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Ergonomic design and analysis of a post in a stall

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Abstract

Purpose:
The present work is a study of a street stall, which offers the public newspapers, magazines and books, as well as sweets, crisps, etc, and which has a very reduced space at its disposal for keeping and arranging goods.

Method:
We will apply the design for maximums and minimums based on percentiles. With these facts it was possible to model a stall with the CATIA system which has an ergonomic analysis module for the intended objectives.

Result:
The solution reduces muscular tension provoked by inadecuate positions.

Discussion & Conclusion:
This implied a completely new distribution of the space inside the stall

1 Introduction

The present work is a study of a street stall which offers the public newspapers, magazines and books, as well as sweets, crisps and diverse groceries of this kind, and which has a reduced space at its disposal for keeping and arranging goods.

In this context we will apply the design for maximums and minimums [3] based on percentiles, according to what corresponds, and in this way observe the ergonomic differences between the percentiles economically used for the design of extremes: percentile 5 and 95.

The first step has been the analysis of the current situation, for the purpose of which a survey was done of the owners of an average stall in order to discover the ergonomic problems which appear due to design.

Thus, with the aim of modelling the stall through a design-aided system, measures, photographs and videos were taken about the tasks done by the labourer inside the stall.

With these facts it was possible to model a stall with CATIA system[2], which has an ergonomic analysis module for the intended objectives. Likewise, through the RULA [1] method, about postural analysis, which is integrated within CATIA, it is possible to value the different positions adopted by the stall-labourer, in order to know those which may cause discomforts or lesions and avoid them by means of proposing the new design of the systems that provoke them [5]..

Next, having carried out the analysis, we looked for a viable solution that solved the points at issue shown by the RULA analysis and the observation practised. This implied a completely new distribution of the space inside the stall. A system has been designed for the storing of small goods (sweets or chewing-gums, among others) which solves the problems of reaching caused by the height excess or for being too low[10]. The labourer legs location zone has also received a special treatment since it is a zone that had reaching problems where, through a series of raising and retractile platforms, the space available has been optimized, distributing it between the storage of goods and the space necessary for placing the legs.

Finally, we prepared a new ergonomic study applied to the solution proposed, leaving the conflictive points within acceptable margins according to the stated by RULA analysis.

2 Security rules at work

A work environment adapted to the worker does not affect only his health, but it will also affect his productivity [6]. It is widely known that those environments that causes dissatisfaction, pain or discomfort in the worker, will cause a decrease in efficiency and in the quality of the product or the service. Ergonomics gives solution to those work conditions which cause health disorders in the worker. These disorders can be of several kinds [5]: hearing ones, nervous ones, psychological ones, or as in the case that concerns us, skeletal muscle ones.

Likewise, as a work consequence, we can consider temporary, normal yet unavoidable, or chronic disorders, which interfere with activities, or remain daily and must not be considered an acceptable work consequence.

In view of the subsequent ergonomic analysis, we will focus on skeletal muscle disorders. These disorders are recognised as an important work health problem, and can affect mainly to:

- Tendons.
- Nerves.
- Ligaments.
- Muscles.
- Cartilages.
- Joints.

- Spinal discs.

The main causes of these affections are [3] [9] [10]:

- Repeated efforts.
- Swift movements.
- Great force.
- Contact stress.
- Extreme positions.
- Vibration.
- Cold.

2.1 Integrated ergonomic programme.

Given the complex nature of skeletal muscle disorders, there is not such a model that adjusts to all possible cases for the purpose of tackling the decrease in their incidence and seriousness.

Faced with the diseases caused by repeated movements or efforts, we recommend carrying out an integrated ergonomic programme [8] consisting of:

- Evaluate the tasks under suspicion of possible risk factors.
- Recognise the problem.
- Identify and evaluate the causes.
- Seek possible solutions.
- Involve well-informed workers as active participants.
- Take care of the health of the workers with skeletal muscle disorders [5].

2.2 Control measures

It will be necessary to carry out a surveillance and evaluation of the medical and health information, for which purpose engineering and administration controls will be performed.

The goal of engineering controls is to eliminate or to reduce risk factors at work, whereas the aim of administrative control consists of lessening the risk reducing the time of exposure.

Engineering controls:

- Work engineering methods: eliminate unnecessary efforts and movements [4]:
-Time study.
-Movements analysis.
-Mechanical help: to eliminate or reduce the efforts required for manipulating tools, objects, etc.
-Tools design and selection: reduce the force required, the time of handling, and improve positions.
-Maintenance and Quality Control Programme: reduce unnecessary forces and efforts linked to unuseful work.

Administrative controls[3] [9]:

-Work guidelines allowing workers to take breaks or extend them as necessary and at least once an hour.
-Redistribute tasks (rotate, share out): a worker must not perform large task requests during a whole day.

2.3 Position ergonomics principles: working area location

A correct height of the hand-working zone facilitates work efficiency and reduces tiredness [6].. The majority of work operations are better performed near the elbow level.

