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COMPARISON OF PEN-AND-PAPER BASED AND DIGITAL HUMAN MODEL BASED ERGONOMIC RISK ASSESSMENTS – A CASE STUDY ON AN INDUSTRIAL WORKPLACE

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Abstract: *Usage of various software for ergonomics is more and more prevalent among researchers and ergonomists, which can be useful in ergonomic risk assessment and anthropometric design. Many kinds of research can be found on the subject; however, pen-and-paper and the software analysis are rarely compared, and the differences are rarely presented. In our research, a comparison was made between the pen-and-paper and the software -based risk assessment methods using RULA and OWAS. The results were similar in both cases, RULA and OWAS gave the same score for the examined workflow, however, practical issues appeared.*
Key words: *Ergonomic risk assessment, Software for ergonomics, RULA, OWAS, pen-and- paper methods, ViveLab.*

1. INTRODUCTION

Ergonomic risk assessment and employee safety are more important these days than before.

Software for ergonomics are nowadays more widespread among researchers and ergonomists. They can be used for anthropometric design (fit tests, reachability analysis, etc.), and ergonomic risk assessment [1]. The most known applications are, e.g., evaluating manufacturing processes [2], and various fields of human-machine interaction, like vehicle design [3]. There are different kinds of ergonomic software available on the market.

In our research with the collaboration of a company, we selected four assembly workplaces for evaluation. This paper presents the analysis of that workplace where the most significant ergonomic risk was identified, caused by medium heavy work pieces and the elevations. The main goal was to make a risk assessment for the workflows. This can be achieved by relatively simple pen-and-paper methods, however, we had the opportunity to use a software for that purpose. Therefore, a comparison was able to carry out between the pen-and-paper and the software -based risk assessment methods. Thus, we can evaluate the workplaces and see whether there is a difference between the two solutions as well.

2. BACKGROUND

2.1 Industrial Workplace Ergonomics

Human Factors / Ergonomics (HFE) in the industry can increase efficiency and in the long term can keep costs low. One of the main jobs of HFE is to keep workers health and safe. An ergonomically not optimal workstation will increase work-related Musculoskeletal Diseases (MSD).

To prevent this, HFE mainly uses risk assessment methods. The creation of these methods is guided mostly by standards that were written by health professionals of work-related MSD and other injuries such as Repetitive Strain Injury (RSI) and Cumulative Trauma Disorder (CTD).

To increase the accuracy of the data, workers during their tasks are usually recorded with multiple video cameras. It has a twofold advantage over direct observation.

2.2 Pen-and-Paper Ergonomic Risk Assessment Methods

In the case of ergonomic risk, we are talking about the probability that a specific element of the Human–Machine–Environment system is damaged by the interaction between the machine and the user. The assessment of ergonomic risks calculates or estimates values of these risks by various methods. The main result shows how fast it is necessary to take action in the workplace [4].

Several methods have been used to evaluate these ergonomic risks. For example RULA [5], REBA [6], MAC [7], JSI [8], OWAS[9], NASA – OB [10], CERA [11].

Each method differs slightly from the others, so their results may be different. Some methods are rigorous, and others are too tolerant of bad postures. With the help of these methods, we can prevent first musculoskeletal disorders.

Traditional pen-and-paper (aka paper-and-pencil) techniques have been transferred to computer environments as technology evolved, making evaluation easier; however, they remained based on the above-mentioned estimation methods.

2.3 Digital Human Modeling

Nowadays, all engineers are expected to learn and use Computer-Aided Design (CAD) modelling. In connection with this, Digital Human Modelling (DHM) has also been developing and started to play an essential role in the use of ergonomic methods. Computer-aided ergonomic methods, that allow us to set accurate angle values for the human model and obtain more accurate results, have been developed. Here, we mention only a few software which are currently used, e.g., ViveLab, Jack, RAMSIS, SAMMIE, DELMIA, Anybody, SANTOS, IMMA [12-14].

