Comparison of the Results of Various Methodologies for Evaluating the Ergonomic Workload of a Worker During the Performance of a Work Task

Naqib Daneshjo [1], Albert Mareš [2], Peter Malega [2], Jakub Kóňa [1], Michal Jankovič [1]

[1] *University of Economics in Bratislava, Faculty of Commerce, Dolonozemská cesta 1, 852 35 Bratislava 5, Slovak Republic*
[2] *Technical university of Kosice, Faculty of Mechanical Engineering, Letná 9, 042 00 Košice, Slovak Republic*

***Abstract* – The article describes the analysis of a work operation on a virtual model of a production workplace. In order for the virtual workplace to correspond to reality as much as possible, 3D scanning was used to create a digital model of the part that the worker is manipulating. Tecnomatix Jack software was used to create a virtual workplace model and simulate worker movements. The operation was analyzed by four different methods, namely RULA analysis, OWAS analysis, Comfort Assessment analysis and Lower Back analysis. The results of all analyzes for the same task show that the job is not properly designed and it is necessary to propose workplace changes to eliminate the identified problems.**

***Keywords* – ergonomics, operator, workplace, Tecnomatix Jack, RULA, OWAS, LBA, CA.**

1. Introduction

As the requirements for the quality of products and services are constantly growing, the demands on the execution of work also increase. Modern production is influenced by a number of factors, whether production, logistics, organization and many others [3], [9]. All of them have the task of improving the final product more and more so that it is as attractive as possible for the customer. Each of these requirements is closely linked to the worker who is in close contact with all the attributes contributing to production [2], [8]. The employee is responsible for quality performance of the required work in a predetermined time under precise conditions. In order to perform his role as well as possible, working conditions must be adapted so that the worker can perform as well as possible, without affecting his health, either in the short term or in the long term. Momentary inattention, ie the failure of the human factor, can lead to serious injuries, which can also have long-term consequences [3], [5]. Since human error cannot be ruled out, it is necessary to try to prevent it by adapting and securing the workplace. This can be achieved by ergonomic analyzes of the operator during work. These analyzes help to determine the correct movement of the worker around the workplace and to perform the necessary actions in the correct way [7], [13]. They further improve comfort at work and this reduces the likelihood of injury. However, they have the greatest benefit in the area of preventing injuries from long-term and stereotypical loading of certain parts of the body [6]. These health problems tend to be mostly persistent, so any seemingly small thing that can prevent a serious health problem is important.

The digital CAD model of the analyzed operation was created in the SolidWorks application environment [12]. The CAD model of the part was created using a Faro hand-held scanner, equipped with a laser scanning head, which was used to scan the real component. This method was chosen in order to maintain the exact dimensions of the part and its

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Corresponding author: Naqib Daneshjo,
Faculty of Commerce of the University of Economics in Bratislava, 852 35 Bratislava 5, Slovak Republic.
Email: daneshjo47@gmail.com

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shape. Some elements of the part were then remodeled in the SolidWorks environment [11], [14].

The finished model of the workplace with the component was subsequently transferred to the Tecnomatix software environment, where a simulation and animation of the operators' movements on the selected work section was created [1], [4]. Based on the performed analyzes, problematic actions were identified and subsequently improvements were proposed to eliminate these problems. An analysis of the modified workplace was re-performed to verify that the improvement had been achieved.

2. Creating Part Model

As already mentioned, a CAD part model was created using a 3D scanner. During the scan itself, the reflected laser beams create a cloud of dots, which together form the geometric shape of the column. The software measures the distance between the point of reflection of the beam and its transmission, which allows each point to be defined individually in space. It also measures and stores distances between all adjacent points that form an area when connected. Because it is not possible to scan an entire part at once, the total scan is made up of several sub-scans. The individual scans are color-coded (Figure 1) for better orientation when creating the scan. On the left in the picture you can see the tree structure in which all partial scans are. This allows you to alter or completely delete any scan: for example, unwanted column rack scans, or erroneous scans caused by e.g. by moving the scanned part, etc.