If the working surface is too high, the neck and shoulders become rigid and painful, since the arms must be kept elevated. This occurs both in a standing position and in a sitting position. If the working surface is too low, it is easy for pain to appear in the low part of the back, since the work is done with the body bent forwards [10]. This becomes a serious matter when standing. Sitting down for a long time, a work height too low causes aches in the shoulders and the back. How can these situations be corrected? How can these situations be corrected? [9]

1. For sitting workers, the working surface height should be at the elbow level approximately. When downward forces are applied, the working surface height should be slightly under the elbow level. If a keyboard is used, the height at which the fingers work should be at the elbow level, or slightly under it.
2. An exception must be made with the precision work while sitting. In this case, the object can be somewhat upper the elbows so that it allows the worker to see fine details. In this case an armrest must be provided.
3. For standing workers, their hands should be somewhat under the elbows. For tasks requiring exactness, the elbow level can be the most suitable. In light tasks of assembly or packing of many objects, the hand level should be around 10-15 cm under the elbows. An even lower height is the most appropriate when an important force is required, so that the body weight can be used. Nonetheless, a too low work height should be avoided, which may cause pain at the lowest part of the back.
4. Where possible, use an adjustable work table, for instance, a raising table with a hydraulic device for raising or lowering it [11].
5. Use under the tables, work surfaces or elements, a wooden platform, or a similar flat structure, in order to raise the hands working position. Make use of platforms under the feet or of the chairs to lower the real work height in relation to the elbow level. These adjustments are very effective.
6. Place the tools and controls used frequently in the prominent area for the hand movement (at the elbow level, between 15 and 40 cm in front of the body, and no more than 40 cm towards the sides).
7. Place all the materials frequently used inside this prominent area or at its border. When the materials are supplied in boxes or buckets, or in pallets or shelves, they should be placed in an easy reaching area around the elbow level.
8. In similar job positions, arrange the tools, controls, materials and other elements layout in such a way that they are all well combined. For example, when different kinds of materials are collected at the same time, or some after the others, place them inside the same area in different containers. Standardize the placement of all these elements taking into account the workers opinions.
9. If it was suitable, divide the surface of the work table into areas for the different tasks, so that the operations are done in sequence. These guidelines will be the ones applied in the stall work ergonomic study which concerns us, naturally those which are relevant, taking into account that the previous are general guidelines to be put into practice in this particular case.

2.4 Design principles

When it comes to doing the design or the modification of a work position, it must be taken into account if it Hill be used by just one person or by more. In the first case, the specific anthropometry of the person who will be in it Hill be taken into account, and in the second case, it will have to be designed considering the anthropometry of a group of individuals, which can be performed in several

ways according to the cases. We will confront thus before the following possibilities [3]::

Design for the extremes.
Design for an adjustable interval.
Design for the average.
Design based on the use of percentiles.

2.4.1 Design for the extremes

It is taken into account the size of the person in worse conditions for the use of the system which is being designed.[3]
For a better understanding we will make use of two examples:
a) Location of a front panel to be used by hand for a determined number of people.
- The person with the lowest arm reach will mark the distance to the panel.
- If we design for the minimum, everybody will reach.

b) People passing doors height:
- The tallest will be the ones who will hit their forehead if the design does not consider them.
- It is necessary to design for the maximum.

2.4.2 Design for an adjustable interval

This is the best type of design, since in principle everyone will be able to adapt the design to their own size [3]. Seat height for a determined number of people:

- Lower limit for one with the lowest popliteal height.
- Upper limit for one with the highest popliteal height.

Everybody could adjust the seat height to their necessities.

2.4.3 Design for the average

This is another criterion for tackling certain types of design; to be used when there is no knowledge about the people who will be using the system in study or the number of individuals [3].
For example: Teaching classroom bench seat height.
We will calculate the average popliteal height of a certain population, either through tables already published, or through one obtained by an anthropometric study of that kind of population.
Nonetheless, if the average is used, there will be people whose feet will be hanging, and others whose knees will be too high.

2.4.4 Design based in the use of percentiles

When we design using percentiles to select certain system measures, we take into account almost all the population that will use that system. It is a method that combines the design for maximums and minimums with a selection of the population which leaves out of those designs a very small percentage, but which makes that design to have a reasonable manufacturing price [3]] [9] [11].
The question we ask ourselves in these cases is, for example: how high should submarine cabin doors be for a 95% of the population not having any access problems? As space is limited in a submarine, it must be adjusted in this way.
When the population is very large, it is impossible to measure every person. A representative sample of the population is selected, which will be larger or smaller according to the desired error. Anthropometrical data tends to a normal distribution. The sample measures are taken and the average (X) and the standard deviation (s) are calculated statistically from each dimension of the population.
In the same manner we can calculate the most used percentiles in anthropometric design, which normally are 5% and 95% for minimums and maximums respectively. It is also normal to find 10% and 90% and even 1% and 99%.
According to the couple of percentiles selected, that assures us that in the first case for example, the chosen design can be used by those whose measures are between 5% and 95%; thus leaving out of comfortable use 10% of the population.

Fig. 1- 5%,50% and 95% percentiles from men and women.

3 Data acquisition process

To perform the task which concerns us, we studied a stall from the city of Valladolid, precisely for putting into practice the design based on percentiles and thus observing the differences as far as ergonomics is concerned between percentile 5 and 95.
The first step was conducting a survey of the owners of these stalls in order to discover the ergonomic problems of those on account of the design.
Next, we took measures, photographs, and videos of the tasks performed by the worker inside the stall.
This allowed us to model the stall with the program CATIA v5 [2], with its modelling and ergonomic study modules. With the photos and videos taken, we obtained part of the necessary information for performing the ergonomic study.
Next, [7] with the data obtained, we looked for a viable solution which would solve the conflictive points. We performed a new ergonomic study with the solution given.
We verified that the main problems of the worker are the ones caused by the limited room available in the stall, that's to say, the room distribution for goods storage and consequently the bad positions which are made compulsory in order to reach some goods which may be either too high or too low. It also happens frequently that the person must stand up repeatedly, with the problems which the bad positions adopted in a small interval of time entail [10].
Summarizin precisely the problems found:

- Goods storage
- Very forced positions for high reaching.
- Standing up repeatedly off the seat.
- Lack of space to manage.

4 RULA evaluation method [1]

The continued or repeated adoption of painful positions while working generates tiredness, and in the long run can cause disorders in the skeletal muscle system. This

static or postural weight is one of the factors to be taken into account in the evaluation of the work conditions, and its reduction is one of the essential steps to adopt within job improvements.

