# Ergonomic Design through Virtual Humans

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**ABSTRACT**

This paper presents a methodological approach to analyze ergonomic issues of equipment specifically designed to load refrigerated display units. The methodology is based on the integrated use of virtual humans and prototyping techniques and on the comparison between the analysis of AS-IS product and TO-BE design concepts to highlight improvements or worsening of the new design and eventual residual deficiencies. In particular, Digital Human Models have been adopted to evaluate different technical solutions for pick and place operations of food items on the display unit shelves according to the specific needs of supermarket operators and to ensure health and hygienic conditions. We first present the state of the art of digital human models and the referring standards for workplace regulations in terms of postures and fatigue. The adopted methodology is described including chosen virtual humans, refrigerated units and handled products. Then, the application of the methodology is described as well as the ergonomics tests and results obtained for the AS-IS and TO-BE solutions. Finally, discussion of results and conclusions are reported.

**Keywords:** ergonomic design, virtual humans, refrigerated display unit.
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## 1 INTRODUCTION

Today, human centered engineering is deeply integrated into product lifecycle in the fields of aerospace, aging, health care, and transportation, among others. Human factors are involved in several steps of product life (design, manufacture, maintenance, etc.) and the capability to keep them into account effectively is a key point for a winning product on the market. Several aspects have to be considered, such as ease of use and maintenance for all those who deal with the product (worker, seller, end user, etc.), handling capability, physical condition and risk prevention. How a human will function in relation to a product or system is difficult to predict; yet, ergonomic considerations traditionally have been addressed by intuition or rough calculations. It can happen that the physical tests are performed long after the product or system can be changed easily or without a huge loss of time and money. Too often, this leads to re-design or massive cost overruns to correct deficiencies neglected early in the process.

Virtual ergonomics permits designers to create and manipulate virtual humans and to investigate the interaction between the consumer or worker and the product. For example, in product design, human

factors such as positioning, visibility, reaching, grasping and lifting of weights can all be evaluated providing a feedback to designers in the early steps of product development.
This paper refers to this context and addresses commercial refrigeration industry and, in particular, those companies specialized in display units. It describes the use of virtual ergonomics techniques in the design process of auxiliary equipment specifically conceived to load refrigerated display units commonly used in supermarkets.
The aim consists in creating a work paradigm enabling designers to easily introduce virtual ergonomics in their everyday activities by means of a step-by-step procedure based on the use of digital human modeling tool (in our case the commercial system Jack) and ad-hoc parametric products libraries. In particular, Digital Human Models (DHM) have been used to evaluate different technical solutions for pick and place operations of food items on shelves according to the specific needs of supermarket operators and to ensure good health and hygienic conditions.
After the introduction, the paper in the second section presents the state of the art of DHM tools and the referring standards for workplace regulations in terms of postures and fatigue. In the third, the adopted methodology is described including chosen virtual humans, refrigerated units and handled products. The fourth section is dedicated to the application of the methodology and the ergonomics tests we carried out are shown for both the AS-IS and TO-BE solutions. Finally, discussion of results and conclusions are reported.

## 2 STATE OF THE ART AND RELATED WORKS

Digital human modeling started in the 1960s and was mainly referred to ergonomics analysis in aeronautics and automotive industries. Later on, a number of human modeling tools have been developed exhibiting increased capabilities and functionality to fulfill the requirements of a wide range of applications [1-3]. Many research groups have been working on virtual humans and various commercial systems are now available. Moreover, military authorities continuously funded researches for the development of more sophisticated digital humans [2,4], such as Santos, a virtual soldier, developed by the Virtual Soldier Research Program at Iowa University.
We grouped virtual humans into four main categories [4]: digital humans/actors for entertainment, virtual manikins for clothing, virtual humans for ergonomic analysis and detailed biomechanical models.
Digital humans/actors for entertainment [3,5-9] are used to populate scenes for movies and videogames production. Also virtual crowd simulators belong to this group and they are used to create virtual scenes to represent for example platoons, fighters or civilians, to simulate emergency situations and for training purposes.
Virtual manikins for clothing [3,10-14] are used to create virtual catwalks, catalogues, and try-on show rooms and to design garments. The applications are various and imply the use of virtual mannequins characterized by different levels of complexity and details according to the goal. Modaris, Vsticher and 3D Runway are some examples of commercial CAD clothing systems that use 3D virtual mannequins.
Virtual humans for ergonomic analysis [1,2,15-27], also called computer manikins [2], are adopted to assess compatibility and usability of products and machinery or workplaces. It is possible to create manikins of different sizes using anthropometric databases based on military and civilian anthropometric surveys. Some examples are Jack, Ramsis, Safework, HumanCAD and BHMS. They permit to define complex scenes, analyze postures, simulate tasks and optimize working environments and are used especially in automotive and aeronautics domains.
Finally, detailed biomechanical models [4,28-34], more complex than the previous ones, are characterized by a complete musculoskeletal model. Tools, such as LifeMOD, SIMM, MADYMO, and Santos [4] belong to this group.
As said, according to the specific needs, digital humans and related tools can be used in various areas/applicative domains [1-3], such as automotive, aeronautics, architecture and civil engineering, bioengineering and medicine, videogames and movies, education and training.
During product life cycle, DHM systems can be used to show and analyze how humans should act in various situations and execute required tasks but also to predict the impact of their actions on musculoskeletal apparatus. In fact, most of them incorporate methods to assess the exposure to risk factors for work-related musculoskeletal disorders. Several researches have been conducted in this field [36, 37]. G. C. David in [38] provides an overview of available methods and subdivided them into