In this article, usability tests of two software are presented along with the early results of the research. First, a cloud-based software, ViveLab [12] was chosen, because it is a new, Hungarian software with notable features, and it was easily accessible for us. It is primarily used for risk assessment of industrial workplaces, ergonomic evaluation of products, reachability tests, and path reviews with spaghetti diagrams.

3. METHODS AND TOOLS

During our research, more methods and tools were used. In the factory, two cameras recorded the workflow from different angles. After the observation, we made an interview with the participants. For evaluation with DHM we chose ViveLab software, has a very developed user interface (easy to use). As risk assessment methods we chose RULA and OWAS, because the workflow is relatively short and repetitive, and ViveLab has an implemented version of these two methods. We also examined the workflow with ISO11226 standard with the help of ViveLab, however this cannot be used for a comparison.

3.1 ViveLab

ViveLab is a DHM-based software for ergonomic analysis. The software was released in 2015. It is a cloud-based software, which is one of its main advantages. It means the shared model spaces (so-called “virtual labs” or only “labs”) can be available from all countries, only a utility software, Citrix Receiver must be installed. Anyone can register on the webpage [14] and get a one-hour trial license.

After login, we can create labs, and work with coworkers in the same lab at the same time. The built-in human model has various databases of accurate body dimensions. We can adjust the percentile, age, somatotype, and acceleration of our human mannequin. The parameter of acceleration means we can adjust the birth year of the human, since, over the decades, the later they are born, the higher they will be. There is an opportunity for import CAD models, Xsens motion capture file, and we can create our animation manually as well. The software includes three implemented risk assessment methods (RULA, OWAS, NASA-OBI), two implemented standards (ISO 11226, EN 1005-4), and two other analysis techniques (reachability zone, spaghetti diagram). After analyzing the human motion and postures, we can generate risk assessment documents and query statistics.

3.2 RULA

The Rapid Upper Limb Assessment (RULA) [5] is a test method for ergonomic examination of the workplace based on MSD reports. Although its name refers to the evaluation of the upper limb, the method takes into account the position of the legs and also examines the biomechanical and postural load on the whole body by a more detailed analysis of the upper limbs, neck and torso. It is a worthy method for ergonomic examination of sedentary work, such as computer workstations. [15] [16]

RULA scores indicate the importance of actions to reduce the risk of MSD. At the end, we get information on the importance of further investigation and how quickly the workplace needs to be changed. The method evaluates postural stress at a specific point in the work cycle. One has to evaluate the riskiest posture. The riskiest posture can be selected based on the duration of the posture (i.e. longest posture) or the degree of posture discomfort (i.e. posture). In the case of a long work cycle, it is worth examining the posture at regular intervals. However, it is crucial to consider the proportion of time spent in the posture.

3.3 OWAS

OWAS stands for Ovako Working Posture Assessment System. The OWAS valuation method was developed in Finland in 1973 by Ovako Oy, a steel company, to determine the workload for the repair of cast iron furnaces. The method identifies the most common postures in the workplace with respect to the back, arms and legs and takes into account the weight of the load. A combination of these can identify 252 possible postures. [9]

The main difference from the other methods is that the posture and the weight to be lifted have to be observed at several moments of the work process being examined. It is called method sampling, which usually ranges from 30 to 60 seconds. At each sampling, coding should be done based on the position of the observed back, arms and legs, and finally, the weight raised [17] [18].

The four-digit code consists of the position of the back (first digit), the position of the arms (second digit), the position of the legs (third digit), and the load (fourth digit).

3.4 ISO 11226 standard

ISO 11226 was established in 2000. The purpose of the International Standard is to add critical values and requirements to the loads caused by static (≥4s) postures and thereby reduce the resulting risks. Fatigue and pain during work can result from poor working conditions and poor postures. Bad movements that cause musculoskeletal disorders can lead to dangerous situations and increase risk. [19]

The standard assigns specific angles to different body parts, which form the basis for requirements and recommendations. It provides a kind of guidance to the designer during the design process. The standard applies to the adult population, including the working age population.