RULA method (Rapid Upper Limb Assessment) was developed at the University of Nottingham in 1993 (Institute for Occupational Ergonomics) in order to evaluate workers exposition to risk factors which may cause disorders in the body parts subjected to tension [1].

RULA evaluates concrete positions; those implying a greater postural weight must be evaluated. The method application begins with the observation of the worker's activity for several working cycles. From this observation we must select the most significant tasks and positions, either for its length, or for presenting beforehand a greater postural weight. These will be the positions evaluated.

RULA divides the body into two groups:

Group A, including upper limbs (arms, forearms and wrists).

Group B, covering the legs, the trunk and the neck.

By means of the tables associated to the method, a marking is assigned to each corporal zone (legs, wrists, arms, trunk…) for, according to those markings, assigning values to each group A and B.

The code for the marking assignation to the limbs is the measuring of the angles forming the worker's body parts. The method assigns for each limb the angle measuring form.

Subsequently, the global markings of the groups A and B are modified according to the type of muscular activity performed, as well as to the force applied while the task is being performed. Finally, we obtain the final marking from those modified global values.

The final value given by the RULA method is proportional to the risk entailed by the task performance, so that higher values indicate a greater risk of appearance of skeletal muscle injuries.

There are tables for the manual application of the RULA method, but in this case we will do it through the CATIA program in its ergonomic analysis module, which will provide us with the results of the studied positions with the modelled figures with the proposed percentiles, and all this around the stall modelled with the data obtained from reality.

5 RULA ergonomic study[2][1]

Next we will study the critical cases detected while observing the job done by the stall worker. The most difficult positions for ergonomic study are those in which the objects are placed further from the arm reach or in the most inaccessible spots, which require crouching down or stretching. These are:

Case 1) Crouching down at the window area.
Case 2) Taking object from a shelf.
Case 3) Stretched.
Case 4) Using the cash register.
Case 5) Exchanging money or goods.

In all cases the person must be studied from both sides of the body, that is, from the left and from the right. Moreover, it is necessary to determine the efforts for men and women, since both sexes do not have equivalent measures; and finally verifications must be done for two extreme percentiles, such as 5% and 95%.

In the first place, we have modelled the stall, obtaining the configuration represented in figure 2.

5.1 Crouching down at the window area.

Man percentile 95: Next we can observe a man belonging to percentile 95 at the position crouched and the result of the RULA analysis:

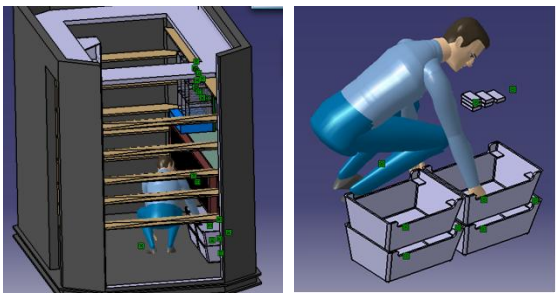

Fig. 2 Man P 95%, crouching down at the window area.

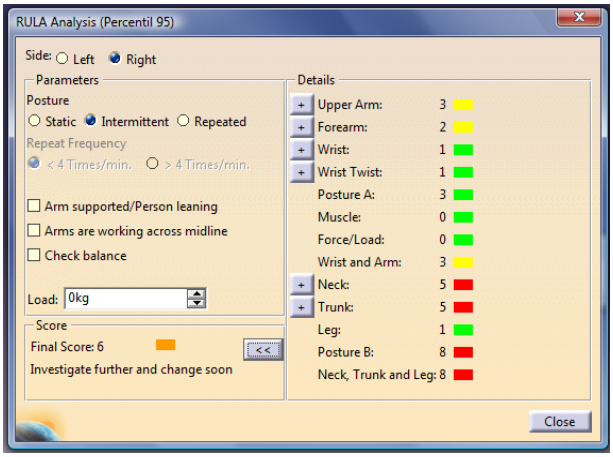

Fig. 3 Man and woman P 95%, crouching down at the window area. Right side.

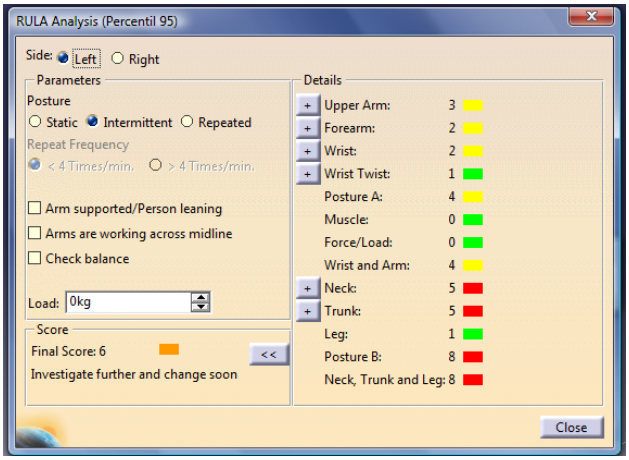

Fig. 4 Man and woman P 95%, crouching down at the window area. Left side.

The result indicates us that both in the right side of the body and in the left one, the trunk and the neck are in a harmful position which is necessary to correct as far as it is possible. The most affected areas are the neck and the trunk.

In the case of the man and woman of percentile 5% we obtain identical results in this position; necessity of correcting conditions in the neck and the trunk.