three categories: self-reports, observational methods and direct measurements. In this paper, we refer to the second category, and in particular to those implemented in DHM systems:

- RULA (Rapid Upper Limb Analysis) to investigate work-related upper limb disorders.
- NIOSH (U.S. National Institute for Occupational Safety and Health) lifting equations to evaluate lifting and carrying tasks-
- OWAS (Owako Working Posture Analysis System) to analyze postures during work.

In addition, there are national and international standards, such as European Standard UNI-EN 1005-4:2005 and UNI EN 1005-5:2007 [39, 40], which use a number of zones to evaluate mentioned aspects. They define acceptable values for low and high frequency movement related to trunk, upper arms, neck, and so on.

To conclude, today's tools for human modeling offer a comprehensive set of functions and permit to study and solve several ergonomics problems the designer may face through the product life cycle. However, there is still the need to identify methodological approaches and guidelines [41] for a correct and efficient use in each industrial context. In this paper, we face this problem with regard to the design of new equipment to load supermarket refrigerated display units since workers need to execute repetitive tasks with postures and movements as safely as possible without causing musculoskeletal disorders and health risks. Our goal is to identify which issues should be considered (e.g., which shelves should be considered for ergonomics analysis) avoiding unnecessary simulation tests and to provide quantitative data from which the designer can extrapolate design guidelines to modify already existing products or to develop new design concepts taking into account ergonomics requirements since the early stage of product development.

## 3 ADOPTED METHODOLOGY

The methodology has the goal to increase repeatability and robustness of ergonomic analysis using virtual prototyping techniques and DHM tools, specifically those belonging to the third group, namely virtual humans for ergonomic analysis. The methodology is based on a comparison between the analysis of AS-IS product and TO-BE design concepts to identify improvement or worsening of the new design and eventual residual deficiencies. Since ergonomics constraints highly impact on product architecture, the earlier the new concepts are validated the faster the product development process comes to an end. Referring to the vertical open refrigerated display unit (Figure 1), to perform an ergonomic assessment we need only shelves number and positions, size of each shelf, and overall dimension of the structure. This means that ergonomics validation can be performed quite early in the design process.


a)

Fig. 1: a) Example of vertical refrigerated display unit; b) main dimensions.

Each analysis is guided step-by-step and a parametric library of 3D models of refrigerators structure and of exposed goods help the designer performing repeatable and reliable test campaigns.

The analysis consists of three main steps (Figure 2): the first one is dedicated to the set-up of the virtual environment in which the simulation takes place, in the second step the test campaign is setup and simulation are run and, at last, the third step is dedicated to the analysis of results according to ergonomic standards and eventual issues still to be solved are identified.

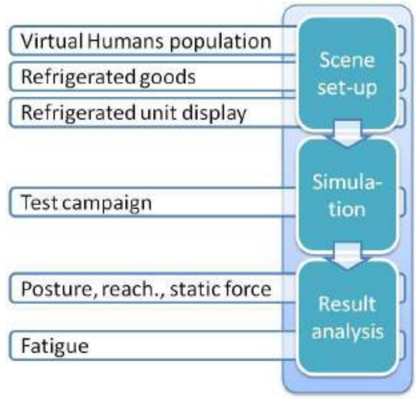



Fig. 2: Methodology combining ergonomic analysis.