3.5 Collaborated Company

This research was supported by OBO Bettermann Hungary Ltd. The assessed cases can be considered as typical; therefore, the experiences and results of this case study can be considered as a basis of generalization.

OBO Bettermann Hungary Ltd. mainly produces metal or polymer fastenings. Products include connection & fastening systems, transient & lightning protection systems, cable support systems, fire protection systems, cable routing systems, etc.

OBO today produces over 30,0000 articles with 4000 employees and achieves an annual turnover level of over 550 million euros with more than 40 subsidiary companies worldwide.

In this paper, the results of assessment of one workplace are presented.

3.6 Participants

In the chosen workplace, two employees had worked. We have done a few interviews with the workers to have some expression regarding the user experiences during the observation. We also collected demographic and anthropometric data (age, education, gender, height) and details regarding the working experiences at the current workstation. We also asked the employees regarding their health condition, for instance, potential health problems caused by the assembly process.

3.7 Work Cycle

The worker took the hooks into his hands, then removed a workpiece from the pallet and hung two hooks on each end. He then removed the next workpiece from the pallet and hung it after the previous. The number of workpieces hanging one after another depends on the length of the workpieces. For the work cycle under review, this number was three. The weight of each workpiece is 4 kg.

4. RESULTS

The following results are experimental, however, based on the assessment, we can give suggestions regarding the workplace.

4.1 Pen-and-Paper Based Ergonomic Risk Assessment

Rapid Upper Body Assessment (RULA) has been chosen for our comparison partly because it is included in ViveLab and mostly due to the reason that the workstation has a short cycle with no deviation in legwork apart from normal walking. If that were the case, we would have used Rapid Entire Body Assessment (REBA). OWAS was added to the assessment to take a closer look at the often repeating bad postures.

The results from RULA are the following, which are also illustrated by figures.

As it can be seen in Figure 1, the upper arm position on the left side is higher than the shoulder line.