5.2 Taking object from a shelf.

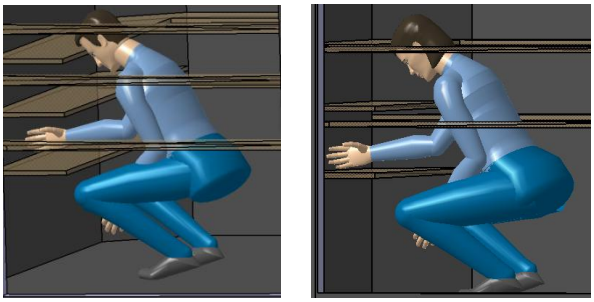

Fig. 5 Man and woman taking object from a shelf.

We will now observe a case similar to the previous one, the worker crouches down to take an object from a shelf.

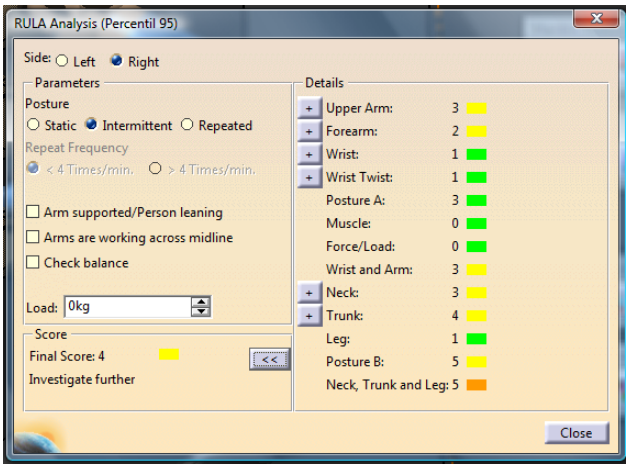

Fig. 6 Man and woman P 95%, taking object from shelf. Right side.

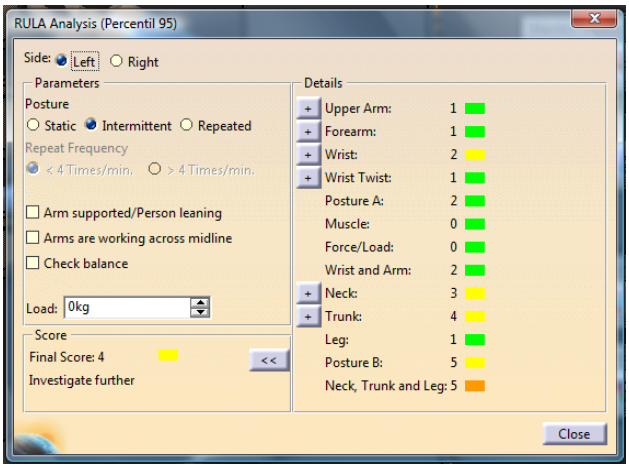

Fig. 7 Man and woman P 95%, taking object from shelf. Left side.

In the case of percentile 5% both in man and woman and in both sides of the body, left and right, the result is better. The item “Neck, Trunk and Legs” is obtained in yellow. Nevertheless, the assessment of the square “Score” is also 4 in yellow, meaning that it is not at its best and it is necessary to intervene to avoid those tensions.

5.3 Stretched

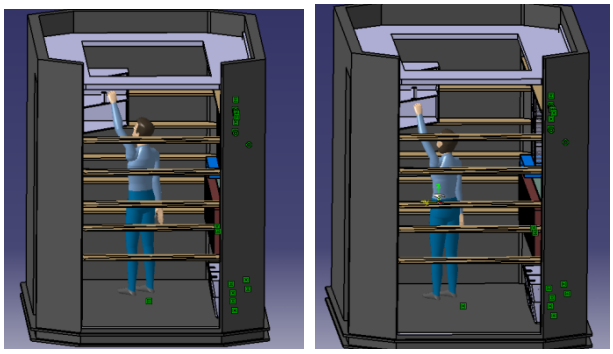

Fig. 8 Man and woman P 5%, stretched.

In this case we will study firstly percentile 5% for being in worse conditions to reach objects from a high place.

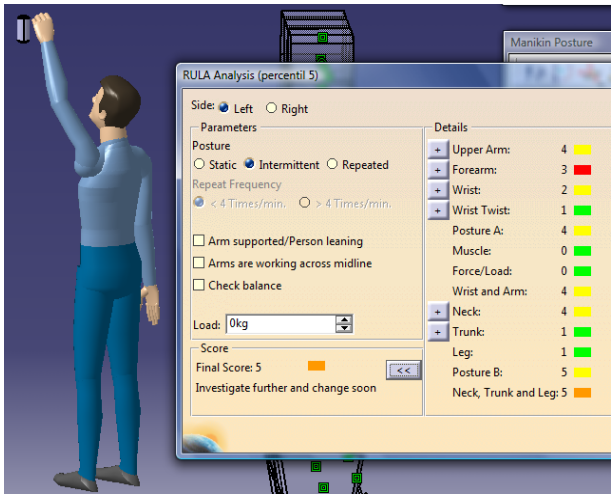

Fig.9 Man P 5%, stretched. Left side.

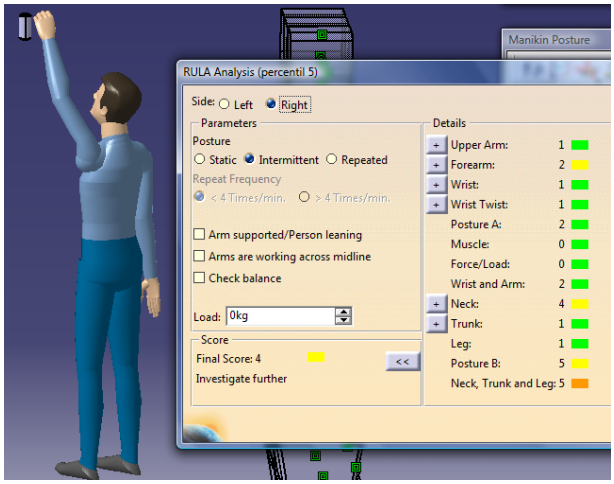

Fig.10 Man P 5%, stretched. Right side.