The first step, namely "Scene set-up", consists in the definition of the virtual environment reproducing the conditions people will deal with in real life. Most of details can be neglected and simplified 3D models of systems are used to speed up the simulations. In the case of refrigerated display units each model or series have got fixed dimensions of the cabinet, while normally shelves position can be changed according to specific needs. To simulate display units from the point view of the customer or of the worker loading the shelves, we need to consider also the displayed goods. In particular, food packages can be of different dimensions, weight and typology (e.g. carton boxes, plastic bags, bottles or pots). To deal with the variability of display unit configurations and of products a simple but effective database of 3D parametric models has been created and populated. In this step virtual humans gender and size are chosen so that every kind of user of the system can be taken into account. To perform this task most of virtual humans tools provide automatic sizing according to different anthropometric database (i.e., anthropometric data from the NHANES survey, North America automotive working population or Chinese database) so that all the target population is successfully represented. Eventually, physically disabled people, e.g., on a wheelchair, can be taken into account as well.

In the second step, namely "simulations", required tests are defined and performed. Even if the tasks to be accomplished (i.e., loading a shelf with goods or taking one out), are simple and no training is delivered to any of the people interacting with the system, the number of combination of initial and final positions of the good and postures of the virtual human requires an accurate planning phase. For each simulation the planning defines model and configuration of the display unit, which virtual human must be used and which task s/he has to perform, and, at last, which good must be handled.

The third step, "result analysis", consists in collecting, comparing and evaluating all the results obtained. An ordered representation of outcomes of the tests performed in the previous step allows technicians highlighting design mistakes, lacks or deficiencies. Results obtained can be in the format of a picture or the value of an index or in other formats depending on what is relevant for the simulation. Results are organized in tables and histograms allowing the designer to evaluate rapidly not only the specific machinery but also to compare different types of refrigerated units respect to packed food loading and expository space. The outcome gathered is then considered as a product design specification as conventional ones.

The three-steps analysis has been performed on the existing system (AS-IS) to assess problems not yet solved (or even faced) and to the tentative design solutions competing to become the following generation of the system. The main point consists in exploiting the results obtained from the analysis in order to modify the existing design obtaining a new one, which will go thought another analysis cycle.

## 4 VIRTUAL ERGONOMICS OF NEW LOADING PLATFORMS

The methodology has been applied during the development of new refrigerated display units. In particular, the involved company is aware of some drawbacks of their products concerning reachability of goods in highest and lowest shelves. This problem is well known and affecting all display units of this kind on the market. Simply changing unit dimensions cannot solve this problem. For example, a smaller cabinet is less attractive for supermarket customers and needs more frequent reload operations. Thus to ease the manual loading of goods, lifting work platforms have been designed and are under investigation. Such platforms by lifting worker and goods at the desired height could help meeting the ergonomics requirements, at least for the highest shelves.
We conducted a preliminary study on the display unit and workers' tasks and attitudes (Figure 3a,b). Actually, interviews and observations of personnel in charge of loading display units highlighted some unacceptable practices such as assuming wrong and dangerous postures, e.g., stepping onto the first shelf of the unit to better reach the highest one (Figure 3c).


a) b) c)

Fig. 3: Postures assumed by the operators.

The methodology has been applied to the vertical open display shown in Figure 1. This unit has been taken as an example since it is considered a good representative of vertical unit family. At first, the current version of the refrigerated display unit is simulated (AS-IS); then, without changing the system, simulations are run using lifting work platforms (TO-BE 1). At last some modifications are introduced in the system to overcome issues not addressed with platforms (TO-BE 2).

For each analysis the virtual human chosen to represent operators are females of 5th and 50th percentile and males of 50th and 95th percentile according to ANSUR anthropometric database. These percentiles have been selected in agreement with the company staff and according to their needs. In fact, this set permits to cover European population of interest (mainly South Europe) and to evaluate different level of performances with respect to each selected percentile.
Details concerning the application of the methodology, results obtained and solution proposed are described in the following sections.