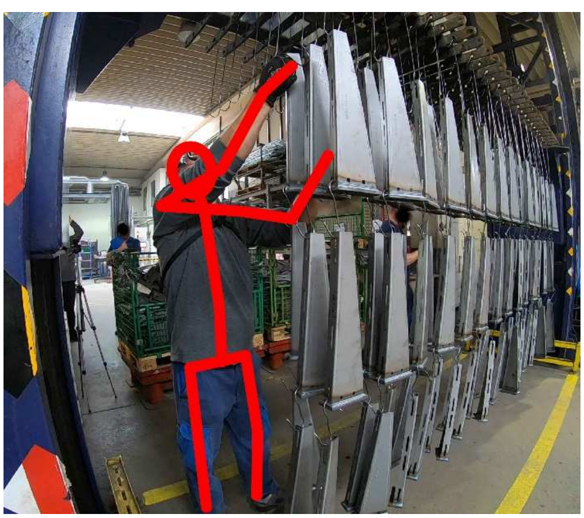

Fig. 1. Upper arm position

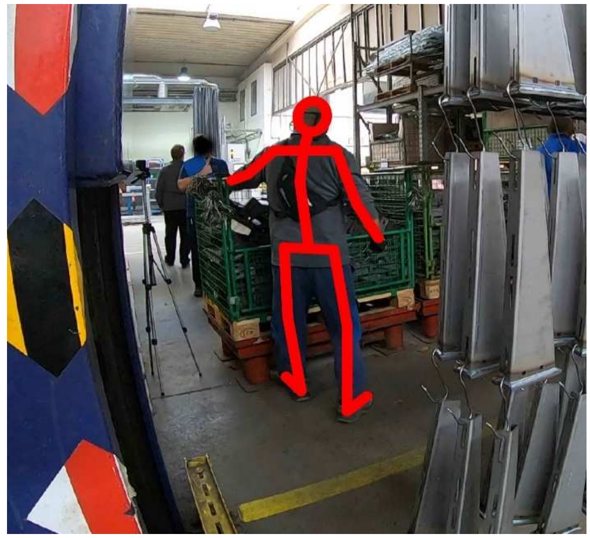

Fig. 2. Upper arm position abducted

The shoulders are also raised, and the arms are abducted (Fig. 2). For this, by RULA standards, 4+2 points are given for the upper arms.

From the same figures, we can see the positions of the lower arms which earn this way 2+1 points for being stretched out and abducted.

The wrist score can be evaluated from the next figure (Fig. 3). The wrist is twisted and has a +15 degree position compared to the neutral. The score is 2+1 points in this case.

The necks position can be seen in Figure 1 and 3. In Figure 1, the neck is bent backwards, while in Figure 3, the neck is twisted and bent forward. These postures result in a 4+1 score.

The worst of the trunk’s position can be seen in Figure 3: The trunk is bent forward and sideways. The score for this is 2+1 here.

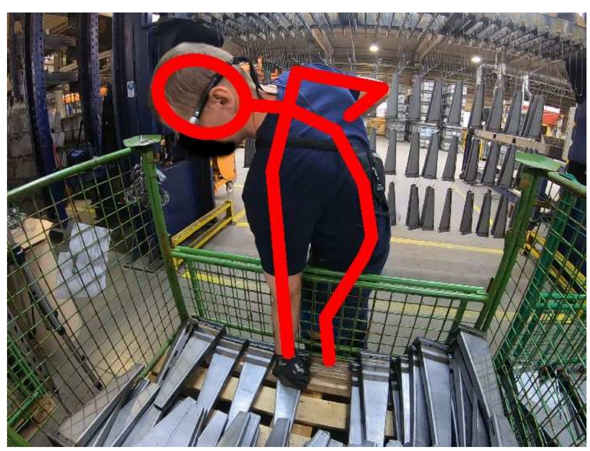

Fig. 3. Wrist position

The legs score is 1 because the feet are always supported, the workstation does not require sitting.

The Arm Muscle score is 1, because they are doing the same movements more than 4 times a minute. The weight of each item is 4 kg. This makes it 12 kg for the 3 items they carry during their work. Since they do it faster than 4 times a minute, the Force Load scores for the arms and the trunk and legs are both 3 points.

Their trunk posture does not change too much therefore the Upper Body Muscle use can be scored 0.

The summary of RULA can be seen in Fig. 4 with a final score of 7, which means the workstation should be redesigned.

For the OWAS analysis, Figure 1 has been used since this posture repeats the most during the work they do at this workstation and this is the one that influences the RULA's score the most.

By using the OWAS table, the score of this posture is the following.

The back is straight: 1 point; the arms are both at or above shoulder level: 3 points; the legs are standing straight: 2 points; and the load is between 10 and 20 kg (12 kg): 2 points. From the OWAS table, this results in 1 point. By the OWAS results, there is no need to change this posture. If the back was bent or twisted, the points would be 3 while the other subscores stayed constant. Since in practice of ergonomics, one must consider the assessment that gives a harsher result as a base, this would mean that even though one assessment from the two does not recommend any actions, it should still be changed.

4.2 Analysis in ViveLab

In ViveLab, an animation of the workflow was made. The animation was made according to the video recording; therefore, a little chance of error is present.

The software is capable of doing statistics about the animation, and surprisingly OWAS did not show any high score, although the workflow was clearly not acceptable in the long term. In the particular work cycle, one arm was elevated above the shoulder 5.3% of the examined time interval.