As we can observe, the raised arm is the one showing problems due to the effort required to reach the tin. The arm which rests does not have any problem.

In the results which we can observe next, we can appreciate how in the case of the woman the same problems appear than in the man’s case, but also the reach is smaller.

Following we can see the reaching area of each of them, and the correspondent ergonomic study.

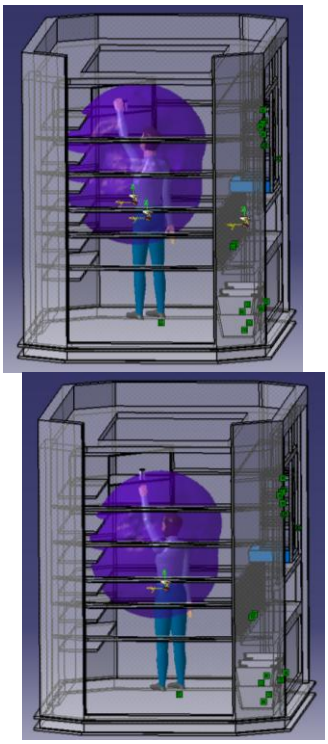

Fig. 11 Man and woman percentile 5% reach, stretched.

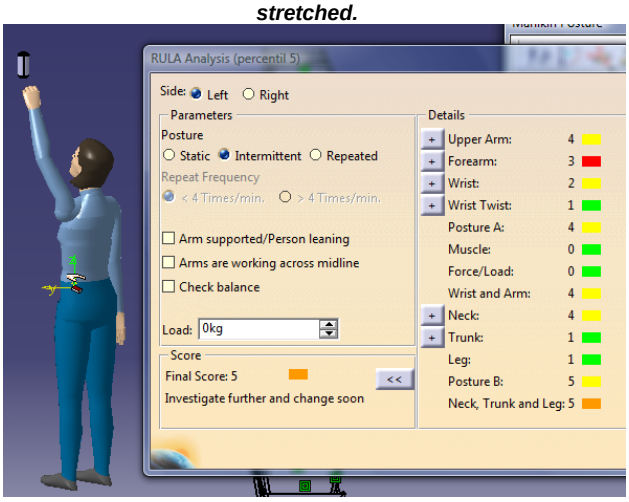

Fig.12 Woman P 5%, stretched. Left side.

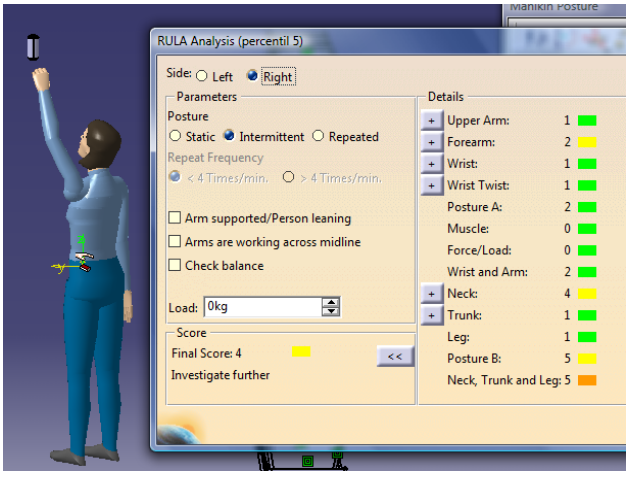

Fig.13 Woman P 5%, stretched. Right side.

For percentile 95% results are repeated as in percentile 5%, so there is the same need to intervene to avoid tensions detected mainly in the raising arm. The only difference is that people with percentile 95% have greater reach.

5.4 Using the cash register.

The following case studied is the one where the model uses the cash register, since it is one of the most frequent movements. It will be studied for men and women, and for both percentiles 95% and 5%.

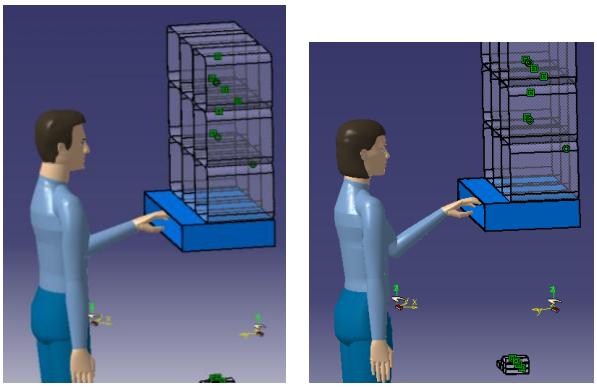

Fig.14 Man and woman P 5%, using the cash register.

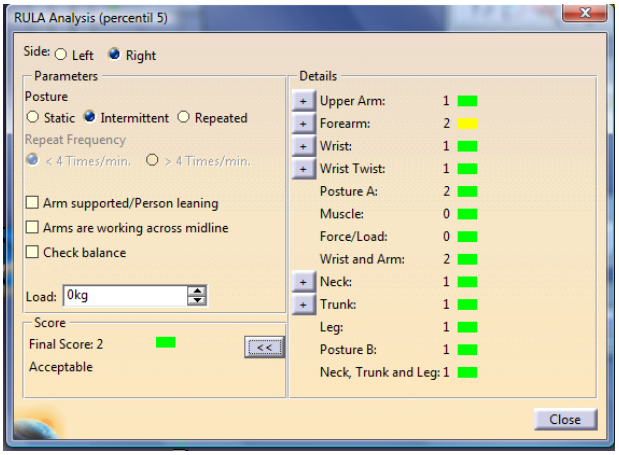

Fig.15 Man and woman P 5%, using the cash register. Right side.