### 4.1 AS-IS Simulation

The analysis of loading operations has been conducted considering: a vertical display unit with 5 shelves, four virtual human, two different goods of 1kg and 3kg of weight, the lowest and the highest shelves (see figure 1 for main dimensions). We identified these shelves as the most critical from previous analysis carried out on similar display units. The posture assumed by the virtual human to reach the maximum distance on the shelf has been assessed by means of OWAS method. The task of loading a product is reproduced to measure lower back load as well as static force; then, fatigue, repetitions and recovery time are analyzed. Figure 4 shows the data of the analysis for the first and last shelves.
For the highest shelf we decided to consider the virtual humans also standing on the first shelf. Actually, even if the workers are recommended not to do so, it is the most effective position for reachability and sometimes they do it anyway. Taking into account this extreme configuration allows keeping in touch with the real problems and (wrong) behaviors workers sometimes assume, and gives important advices for the development of viable solutions. Once performed the simulation campaign the results are summed up to draw some remarks. Table 1 shows the results concerning the highest

shelf. We can observe that the female can reach only partially the shelf (no more than 50%) while male can reach 100% but with a posture barely acceptable (OWAS class 2) for male 95% and not acceptable (OWAS class 3) for male 50%. Similarly for the lowest shelf, the females cannot reach the back with a posture that is barely acceptable (OWAS class 2), while males can reach 100% of the shelf but assuming a posture (OWAS class 4) that is risky and requires urgent correction.
On the contrary, the resulting values obtained for lower back analysis, static strength and fatigue are not critical. The shift of the load from 1kg to 3kg does not produce any change in the muscular load distribution while forces increase. For the lowest shelf, work cycles and recovery times are particularly positive for females handling the load of 1 kg, while for the highest male with the heaviest load they are disadvantageous.

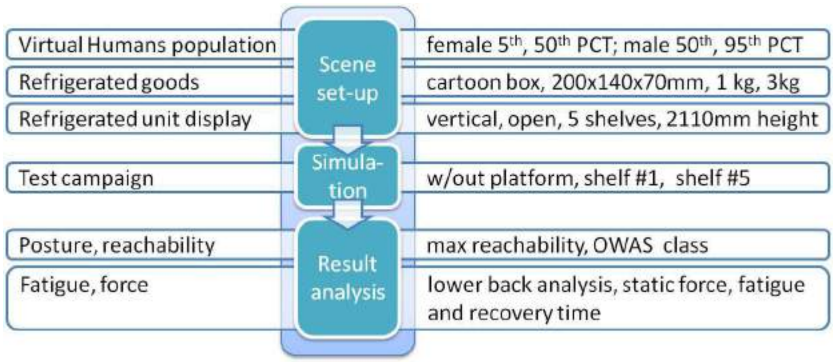



Fig. 4: Input data and performances measured for a single analysis.

| AS-IS HIGHEST SHELF | | | | Female 5% | Female 50% | Male 50% | Male 95% |
|---|---|---|---|---|---|---|---|
| REACHABILITY | | | % reached | 40 | 50 | 100 | 100 |
| POSTURE | | | Owas class | 1 | 1 | 3 | 2 |
| FATIGUE | Load 1 Kg | Lower Back analysis | L4L5 (Nm) | 30 | 20 | 55 | 95 |
| | | | Spinal Forces(N) | 800 | 1500 | 1200 | 2050 |
| | | | Muscle tension (N) | 250 | 100 | 400 | 750 |
| | | | Static force | 150 | 150 | 275 | 390 |
| | | Fatigue - recovery | Cycles | 25 | 27 | 29 | 28 |
| | | | Recovery Time (s) | 8,19 | 4,03 | 0,12 | 2,17 |
| | Load 3 Kg | Lower Back analysis | L4L5 (Nm) | 45 | 25 | 70 | 110 |
| | | | Spinal Forces (N) | 1000 | 700 | 1800 | 220 |
| | | | Muscle tension (N) | 270 | 240 | 500 | 770 |
| | | | Static force | 150 | 420 | 280 | 390 |
| | | Fatigue - recovery | Cycles | 25 | 27 | 29 | 27 |
| | | | Recovery Time (s) | 10,32 | 5,07 | 1,23 | 2,75 |
| | NIOSH | | RWL(1) | 3,88 | 3,65 | 3,37 | 3,65 |
| | | | LI(2) | 0,39 | 0,41 | 0,45 | 0,41 |
| | | | CLI(3) | 1,39 | 1,48 | 1,6 | 1,47 |

(1) Reccommended Weight Limit; (2) Lifting Index; (3) Composite Lifting Index

Female 50th PCT

Tab. 1: Highest shelf: Results of the AS-IS analysis.