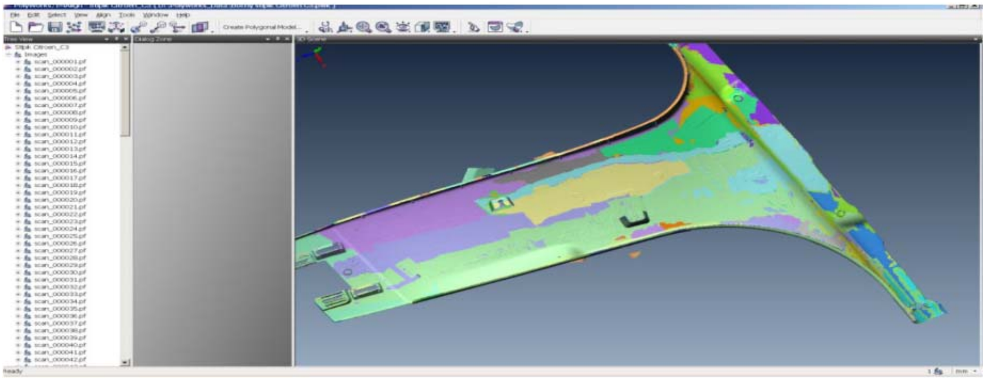

Figure 1. Color separation of individually subscans

The individual sub-scans overlap at the borders. Points were then added along the area boundaries at certain distances so that, after connecting them with curves, areas were created that corresponded as closely as possible to the clouds of the scan points (Figure 2). Subsequently, the boundary curves were merged to reduce the number of areas to a minimum. The result is smoother transitions between surfaces and increased accuracy in describing the point cloud. From the created surfaces, a volume model was finally created by adding thickness to the surface.

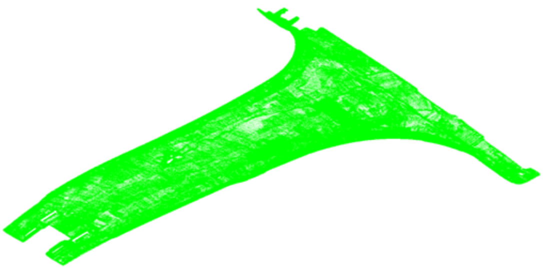

Figure 2. Modified point cloud-ready to create surfaces

Since the component also contains articulated geometric shapes such as protrusions for holding the clips, which serve to clamp the part to the rest of the body, in which there are cavities that cannot be scanned, thus creating holes in the scans. In this case, the laser could not penetrate through the small holes inside the scanned area and, even if it penetrated, it could not bounce back to the scan head. In another case, although the laser bounced off the inner and very small jagged parts of the part, it produced inaccurate scans that mixed with each other to create very inaccurate surfaces. These errors were mainly due to limited access for scanning at the correct angle and at the correct distance from the part surface. In both cases, the holes were then manually patched and the missing elements were modeled. The resulting part model is shown in the figure below (Figure 3).

Figure 3. Final part model

3. Creating a Simulation Model

Tecnomatix Jack software was chosen to perform the analyzes. CAD models of the part and the workplace were imported into the Tecnomatix application environment and subsequently a simulation of the worker's work was created.

As all the work is done standing, the analyzes have focused mainly on assessing the load on the torso, back and limbs. In this case, the angles for evaluating the position of the fuselage are related to the vertical plane. The position of the head and neck is evaluated from the point of view. Two points are used to evaluate the load on the upper limbs. The outer part of the collarbone and the elbow joint.

Upper limb restraint is defined as the angle at which the limb animals in the working position relative to the neutral position of the arm. The neutral position is when the hand is free hanging near the body.

When working with parts, the most important parameters are the weight of the load, its shape and stability. Furthermore, the possibilities of gripping the selected part are very important. The vertical plane rule applies when handling loads. This rule states that the center of gravity of the body should be as close to the body as possible. Therefore, the greater the distance between the object's center of gravity and the worker's center of gravity, the greater forces must be expended to manipulate it. The so-called horizontal (horizontal rule) also applies. He talks about the fact that when carrying loads over a shorter distance, it is necessary to carry the objects at the same working height [3], [10].