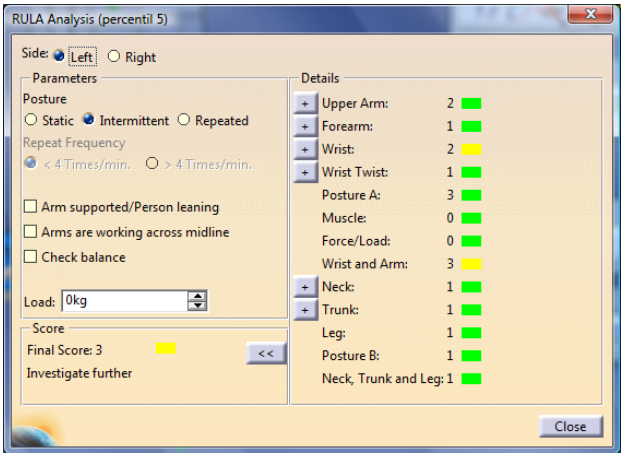

Fig.16 Man-woman P 5%, using the cash register. Leftt side

In the case of the woman with the percentile 5% exactly the same results are repeated than with the man.

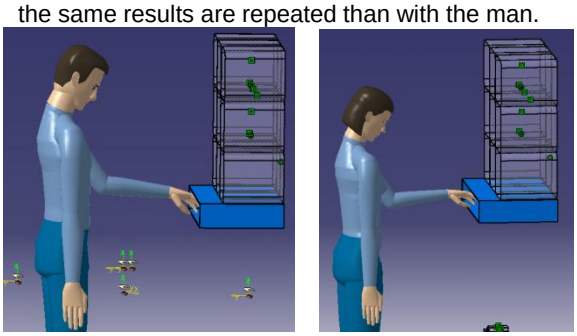

Fig.17 Man and woman P 95%, using the cash register.

If we observe simultaneously figures 18 and 21, the people with percentile 5% have their forearm raised, whereas in the ones with percentile 95% the forearm descends.

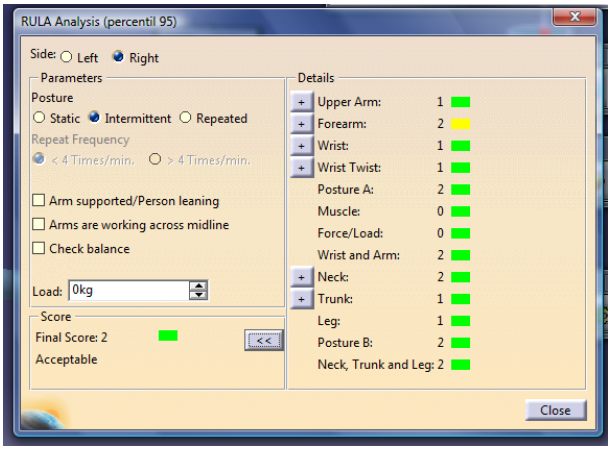

Fig.18 Man P 95%, using the cash register. Right side.

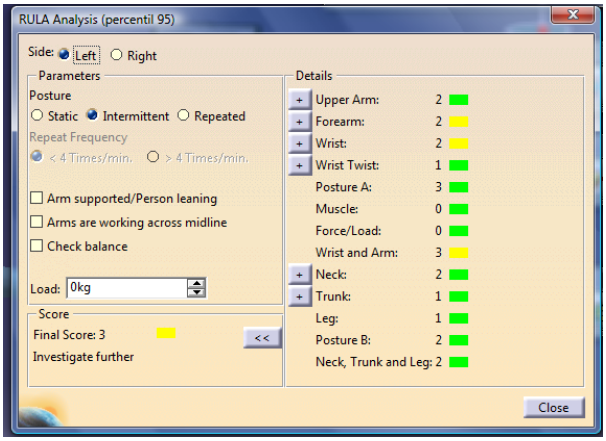

Fig.19 Man P 95%, using the cash register. Left side.

Again, the results of the RULA analysis for women are the same of the men's with percentile 95%.

Although individually both wrists are in tension, globally we merely find problems in the left one. As a conclusion to the results set, we can say that the greatest problems are in the crouching position for percentile 95%, and in the stretching position of percentile 5%, which also adds to the scarce reach towards objects at a certain height.

5.5 *Exchanging money or goods.*

The last case to be studied is the exchange of money and goods between the worker and the client.

Fig.20 Man and woman P 5%, exchanging money or goods.

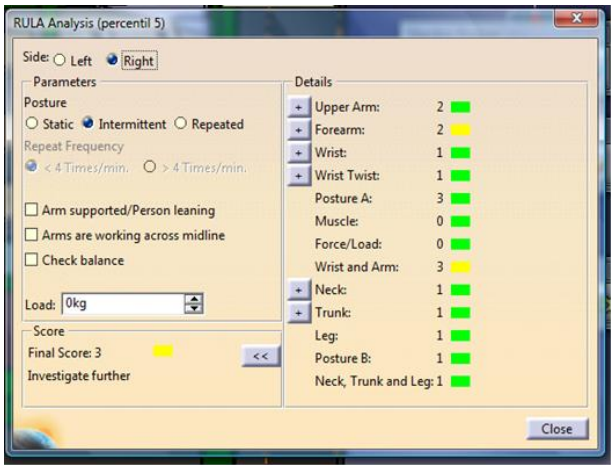

Fig.21 Man P 5% and women P95%, exchanging money or goods. Right side.

