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Comparison of Digital Tools for Ergonomics in Practice

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Abstract

Nowadays science is characterized by a phenomenon that has become the link. This trend is digitalization. Ergonomics has also not avoided this trend. The results of these trends are software tools, which include sophisticated digital human models and the latest ergonomic methods. Each instrument has its strengths and weaknesses. Therefore it is not only important to control the software, but also to be able to interpret and apply their outputs. This paper discusses a specific case study of a production workplace model. This model was evaluated with the help of digital human models by means of two software packages (Tecnomatix Jack and Delmia) and theirs ergonomic analysis. Three analyses focused on carrying conditions, lifting and lowering conditions and finally biomechanical conditions were performed. The results from these analyses from both software were compared and eventual differences are explained.

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Keywords: Ergonomic analyses; Digital human models;Tecnomatix Jack; Delmia; Digital factory; Simulation

1. Introduction

Over the last few years there has been a massive development and use of information technology. These technologies are probably the only answer to success in a highly globalized and turbulent market environment. The development of computer and communication technology enables that the methods of engineering work can be changed from scratch.

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This trend in digitalization has an effect on ergonomics. As a result of these trends there are software tools that include complex (sophisticated) models of humans and modern ergonomic methods. Each tool has its strengths and weaknesses. It is therefore not only important to control the software, but also be able to apply their outputs.

Probably the most significant ergonomic benefits of digital modelling is the ability to verify the suitability of the workplaces or the products during theirs development as stated by Regazzoni and Rizzi [1]. The fact that 90% of all errors can be debugged before the actual physical model is constructed reflects dramatically in financial savings. This so called proactive approach [2] is currently the trend and regarding to energy, material and other resources savings in the context of sustainable development becomes the only right way. It is easier to prevent problems in the early stages when theirs removal is very simple and inexpensive than later in production phases when production slowing or damage of workers health threatens. The opposite of proactive approach is so called reactive approach [3] which distinguishing feature is that the solution to problems is searched after they occur, but this may be in many cases too late.

Digital human models are 3 dimensional representation of the reality. Since 1960 when the first attempts to construct visualize first 3D models started, a great progress has been done. Many historically important solutions have been created. Digital human models like Anthropos, BoeMan, CombiMan, CrewChief, CyberMan, ERGOMan, Franky, Safework or Sammie shaped the future. Currently there are several digital human models that are of common use. These are Santos, Anybody, Ramsis, Catia/Delmia Human Model and Jack. Only several digital human models are however suitable for production planning. For example as described by Seidl [4] Ramsis is mostly suitable for designing an interior of cars. For our purposes we selected digital human models represented in Catia/Delmia software [5] [6] and model called Jack from Tecnomatix software [7]. Digital Factory systems represent the next logical step in the gradual creation of tools to support processes across the whole product lifecycle. Already during the planning phase all parts of production system can be verified, so that the subsequent real production of real products will be ensured in terms of quality and in terms of time and cost.

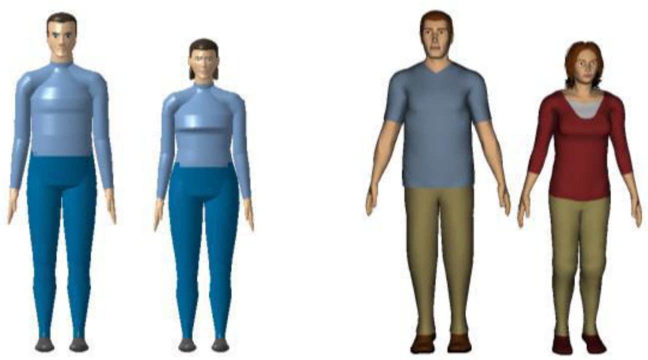

Fig. 1. Male and female digital human models in Delmia and Tecnomatix Jack.

The selected digital human models are fully customizable, so that results of studies carried out are perhaps the most realistic. If we talk about customization of a digital human model, we mean setting its gender, nationality, percentile or specific body measurements, so that our digital human model as much as possible corresponds to specific employees in production. With employee defined like this we then have the possibility to perform a variety of ergonomic analysis. The two mentioned software packages offer various kinds of analysis, however the core part of both software is material handling and work position evaluation. The digital human is placed in a virtual environment, a task is assigned to him and then his performance is analyzed by ergonomic analyses.