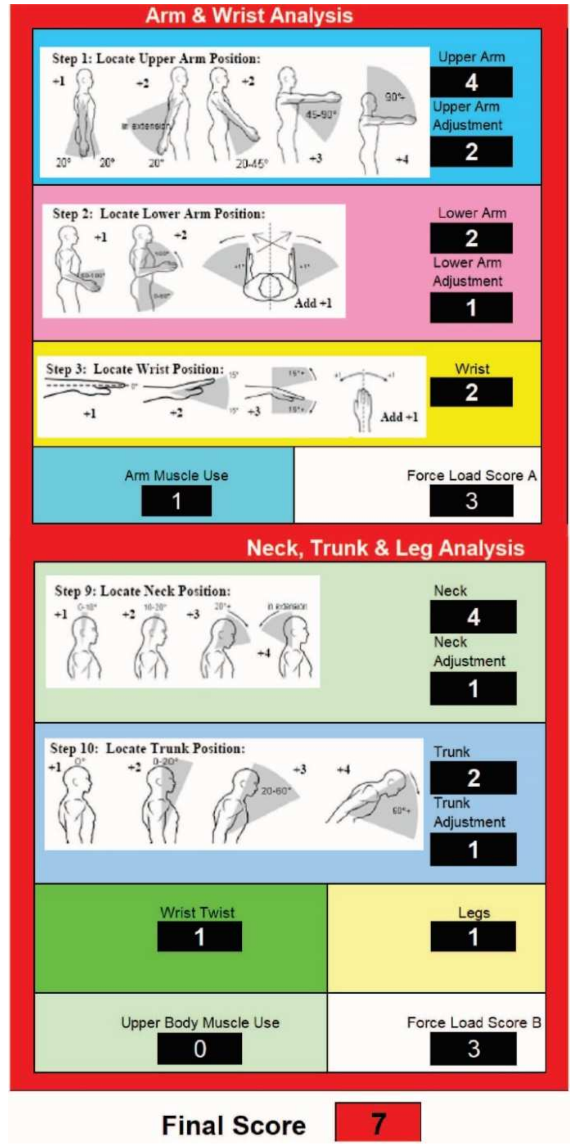

Fig. 4. Pen-and-Paper RULA Score

The other used assessment was RULA. Besides the 3 and 4 scores, it appeared the 7 (the highest) score too (see Fig. 5).

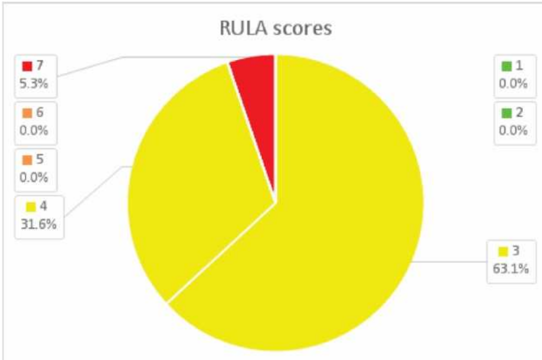

Fig. 5. RULA statistics in ViveLab

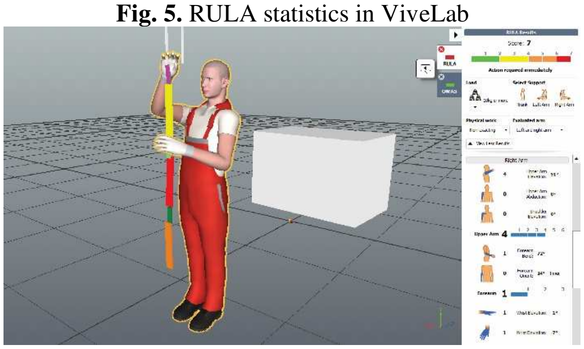

Fig. 6. Critical posture shown in ViveLab

The higher score appears because of the elevated right arm when the worker puts the workpieces on the hook. It is more than 10 kg, which is highly increases the score (see Fig. 6).