After assembling a complete workplace in the Tecnomatix environment containing all the necessary machines, tools and fixtures, a worker model was inserted into the workplace. This manikin represents the worker with his real dimensions and ranges of movement. Subsequently, the movements of the worker in the workplace, including the manipulation of the part, were defined. The part was placed in the exact positions as it is in reality (Figure 4).

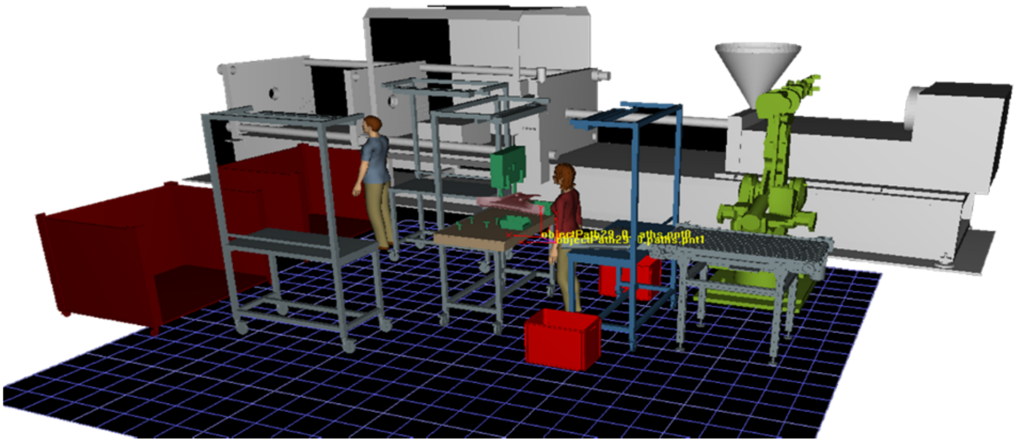

Figure 4. Created workplace model

4. Application of Selected Analyzes in Individual Work Tasks

4.1. Rapid Upper Limb Assessment (RULA) analysis:

Roll is a tool for analyzing the employee's attitude when performing work tasks. It assesses the positional load on the whole body, with emphasis on the risk areas of the neck, torso, back and limbs. The result is a score that informs you to what extent the selected job position is burdensome. The selected scale then determines whether this position is acceptable or needs to be changed.

It is possible to analyze the whole work operation, but due to the scope of the article, only selected positions will be shown. Positions were identified which were assumed to be problematic and to cause excessive workload. The position for placing the part in the transport box was chosen for the analysis (Figure 5).

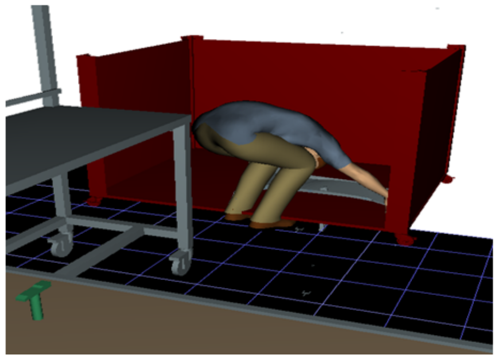

Figure 5. Storing the part in the transport box

Conditions such as forces and loads resulting from the weight of the part, muscle loading conditions, etc. were defined for the given work operation. (Figure 6)