Ergonomic analysis tells us how the worker will work at a simulated workplace. We can find out how workers (from different population size) will perform a given task, analyze the risk of injury, needed power, reach, grips, fatigue, timing of operations, the sequence of work, optimization of tools and machines placement in the workplace, verification of parts assembly and many other factors. The result is a workplace that reflects the abilities and needs of the worker and leads to more efficient, more productive and safer production or assembly with less work accidents [6]. Simulation of work process followed by the right solution can prevent increased absence at work due to health problems, excessive employee turnover and related costs of retraining and also paying any compensation for injured employees.

2. Description of ergonomic analyses used

In this study following ergonomic analyses are used, which were selected based on consideration of our needs.

2.1. Biomechanical (Lower Back) analysis

This analysis measures biomechanical data on a worker in a given pose. From the current human posture, the Biomechanical (Lower Back in Tecnomatix Jack) analysis calculates and outputs information such as the lumbar spinal loads (abdominal force and pressure, body movements) and the forces and moments on human joints. All the outputs incorporated in the model are based on research results and algorithms published by the scientific community [8].

Biomechanical (Lower Back) analysis evaluates the posture and whether it exceeds the compression and joint shear limits recommended by NIOSH [9] –National Institute for Occupational Safety and Health (limit AL = 3400 N, MPL = 6400 N) and the University of Waterloo (AL = 500N, MPL = 1000N).

AL – up to the limit the load can be considered reasonably acceptable.

MPL – this limit represents the limit along which the load is considered hazard.

2.2. Lift-Lower (NIOSH) analysis

This analysis allows comparison of current data for lifting or lowering loads. It can choose between three directives: NIOSH 1981[9], NIOSH 1991[10] and Snook & Ciriello [11]. This analysis is based on the description of the initial position of the body before performing the task and then from the final position of the body after execution to which the body is received.

For our case study directive NIOSH 1991 was chosen. Equation NIOSH 1991 also known as the “revised lifting equation” acts with two-handed manual lifting tasks. The equation allows with a certain degree of symmetry. This equation assumes an adequate bond between the shoes and the surface, e.g. on slippery floors this analysis cannot be used. In this directive the following specifications for lifting load can be selected: frequency of lifting, duration, coupling condition and object weight. The final result is RWL – Recommended Weight Limit, which is the load weight that healthy workers (99% of males and 75% of females) can lift without a risk.

2.3. Carry (Manual Handling Limit) analysis

This analysis is based on a study by Snook & Ciriello [11]. It allows us to compare current data to carry the load and is used to determine the maximum acceptable weight that a worker can carry. This analysis considers two vertical distances above the hand to carry the load:

- For men: from the floor to 79 cm up to 112 cm
- For woman: from the floor to 71 cm up to 104 cm

For this analysis the following specifications for carrying the load can be selected: frequency of carry, distance and population sample. The final result is MAW – Maximum Acceptable Weight, which is the weight that the selected population sample can carry without risk.

3. Methodology

The case study seeks to point out problems that may appear in the evaluation of existing workplaces. The case study was carried out at a specific workplace – sewing seat belts in BOS Automotive Products Company in Klasterec nad Ohri, Czech Republic. The methodology was used as proposed by Chang and Wang [6] and Bures [12]. The first step is always to collect all necessary workplace information (like workplace dimensions or worker data) in order to create the most accurate model possible of the real workplace, on which analyses and experiments will be performed. In order to obtain objective results the workplace was modelled in both Delmia V5 Human and in Tecnomatix Jack software. The following figures show both models of a workplace.

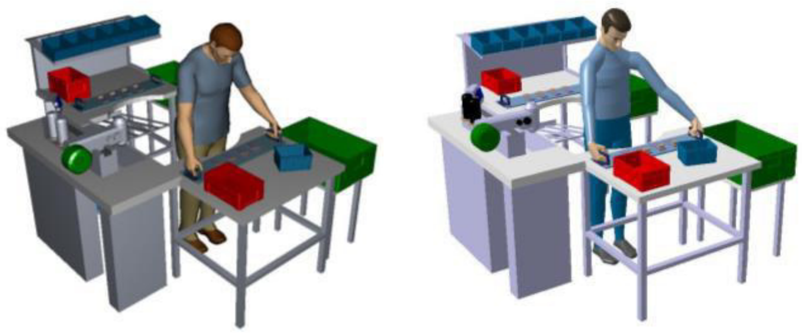

Fig. 2. Tecnomatix Jack and Delmia V5 Human workplace models.