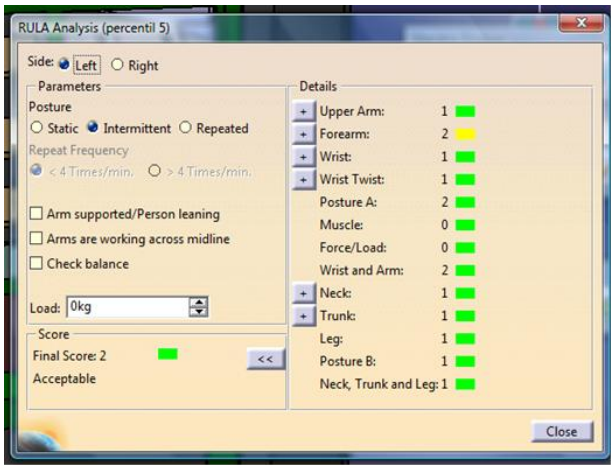

Fig.22 Man and women P 5% and 95%, exchanging money or goods. Left side.

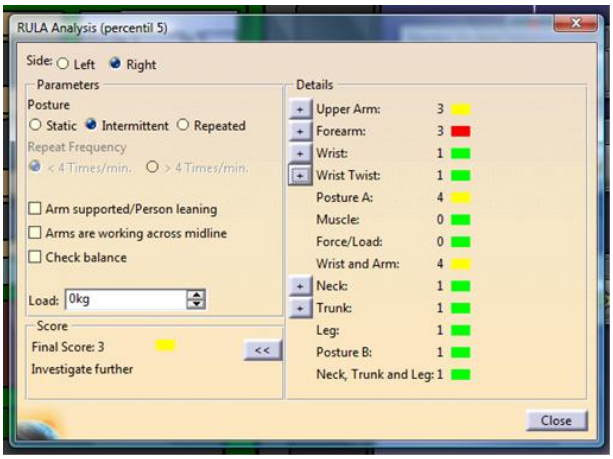

Fig.23 Woman percentile 5% and men P95%, exchanging money or goods. Right side.

This case of exchanging of money and goods implies the worst situation due to the tension in the forearm.

6 Proposed solution

We propose solving mainly the two worst situations, which are the one of crouching and the one of stretching.

The goods which are placed in low positions require being raised at the moment of their obtaining; therefore, to eliminate this problem, we propose a good storage with buckets, that is, perfectly valid for small merchandise such as sugary smacks, sweets, and chips bags. The buckets must be moved with the hand; that way whatever needs to be taken will always be at the adequate height, the most comfortable one.

In figure 25 we show a basic proposal of the solution adopted.

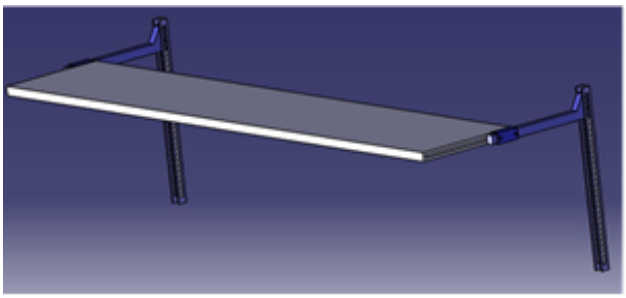

Fig.24 Raising and extraction system.

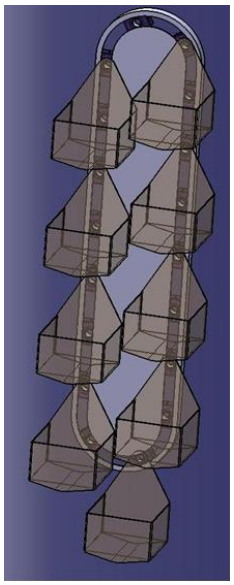

Fig.25 Buckets system.

The other critical situation is when the person must crouch down. To avoid this situation, in the low part of the stall counter we propose a rising and movement mechanism as in the one of figure 24, in which the platform rises with electrical engines in the vertical guides, and it is extracted horizontally by the horizontal guides.

6.1 RULA analysis of the solution adopted

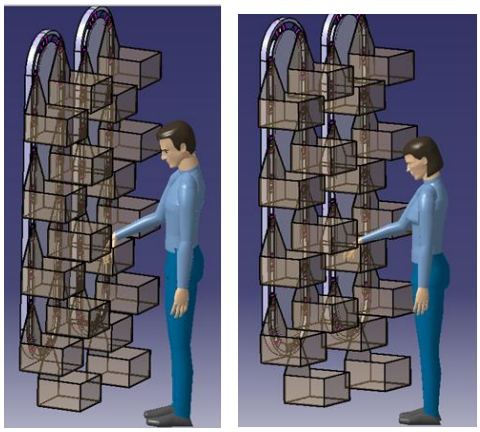

Fig.26 Man and woman taking goods.

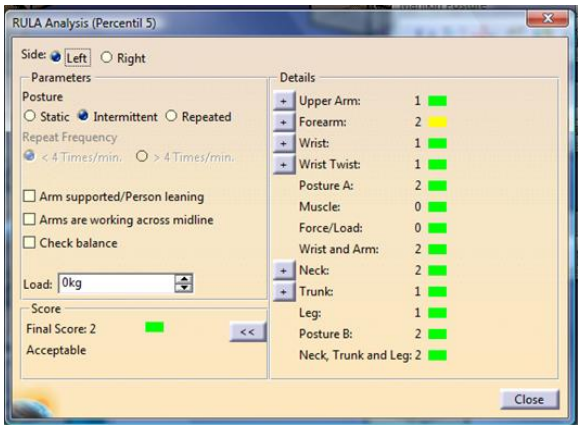

Fig.27 Man and woman P5% and P95% taking goods. Left side.

If we observe figures 27 and 28 [2] [7], in both cases we have eliminated the situations with high tension, since in all cases and in both sexes the goods can be obtained in a vertical position. The left side presents a global assessment of 2 (green colour) and the right one a value of 3 (yellow colour).