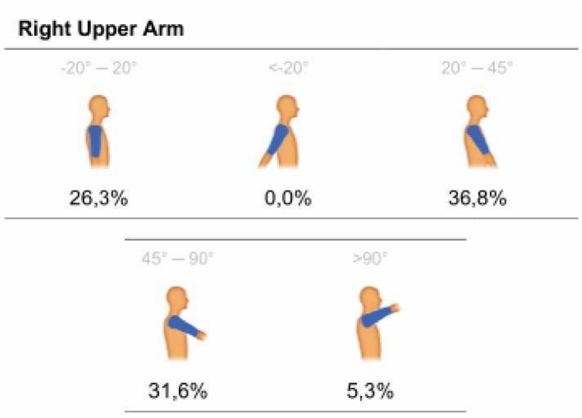

Fig. 7. Right upper arm statistics in ViveLab

The statistics of the right arm position are more detailed than the previous one. They show that the high elevation (above the shoulder) is 5.3 % (like OWAS showed before), however, the smaller elevations are present in a very high percentage (see Fig. 7).

We also made an evaluation based on ISO11226 standard, which is implemented into ViveLab. It showed the same result as the previous methods.

4.3 Comparison

A main difference between the pen-and-paper RULA evaluation and the one that is implemented to ViveLab is that as the first one gives one final score for the whole work cycle. the second one samples and gives a statistical result at the end. Therefore, the analysis from ViveLab gives us a percentage distribution. The different ways could give us different result; however, the main critical postures are the same.

Comparing the two RULA results, the biggest similarity is the highest score. The pen-and-paper analysis and the one implemented in ViveLab showed the maximum score (seven). Both methods were done by a human, so the difference between the two results could be explained with the facts, that animation in ViveLab was made manually, and the researcher, who made the pen-and-paper version, evaluated the workflow according to the video recordings. In both cases, potential human mistakes and risks of subjective judgments are present. Also, the software divides the postures and analyses one by one, while the other method combines the work cycle and takes the most critical postures. Therefore, we suspected a little difference between the two scores.

In the next chosen method (OWAS), the two results were the same. Even with the 10-20 kg weight, which was set up, the score was the lowest (one).

5. CONCLUSION AND DISCUSSION

In conclusion, the two ways of evaluation gave similar results; however, software analysis showed a more nuanced picture.

According to our experiences, applying OWAS and RULA tools were a right choice considering the specificity of the evaluated working task. The two assessment methods complement each other.

For other similar workstation evaluation, we would recommend both Pen-and-paper and DHM-based methods in different circumstances. Pen-and-paper method in cases when quick and general evaluation is required, and ViveLab (or other DHM) software in cases when more visualised and statistically supported analysis is required.

These results are essential for industrial practice and can give us guidance for further evaluations. The comparison was interesting, and we plan to perform more workplace assessments with both pen-and-paper and DHM-based methods because the results could be different for various types of workflows.

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7. REFERENCES

[1] De Magistris, G., Micaelli, A., Evrard, P., Andriot, C., Savin, J., Gaudez, C., Marsot, J., *Dynamic control of DHM for ergonomic assessments*, International Journal of Industrial Ergonomics, ISBN 0169-8141, 2013.

[2] Santos, J., Sarriegi, J. M., Serrano, N., Torres, J. M., *Using ergonomic software in non-repetitive manufacturing processes: A case study*, International Journal of Industrial Ergonomics, vol. 37, no. 3, pp. 267–275, ISBN 0169-8141, 2007.

[3] Bergman, C., Castro, P. R., Högberg, D., Hanson, L., *Implementation of Suitable Comfort Model for Posture and Motion Prediction in DHM Supported Vehicle Design*, Procedia Manufacturing, vol. 3, no. Ahfe, pp. 3753–3758, ISBN 9781486309191, 2015.

[4] Szabó, G., *Practice of Ergonomics*. Budapest: Donát Bánki Faculty of Mechanical and Safety Engineering, Óbuda University, 2014.