According to the results achieved by Wu et. al. [13] we knew that one of the key factors to ensure correct comparison of the outputs is to use completely identical postures in both compared software. Also several more conditions which must be observed in experiments have been stated. These conditions are:

a) Software is able to represent investigated workplaces completely identically.
b) Same size and proportions of digital human models.
c) Analyses must work on same principle, same calculation or same standards.
d) Analyses have the same options.

As can be seen, in terms of visualization and 1st condition the software are able to represent the investigated workplaces completely identically. At both modelled workplaces the same digital human model was chosen to satisfy the 2nd condition. It was a 50th percentile man with 175 cm height and 78 kg weight, and 50th percentile woman with 162 cm height and 65 kg weight. The experiments were performed also for the 5th and 95th percentile, but these results won't be mentioned in this paper. Subsequently the same analyses (3rd condition) were performed for the activities that took place repeatedly on the workplace and therefore it was necessary to pay attention to the size of employee stress. These analyses were:

- Carry (Manual Handling Limit) analysis
- Lift-Lower (NIOSH) analysis
- Biomechanical (Lower Back) analysis

Analyses in the software works on the same calculation and input parameters were the same thus the last 4th condition was fulfilled.

4. Results

All tasks have been evaluated using both models and the results were compared. The overall comparison between the software was made.

4.1. Carry (Manual Handling Limit) analysis

Fig. 3. Position during transferring –Tecnomatix Jack visualization.

The first experiment was focused on transferring the clamping jig to the sewing workplace. This activity was analyzed by ergonomic analysis Carry (Manual Handling Limit in Tecnomatix Jack). In this analysis the following specifications were chosen:

Table 1. Specification for Carry (MHL) analysis.

Carry (Manual Handling Limit) analysis	
1 carry every: 16s	1 carry every: 60s
Distance: 4.3m	Distance: 4.3m
Population sample: 90%	Population sample: 90%

Following table (Tab. 2) shows the results value of MAW – Maximum Acceptable Weight, which is the weight that a chosen population can carry without risk.

Table 2. The results for carry loads.

	Maximum Acceptable Weight [kg]			
	1 carry every 16s		1 carry every 60s	
	Jack	**Delmia**	**Jack**	**Delmia**
Man	11 kg	10,34 kg	15 kg	14,96 kg
Woman	10 kg	9,21 kg	13 kg	13,15 kg

It can be seen that the results are almost the same. When examining the conditions for repetition each 16 seconds the values obtained from Tecnomatix Jack analysis were little bit higher. For repetition each 60 seconds the values were the same after the rounding. In Tecnomatix Jack software the height from the floor of the carried object was set to 111 cm for man and 105 cm for woman. For comparison in Delmia the values of height from floor of the carried object were set the same however slight differences in cm could be caused by the position of wrists. Also there is one last reason for mentioned slight differences which is conversion. The analyses outputs from Delmia are given in Newtons, however in Tecnomatix are in kilograms.

4.2. Lift-Lower (NIOSH)analysis

The second experiment was the same activity as before, but this time it was analyzed by Lift-Lower (NIOSH in Tecnomatix Jack) analysis.

Fig. 4. Initial posture for clamping jig lifting – Tecnomatix Jack visualization.

In this analysis the following specifications were chosen:

Table 3. Specification for Lift-Lower (NIOSH) analysis.

Lift-Lower (NIOSH) analysis
1 lift every: 80s
Duration: 1 hour or less
Coupling condition: Good
Object weight: 5 Kg

The results of Lift-Lower (NIOSH) analysis are in the following table (Tab. 4). The result values of RWL and LI are for a worker after lifting the clamping jig from the table. RWL – Recommended Weight Limit is the load weight that healthy workers can lift without risk.