### 4.2 TO-BE 1 Simulation

Once confirmed company's empirical results with the AS-IS analysis, we proceeded with the study of the lifting work platform devices, which must safely carry a person and the goods to be loaded.

The company proposed three different solutions: with one shelf (Figure 5a) with two shelves (Figure 5b), and with a rotatable shelf (Figure 5c).

a) b) c)

Fig. 5: Platforms to lift and carry worker and load.

The analysis has been carried out according to the parameters of the AS-IS analysis so that results are easily comparable. Figure 6 shows some images related to postures assumed by the different percentiles when using the three platforms.

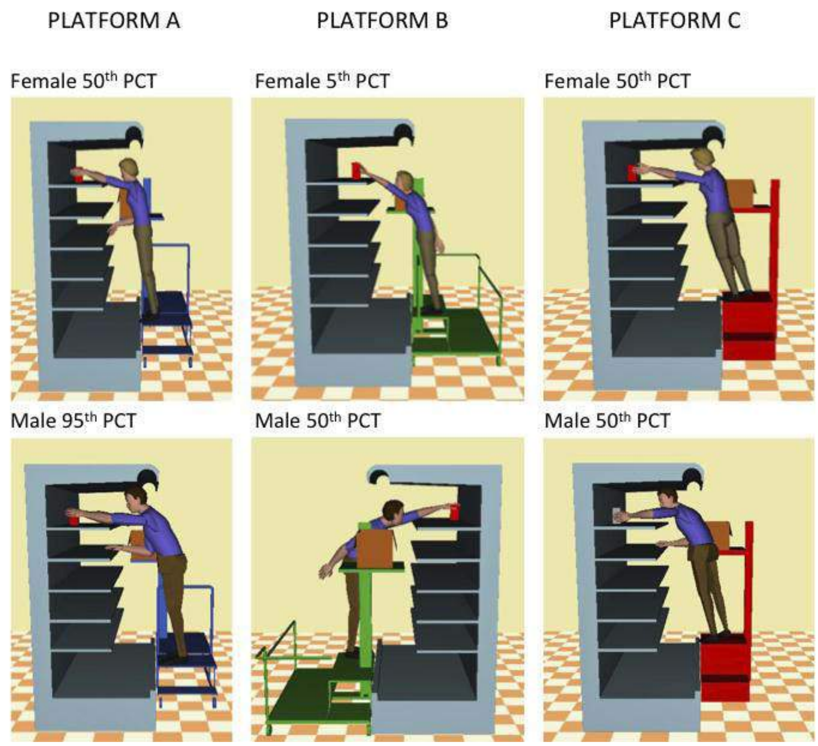



Fig. 6: Postures assumed when using the designed platforms.

As an example, Table 2 reports the data of the TO-BE 1 simulation campaign for the platform C. The main result is that the platform increases females' ability to get closer the back of the highest shelf, but their OWAS class worsens.

Analogous tables have been obtained for the other two platforms.

In summary, the platforms set all the virtual humans back from the display unit determining, for some of them, the worsening of some evaluation parameters (e.g., reachability). By the way, the comparison is done with the AS-IS in which virtual humans were standing on the first shelf, while using the platform the posture is a perfectly viable and safe solution. Moreover, platforms are not suited for improving issues related to the lowest shelf. To address this problem preventing risky postures, a further development of lifting platforms and their analysis comes out to be necessary.