[5] McAtamney, L., Nigel Corlett, E., *RULA: a survey method for the investigation of work-related upper limb disorders*, Applied Ergonomics, ISBN 0003-6870, 1993.

[6] Hignett, S., McAtamney, L., *Rapid Entire Body Assessment (REBA)*, *Applied Ergonomics*. 2000, ISBN 1159691169.

[7] EU-OSHA, *The MAC - Tool - Manual Handling Assessment Charts*, Occupational Safety and Health Administration, pp. 1–15, ISBN 9780717666423, 2014.

[8] Moore, J. S., Garg, A., *The Strain Index: a proposed method to analyze jobs for risk of distal upper extremity disorders*, Am Ind Hyg Assoc J, ISBN 0002-8894 (Print), 1995.

[9] Oy, O., *OWAS (Ovako Working posture Assessment System)*, Finnish Institute of Occupational Health, vol. 1, no. June, pp. 1–6, [Online]. Available: http://www.ttl.fi/en/ergonomics/methods/workload_exposure_methods/table_and_methods/Pages/default.aspx, 2009.

[10] *Man-Systems Integration Standards NASA-STD-3000, Volume I*. 2000.

[11] Szabó, G., Mischinger, G., *Just an other ergonomic tool: the "Composite Ergonomic Risk Assessment,"* in Ergonomics 2013 : 5th International Ergonomics Conference, B. Mijović, I. Salopek Čubrić, G. Čubrić, A. Sušić, Eds., 2013, pp. 169–174.

[12] *ViveLab Ergo*. http://vivelab.cloud/ (accessed Dec. 10, 2019).

[13] Berlin, C., Adams, C., *Production Ergonomics: Digital Human Modeling*. 2017.

[14] *ViveLab Ergo*. https://www.vivelab.eu (accessed Dec. 10, 2019).

[15] Haggag, H., Hossny, M., Nahavandi, S., Creighton, D., *Real time ergonomic assessment for assembly operations using kinect*, in Proceedings - UKSim 15th International Conference on Computer Modelling and Simulation, UKSim 2013, 2013, ISBN 9780769549941.

[16] Domingo, J. R. T., Pano, M. T. S. De, Ecat, D. A. G., Sanchez, N. A. D. G., Custodio, B. P., *Risk Assessment on Filipino Construction Workers*, Procedia Manufacturing, vol. 3, ISSN 23519789, 2015.

[17] Malchaire, J., *A classification of methods for assessing and / or preventing the risks of musculoskeletal disorders*. 2011.

[18] Brandl, C., Mertens, A., Schlick, C. M., *Effect of sampling interval on the reliability of ergonomic analysis using the Ovako working posture analysing system (OWAS)*, International Journal of Industrial Ergonomics, vol. 57, pp. 68–73, ISBN 0169-8141, 2017.

[19] *International Standard ISO 11226-1 Ergonomics — Evaluation of static working postures*, 2000.

Compararea metodelor creion-hârtie și a modelului digital uman în evaluarea riscurilor - un studiu de caz pentru un loc de muncă industrial

Rezumat: Utilizarea diverselor programe software pentru ergonomie este din ce în ce mai răspândită în rândul cercetătorilor și ergonomiștilor, ceea ce poate fi util în evaluarea riscurilor ergonomice și în proiectarea antropometrică. Numeroase cercetări pot fi identificate pe această temă; cu toate acestea, compararea metodelor creion-pix și a celor de analiză software este rară, iar diferențele sunt puțin prezentate. În cercetarea noastră a fost făcută o comparație între metoda creion-pix și metodele de evaluare a riscurilor bazate pe software folosind RULA și OWAS. Rezultatele au fost similare în ambele cazuri, RULA și OWAS au acordat același punctaj pentru fluxul de lucru examinat, dar cu toate acestea, au apărut probleme practice.

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