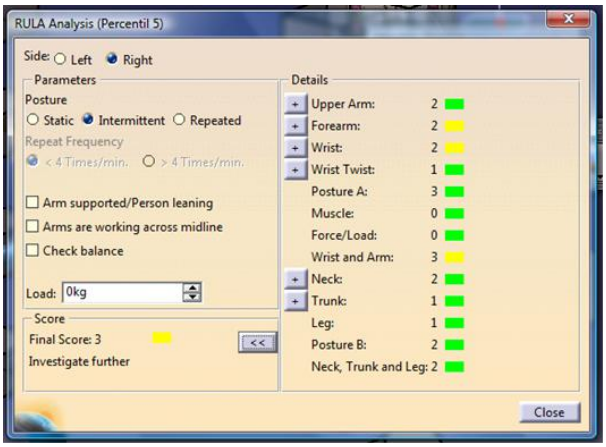

Fig.28 Man and woman P 5% and P95% taking goods. Right side.

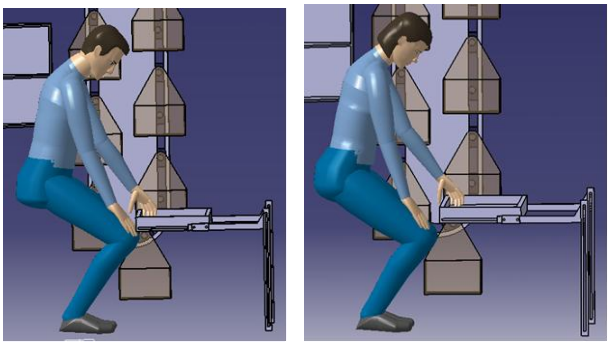

Fig.29 Man and woman taking goods.

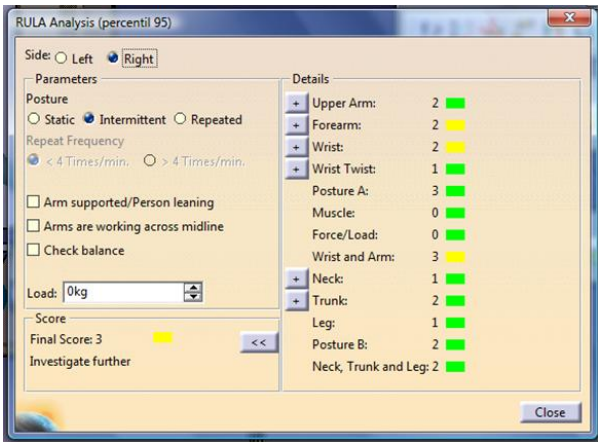

Fig.30 Man and woman taking goods under the counter. Right side.

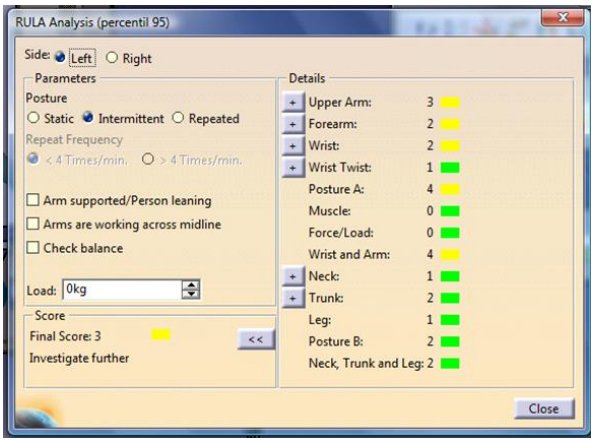

Fig.31 Man and woman P 5% and P95% taking goods under the counter. Left side.

7 Conclusion

As we can confirm in the RULA [1] analysis of the solution proposed, the most important tensions detected (red colour) in the forearm, the trunk, the neck and the item "Neck, Trunk and Legs" have disappeared or have been reduced to a small value of 2 or 3 (yellow colour) [2].

The technical solution of the basic solution proposed is manageable in a technical study, and probably it will not be difficult to project, where even the buckets with a flat performance (trays) may be used to store papers, magazines and books. This would help in organising practically the whole of the goods.

References

[1] Metodo RULA. Website: http://www.ergonautas.upv.es/metodos/rula/

[2] Manuales de CATIA. Ayuda en línea en el programa.

[3] Mondelo P.; Gregory,E.;Barrau, P. Ergonomía 1. Edicions UPC.1997.

[4] Ministerio de trabajo e integración. Lista de comprobación ergonómica. Ergonomic checkpoints.

[5] Instituto de Biomecánica de Valencia y Mutua Valenciana Levante. Evaluación de riesgos laborales asociados a la carga física en el sector comercio-alimentación Nº 17, 2002, pág. 17-21.

[6] Yuste García, Pedro Método de diseño y evaluación ergonómica de puestos de trabajo.

[7] Martínez Ramos, Antolín Estudio ergonómico de un puesto de cajera de supermercado. Adaptación a personas con movilidad reducida. Proyecto fin de carrera. Escuela de Ingenieros Industriales de Valladolid. Spain.2007.

[8] Instituto Nacional de Seguridad e Higiene en el trabajo website. http://www.insht.es/portal/site/Insht/ accessed 10 Feb 2011.

[9] .Mapfre. Manual de ergonomía. Ed Mapfre 1997.

[10] .Michelè Esnault, Eric Viel. Lumbalgias y cervicalgias de la posición sentada: consejos de ergonomía y ejercicios de fisioterapia.

[11] .Prevención de riesgos laborales. Ergonomía y psicología aplicada. Edita: Servivios Técnicos de Prevención. Depósito. Legal: AS-2.994-2005.