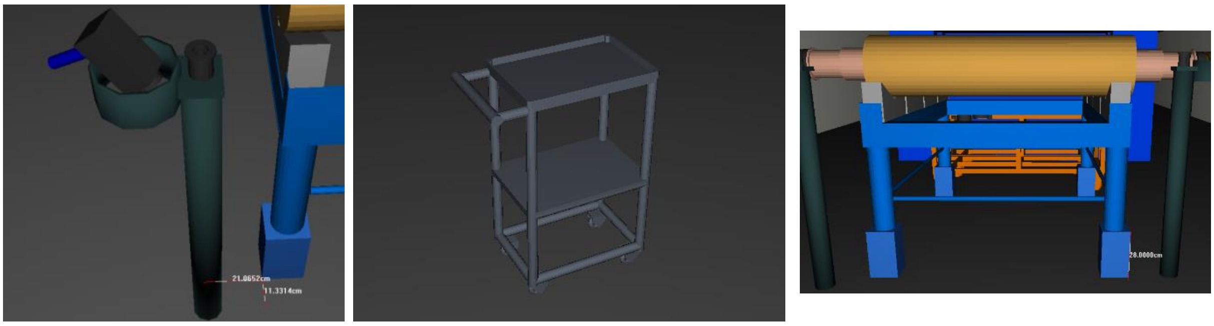

Fig. 4 *A manipulation truck and an example of a change of stand height for cylinders due to the handling plane (source: own)*

As we can see in Fig. 5, after the application of technical solutions, the results from the conducted Lower Back Analysis show a rapid reduction of physical load. The results show also the rectification of work posture.

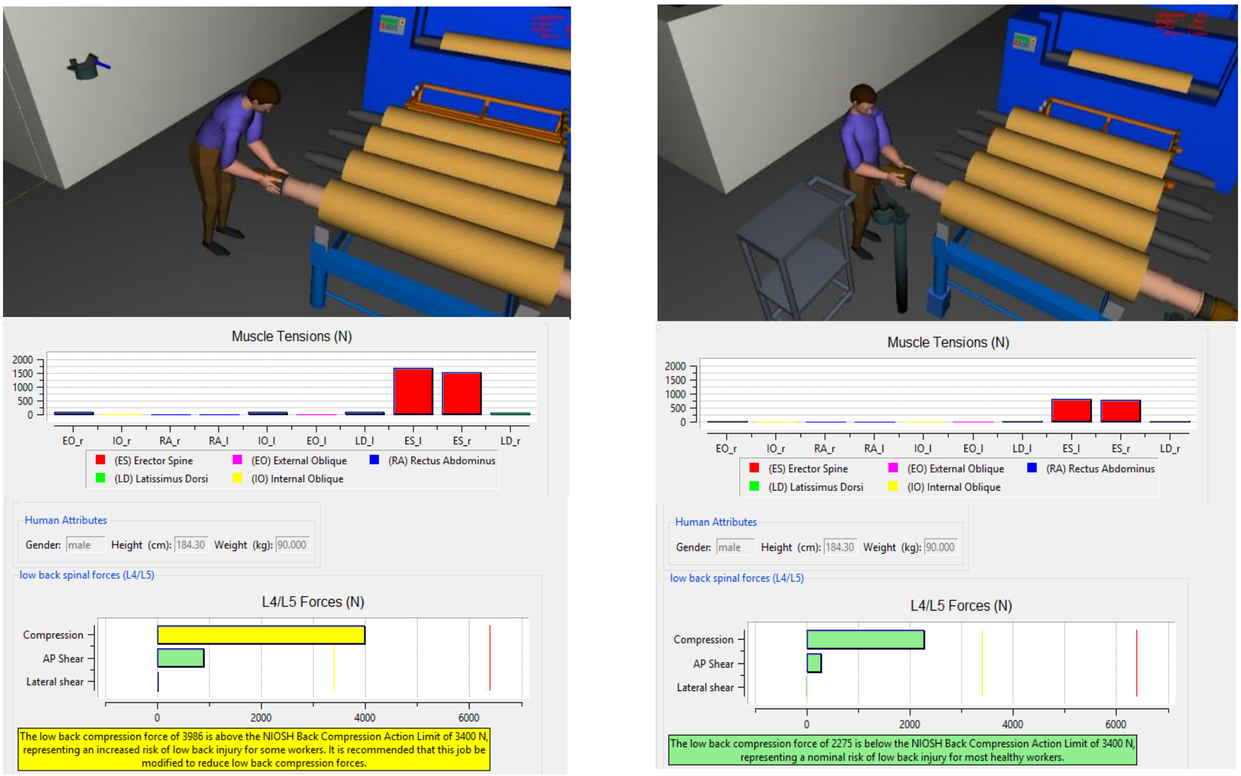

Fig. 5 *A comparison of the original situation with the proposed solutions (source: own)*

The overall effect of the technical solution will result in minimising the impact of compression and shear forces acting on the L4/L5 vertebral joint and also to decrease the muscle activity level of the erector spinae. Reduction of the influence of compression and shear forces between vertebral joint can be approximately by 1711 N, which means a decrease of 43 %. The activity level of the erector spinae can be reduced by 750 N, which means a decrease of 50 %.

CONCLUSION

The main aim of the article was to show the results from the conducted project, which was focused on the creation of a solution for the reduction of manual handling with loads and activities causing MSDs in the selected company. We have applied different types of analytical tools for achieving this aim. The main tools were anthropometrical measures, questionnaire survey and also simulations in VR. Selected benefits from the proposed solutions are mentioned below:

- Reduction of manual handling with loads;
- Reduction of activities causing MSDs;
- Reduction of the influence of compression and shear forces between vertebral joint;
- Reduction of the activity level of erector spinae;
- Reduction of accidents at work;
- Reduction of illnesses from long-term, excessive and unilateral overload;
- Better efficiency of work operations;
- Higher involvement of employees in the process of improvement of the work environment;
- Better efficiency of human work by better quality of work environment;
- Improvement of conditions of work and quality of work life;
- Better manipulation with a load.

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