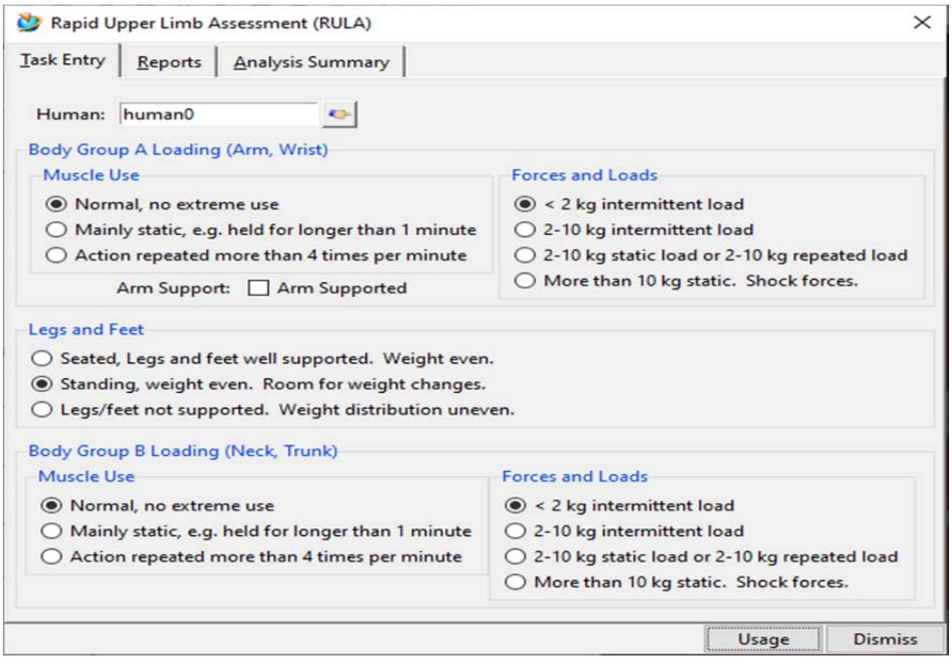

Figure 6. Parameter selection for RULA analysis

The resulting score of this activity is 7 (Figure 7). This score is unacceptable and requires immediate correction.

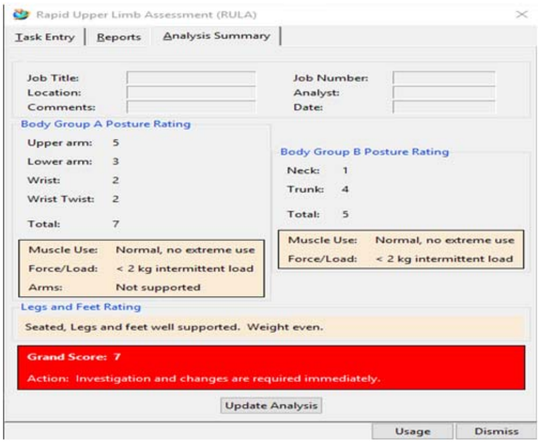

Figure 7. Storing the part in the transport box

4.2. Ovako Working posture Analysis System (OWAS)

The ergonomic OWAS method is used to examine occupational risk factors that relate to muscles, bones and other important influencing factors on a worker. OWAS is based on assumptions that should generally not occur during work:

- Subjective work discomfort.
- Inefficient strain on the muscles.
- Improper loading of all parts of the body.

This method applies the selected work positions to the tested work activity and derives the results. Figure 8 shows the combinations of working positions.