Table 4. The results for lifting loads.

	Recommended Weight Limit [kg]	
	Jack	**Delmia**
Man	21,5 kg	18,7 kg
Woman	19,8 kg	17,2 kg

From Lift-Lower (NIOSH) results it is evident that a man because of his musculature and height can lift much more weight or load than a woman. The result values are higher in Tecnomatix Jack software. The difference is about 13% for both sexes. These differences are caused by more detailed setting of the input parameters in Tecnomatix Jack, where except defined specifications it is also possible to adjust recovery time, uninterrupted work time and detailed object grip settings. These precise settings cause differences in the results.

4.3. Biomechanical analysis

Comparison of the results was also performed for the following posture with Lower Back analysis in Tecnomatix Jack and with the Biomechanical analysis in Delmia software.

Fig. 5. Analyzed posture using Biomechanical analysis – Tecnomatix Jack visualization.

Table 5. The results from Biomechanical and Lower Back analysis.

	Compression limit L4-L5[N]	
	Jack	**Delmia**
Man	1429 N	1513 N
Woman	987 N	1175 N

The results of the Lower Back analysis (Tecnomatix Jack software) are a bit lower than from Biomechanical analysis (Delmia). This is caused by human working position, which is not modelled identically in the software. There is no way to avoid this. As we tried to position the human model in both experiments in the same posture, slight differences in single joints may cause great differences in compression forces. For example we found out, that when the worker is bending in the trunk area, each 1 degree represents change in compression limit of approx. 33 N. So the difference in values for man which is 84 N means difference of 2.55 degrees and the difference in values for woman which is 188 N means difference of 5.7 degrees. As can be seen these differences in postures in degrees are very small.

5. Discussion

The outputs from analyses show that the results are not of an exact match. This fact is caused by different possibility of setting in both compared software. It can't be said that Delmia either Tecnomatix is more precise because it depends on the concrete analysis. For example in case of Carry (Manual Handling Limit) analysis the one made in Delmia was more accurate, because concrete height of manipulation was deducted from the digital human model. On the other hand Lift-Lower (NIOSH) analysis was more accurate in Tecnomatix Jack where the aspect of recovery time and detailed object grip settings could be incorporated in the calculation. Also there is a different involvement of digital human models in the analysis. To compare this on our examples: in case of Carry (Manual Handling Limit) analysis in Delmia the height of carrying is deducted from actual height of digital human model hands, in case of Tecmonatix Jack the height is stated by the user that inputs the right data. When discussing this particular analysis, Delmia also uses interpolation for calculating the result values, Tecnomatix gives us only the border values.

Our experiments confirm that the analyses in both software works on the same principles with nearly the same results. Both software are there for every suitable for ergonomic optimization of workplaces however close attention is needed when explaining the results. Really a close attention must be paid to input values and conditions of the examined activities because every little detail matters and have influence on the result. Results of individual ergonomic analysis between man and woman are naturally different. This difference is caused by different anthropometry of the sexes.

6. Conclusion

This paper showed that there are some limitations in interpreting the results of ergonomic analysis using digital software tools. Results can sometimes lead to conflicting conclusions about the safety of a given task. The presented tools are not alone on the market, but are complex and contain acclaimed ergonomic analysis as well as the most sophisticated digital human models.

The benefit of this paper is an example of how modern technology, such as ergonomic tool Delmia V5 Human or Tecnomatix Jack, can help. These allow the workplace to be evaluated, if it is well organized for humans and if working positions are acceptable, or we can determine which factors may cause a health risk. We can immediately determine how a worker or human will feel in a working position. With these tools we can eliminate the cost of reworking in a real system by uncovering performance problems of people early, thus saving costs, which we would then have to spend on real production. Options of assembly work validation in a virtual environment without the risk of injury that may occur in real system. We can minimize problems with tools, equipment and distribution facilities in the workplace and reduce the number of production problems before real product production. We can also avoid some of the mistakes that we would not know otherwise.

The advantage of these ergonomic analyses is particularly the significant shortening of time in their implementation. With the software it is only a matter of a few minutes. In connection with the possibility of visualization and fast visual simulation of changes in the workplace in a virtual environment, the software greatly benefits optimizing in the workplace.

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