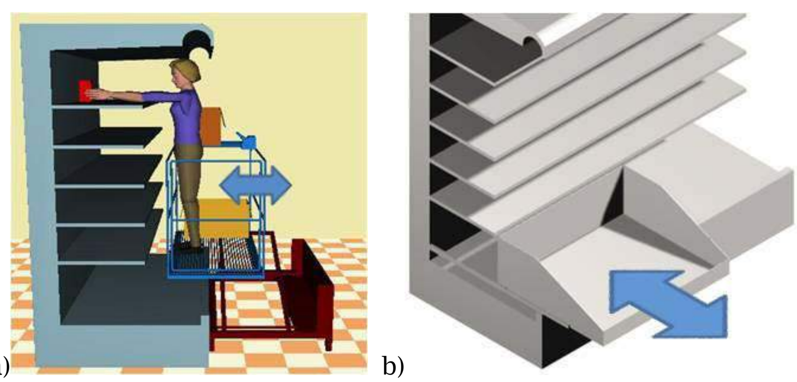
| TO-BE 1 HIGHEST SHELF | | | | Female 5% AS-IS | Female 5% C platform | Female 50% AS-IS | Female 50% C platform | Male 50% AS-IS | Male 50% C platform | Male 95% AS-IS | Male 95% C platform |
|---|---|---|---|---|---|---|---|---|---|---|---|
| REACHABILITY | | | % reached | 40 | 60 | 50 | 85 | 100 | 100 | 100 | 100 |
| POSTURE | | | Owas class | 1 | 3 | 1 | 3 | 3 | 2 | 2 | 2 |
| FATIGUE | Load 1 Kg | Lower Back analysis | L4L5 (Nm) | 30 | 35 | 20 | 35 | 55 | 90 | 95 | 125 |
| | | | Spinal Forces(N) | 800 | 900 | 500 | 1100 | 1200 | 2250 | 2050 | 3100 |
| | | | Muscle tension (N) | 250 | 240 | 100 | 260 | 400 | 740 | 750 | 1100 |
| | | | Static force | 150 | 150 | 150 | 150 | 275 | 420 | 390 | 500 |
| | | Fatigue - recovery | Cycles | 25 | 28 | 27 | 26 | 29 | 28 | 28 | 25 |
| | | | Recovery Time (s) | 8,19 | 4,7 | 4,03 | 8,24 | 0,12 | 4,84 | 2,17 | 11,77 |
| | Load 3 Kg | Lower Back analysis | L4L5 (Nm) | 45 | 40 | 25 | 40 | 70 | 105 | 110 | 150 |
| | | | Spinal Forces (N) | 1000 | 1100 | 700 | 1400 | 1800 | 2700 | 2200 | 3250 |
| | | | Muscle tension (N) | 270 | 260 | 240 | 400 | 500 | 800 | 770 | 1250 |
| | | | Static force | 150 | 150 | 420 | 150 | 280 | 450 | 390 | 500 |
| | | Fatigue - recovery | Cycles | 25 | 27 | 27 | 26 | 29 | 28 | 27 | 24 |
| | | | Recovery Time (s) | 10,3 | 7,74 | 5,07 | 10,4 | 1,23 | 5,6 | 2,75 | 13,24 |
| | NIOSH | | RWL(1) | 3,88 | 10,09 | 3,65 | 9,4 | 3,37 | 9 | 3,65 | 8,25 |
| | | | LI(2) | 0,39 | 0,15 | 0,41 | 0,19 | 0,45 | 0,17 | 0,41 | 0,18 |
| | | | CLI(3) | 1,39 | 0,54 | 1,48 | 0,57 | 1,6 | 0,6 | 1,47 | 0,65 |

(1) Reccommended Weight Limit; (2) Lifting Index; (3) Composite Lifting Index

Tab. 2: Results of TO-BE 1 analysis for Platform C.

## 4.3 TO-BE 2 Simulation

A design review process based on the results of the previous analyses brought to the solution of creating a platform, namely platform D, that is able to raise and then to move towards the display unit getting the worker closer to the shelves (Figure 7a), especially for the highest one. This alternative solution permits to reach 100% of the shelf for all percentiles as well as to improve OWAS class of postures assumed by male percentiles.
Moreover, new design concepts have been developed for the lowest shelf, such as a sliding shelf (Figure 7b), which eases filling out, guarantees optimal reachability for everybody and, in most cases, decreases force needed. Table 3 summarizes the results obtained for the lowest movable shelf and the comparison with the AS-IS simulation.



a) b)

Fig. 7: a) Platform D bringing human closer to the shelves, b) lowest movable shelf in loading position.