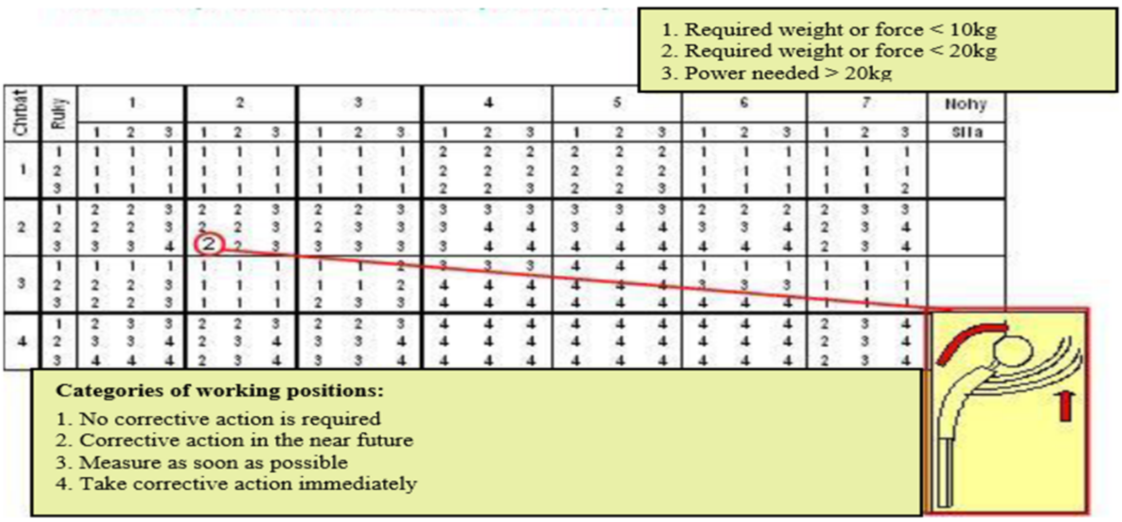

Figure 8. Shows the combinations of working positions

For the same work position as in the RULA analysis, the results of the OWAS analysis (Figure 9) also show an unacceptable condition that requires immediate remediation. The OWAS analysis shows the highest degree of risk that can be achieved.

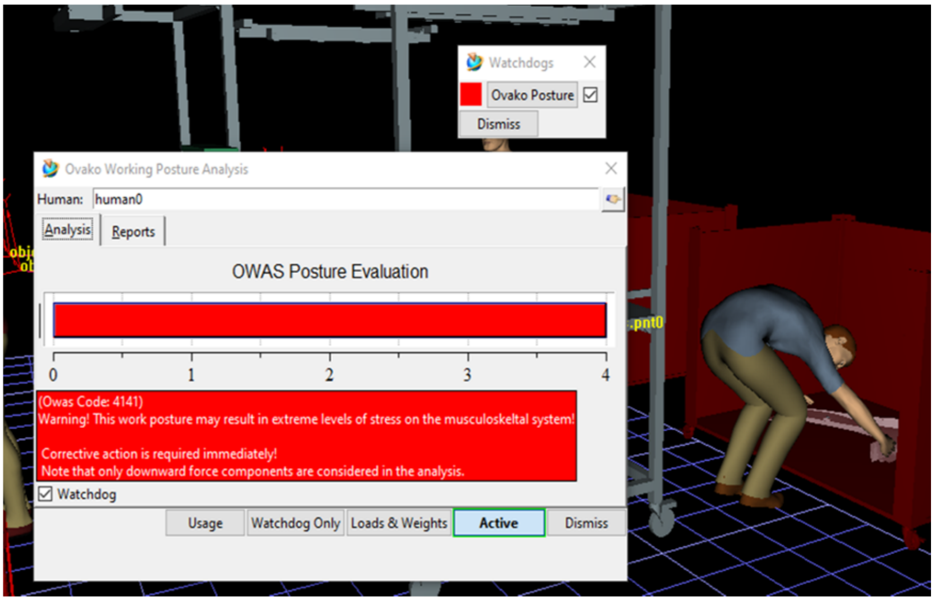

Figure 9. Display of OWAS analysis results

4.3. Comfort Assessement Analysis (CA)

It is a tool for assessing and evaluating comfort. Can determine if the worker is working in the optimal position. During the work process, it displays in the dialog window the current state of comfort of individual parts of the body, ie the degree of their load. Evaluation according to different methodologies is available (Porter, Krist, Grandjean, Rebiffe and Dreyfuss 2D and 3D). It is possible to stop such a course in any position and thus achieve the necessary results. Assessment tool:

- Predicts whether a given human model is in a comfortable position.
- Dynamically displays the comfort range.
- Allows you to customize or create your own comfort ranges for each joint.

We can see results of Comfort assessment according to Dreyfuss 3D in Figure 10.

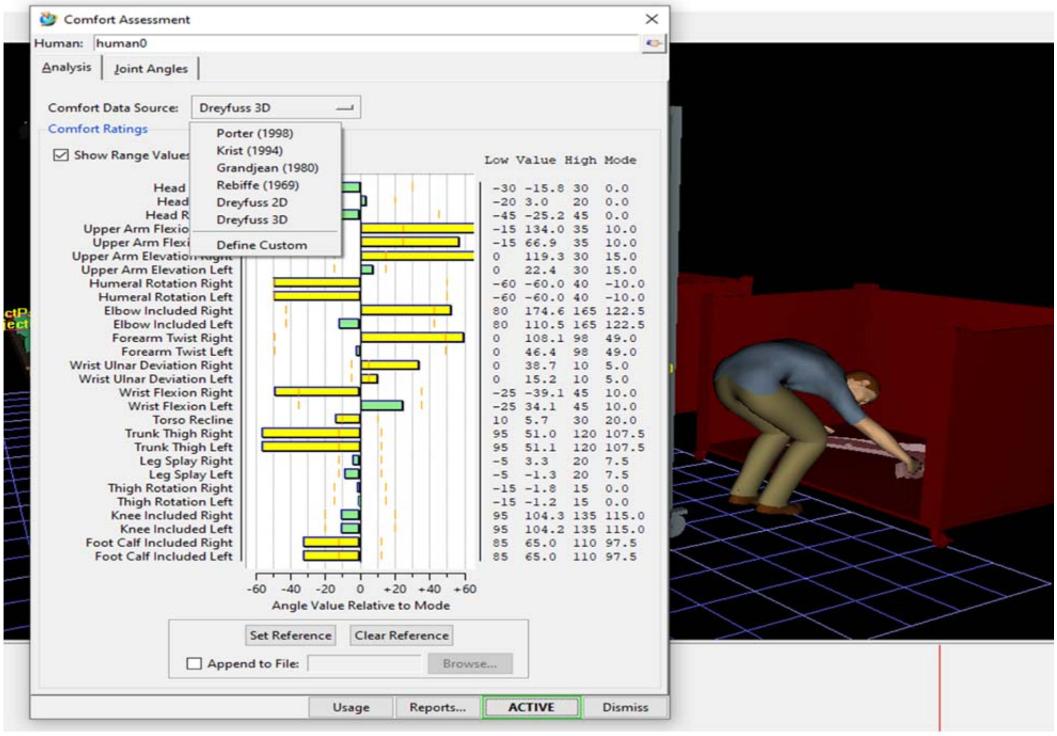

Figure 10. Results of the Comfort assessment

The results in this analysis are acceptable for some parts of the body (green) but not for some (yellow).

4.4. Lower Back Analysis (LBA)

L4 / L5 vertebral compression analysis tool that helps to evaluate the back forces acting on the spine. The tool calculates and displays the compression and shear forces on the L4 / L5 vertebral disc, and compares them with the NIOSH recommended and allowable values. The results of the LBA analysis can be used to design or modify manual tasks to minimize the risk of lower back injuries and to comply with NIOSH guidelines. Results of an LBA analysis for the operation of storing a part in a shipping box (Figure 11).