| TO-BE 2 LOWER SHELF | | | | Female 5% | | Female 50% | | Male 50% | | Male 95% | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | AS-IS | MOVABLE SHELF | AS-IS | MOVABLE SHELF | AS-IS | MOVABLE SHELF | AS-IS | MOVABLE SHELF |
| REACHABILITY | | | % reached | 80 | 100 | 85 | 100 | 100 | 100 | 100 | 100 |
| POSTURE | | | Owas class | 2 | 2 | 2 | 2 | 4 | 2 | 4 | 2 |
| FATIGUE | Load 1 Kg | Lower Back analysis | L4L5 (Nm) | 25 | 50 | 80 | 75 | 120 | 110 | 125 | 150 |
| | | | Spinal Forces(N) | 800 | 1700 | 1500 | 2000 | 2400 | 2100 | 2600 | 3900 |
| | | | Muscle tension (N) | 200 | 520 | 520 | 700 | 1100 | 1050 | 1100 | 1450 |
| | | | Static force | 390 | 450 | 390 | 450 | 450 | 430 | 430 | 440 |
| | | Fatigue - recovery | Cycles | 30 | 30 | 30 | 29 | 26 | 29 | 25 | 28 |
| | | | Recovery Time (s) | 0,45 | 1,62 | 0,57 | 3,364 | 10,2 | 2,088 | 12 | 4,928 |
| | Load 3 Kg | Lower Back analysis | L4L5 (Nm) | 75 | 75 | 85 | 80 | 125 | 130 | 130 | 160 |
| | | | Spinal Forces (N) | 1500 | 1900 | 1600 | 2200 | 2600 | 3150 | 2900 | 4100 |
| | | | Muscle tension (N) | 520 | 700 | 600 | 769 | 1200 | 1200 | 1250 | 1510 |
| | | | Static force | 410 | 470 | 410 | 490 | 465 | 470 | 470 | 480 |
| | | Fatigue - recovery | Cycles | 28 | 29 | 28 | 29 | 18 | 29 | 13 | 27 |
| | | | Recovery Time (s) | 4,48 | 2,29 | 4,54 | 4,816 | 30,3 | 3,016 | 37,9 | 6,534 |
| | NIOSH | | RWL(1) | 3,88 | 4,51 | 3,65 | 4,15 | 3,37 | 3,9 | 3,65 | 3,91 |
| | | | LI(2) | 0,39 | 0,33 | 0,41 | 0,36 | 0,45 | 0,38 | 0,41 | 0,38 |
| | | | CLI(3) | 1,39 | 1,202 | 1,48 | 1,297 | 1,61 | 1,389 | 1,48 | 1,383 |

(1) Reccommended Weight Limit; (2) Lifting Index; (3) Composite Lifting Index

Tab. 3: TO-BE 2 analysis results for 1st movable shelf.

## 5 DISCUSSION AND CONCLUSIONS

This work presents a methodology to ease the integration of a virtual human tool along product lifecycle. Actually, the lack of a structured approach is one of the causes of the limited diffusion of virtual humans tools out of the typical industrial areas in which they were born. To fill out this methodological gap we define the steps required to set-up an ergonomic analysis, manage the data flow among consecutive analyses in an AS-IS vs TO-BE logic, and, finally organize results so that the designers can easily compare different solutions and extrapolate design guidelines for the development of new products.

The application of the methodology to an industrial case study shows the real flow of information along the development process. The synergic use of virtual humans and virtual prototyping techniques allows defining parametric databases of systems and handled products to be used in the virtual scene where the tasks are simulated. Dealing with an organized procedure, designer can concentrate on the development of TO-BE solutions improving ergonomics as well as any other critical aspect of a system.

The case study highlights the importance of an organized procedure and of a quantitative simulation tool to determine which are the main critical points and which direction must be followed to gather the highest benefits. Actually, it may be quite easy to identify an ergonomic issue without any specific tool, but it is not possible to achieve a good design review without a proper virtual humans simulation campaign. Referring to the refrigerated display unit case study, this happened with the design of a first generation of lifting platforms conducted without virtual ergonomic tools. Since forecasting the way a person behaves in relation to a machine is not trivial, expecting to deal with such a complex problem without proper tools may bring to unexpected results. Actually, the first generation of platforms (TO-BE 1) was designed without virtual humans only to improve reachability. All the platforms met this requirement, but in some cases posture and fatigue conditions worsened.

A systematic and organized use of the developed methodology allows designer taking into consideration the multiplicity of issues related to man-machine interface and to make human centered design a normal practice. Human modeling and simulation results permitted to validate alternative design solutions evaluating posture comfort and risk of musculoskeletal diseases, thus operators'

safety, before physically implementing them. Adopting such a methodology, successful technical solutions arise much more easily and, most of all, the system designed can be validated very early in the development process.
In order to perform even more accurate simulations workers' real postures and movements should be retrieved in their workplace. To accomplish to this task we are developing hardware and software solution able to perform low cost motion captures in situ and use data acquired to setup all necessary virtual humans simulations.

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