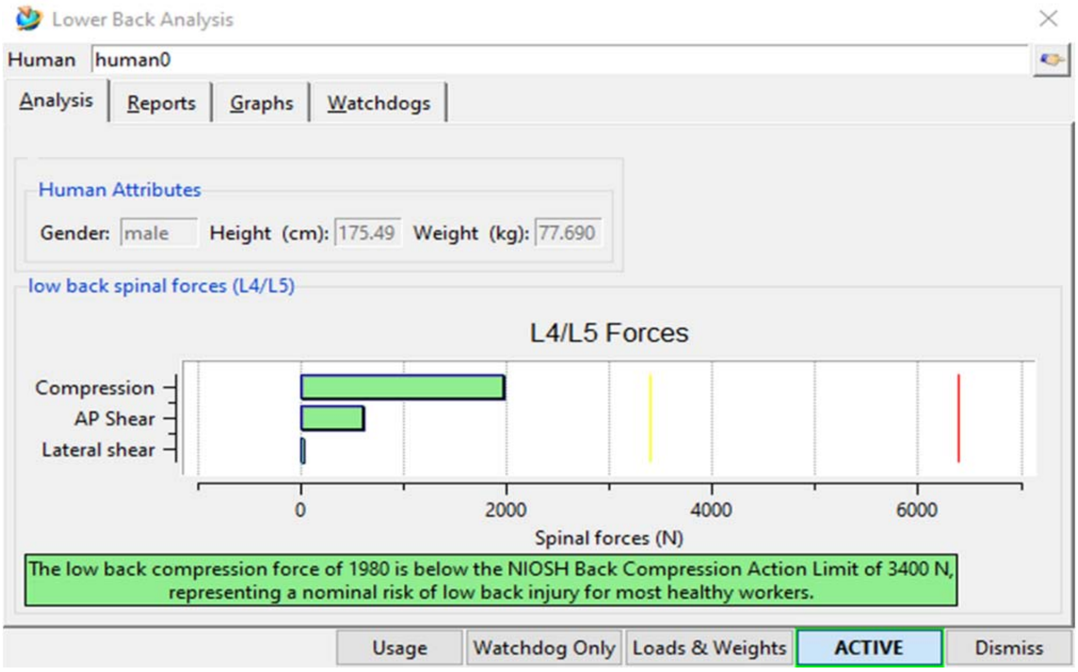

Figure 11. Lower Back Analysis (LBA) – Analysis Tab showing forces

Figure 12 show the Lower Back Analysis (LBA) with graphs for forces, moments and muscle tensions.

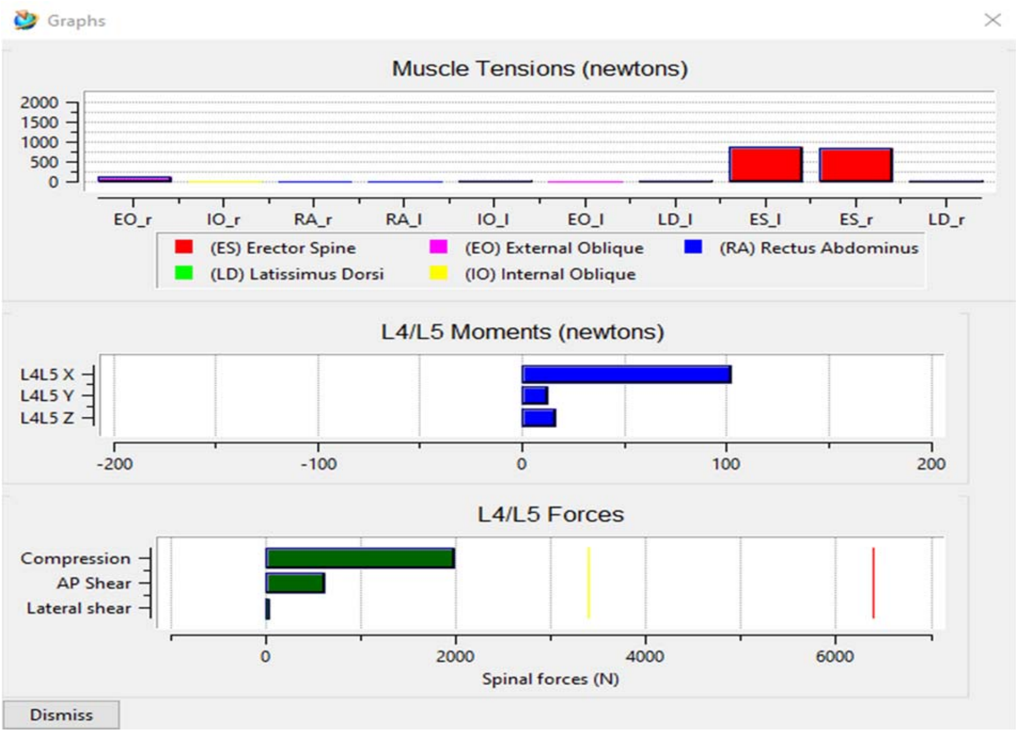

Figure 12. Lower Back Analysis (LBA) with graphs for forces, moments and muscle tensions

From the above results, it can be seen that the maximum permissible load is not exceeded in a given activity, but as far as the muscular tension of the body is concerned, these are considerably stressed.

5. Conclusion

Virtual workstations allow you to simulate and analyze activities and eliminate potential problems even before a real workstation is created. It is possible to analyze all aspects of the workplace, from tools, equipment, through components to manual human activity. There is a large number of analyzes available. If we focus on the analysis of the workload, a number of tools are also available. The question is which tools to use. In general, if an activity is extremely burdensome for the organism, it should not happen that some analysis evaluates the activity as unacceptable and other as unproblematic. Four analyzes were used to analyze the load handling operation: RULA, OWAS, CA and LBA. All analyzes have shown that the analyzed operation is not properly designed and it is necessary to make changes in the workplace in the future to eliminate these problem areas.

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