Ergonomic Evaluation of Physical Risk for Packing Line Operators

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One of the elements of the logistics system is the subsystem of production, which is composed of physical elements such as machinery and equipment, tools, and, most importantly, people. In addition, systems dependent on the human-operator are particularly prone to problems related to: discomfort, ensuring production quality, increases in training costs and absence. The aim of the study was to assess the exposure of upper limbs to musculoskeletal disorders (MSD's) in the sequential packaging of a product, and the analysis of risk factors.
Material and methods: To conduct the evaluation, the occupational repetitive action (OCRA) checklist method was applied. Rated activities related to the sequential packaging of furniture in positions located at the conveyor belt.
Results and conclusion: High risk ratings occurred at two sites, whereas three were rated as medium. The main risk factors influencing the negative evaluations were: insufficient number of breaks, preventing the staff from getting sufficient rest and a short cycle - less than 15 seconds - due to the pace forced by the conveyor belt. Manufacturing engineers and specialists in the field of health and safety should pay particular attention to the organization of the packaging process, and should develop and implement a rotation system, taking into account the load of the upper limbs.

Keywords: transportation OCRA, workload, ergonomics, risk, MSDs.

1. INTRODUCTION

One of the elements of the logistics system is the subsystem of production, whilst the basic elements (resources) of each work process are: people, means of work and work items [Słowiński 2008]. In turn, production systems are defined as a complex system of physical items such as machinery and equipment, tools, and , most importantly, people. Employees in the manufacturing system are "internal consumers" and the system must be designed to meet their needs. At the same time, production systems must produce goods that meet the needs of the "external consumers". In terms of health and safety, the production system is designed to meet the needs of both internal and external consumers [Black 2007]. In addition, production systems dependent on human-operators are particularly prone to problems related to: work safety, discomfort, ensuring production quality, and increased training costs and absence [Kasvi et al. 2000].

Work performed by people is accompanied by exercise, which can cause the appearance of discomfort from musculoskeletal disorders (MSD's) among workers [Vieira and Kumar 2004, Wang et al. 2014], in the form of health problems [Lasota 2001, Lasota 2008a, 2008b]. Studies have shown that the posture of the employee at work, range of motion, strength, repetition and duration must be taken into account when categorizing the level of physical activity [Kumar 1994]. Posture and load on the operator during movement are important variables that must be taken into account in considering the safety of the work, because they are the two most important factors that determine the burden on the employee. The posture of the worker whilst performing his job is influenced by factors such as task accomplished, work, work tools, their design and the anthropometric characteristics of workers [Vieira and Kumar 2004].

Research techniques proposed for estimating the level of discomfort and load profiles associated with employees taking different postures while working can be divided into observational techniques and those based on devices. In the case of observational techniques, the angular deviation of body segments from the neutral position is achieved by means of visual observation, whereas in techniques based on instruments continuous monitoring of body posture is performed by devices connected to the employee. Due to the lack of interference with the labour process, low cost and ease of use, observational techniques are more commonly used in industry [Genaidy et al. 1994].

Observational methods used to assess postural load on the employee include: the Ovako Working posture Analysing System (OWAS) [Karhu et al. 1977], Rapid Upper Limb Assessment (RULA) [McAtamney and Corlett 1993] and Rapid Entire Body Assessment (REBA) [Hignett and McAtamney 2000, Lasota 2006]. All methods were developed for different purposes and therefore they are used under different workplace conditions [Kilbom 1994]. Each technique has its own approach to operator classification, which differs from the other techniques. This can cause variance in the final result for the load of the operator, depending on the technique used.

The publication of scientific studies illustrates the usefulness of such techniques in assessing the posture of workers in different environments such as warehouses [Torres and Vina 2012], construction [Li and Lee 1999] poultry industry [Scott and Lambe 1996], operation and maintenance of vessels [Joode et al. 1997], beverage distribution centres [Wright and Haslam 1999] metalworking [Gonzalez et al. 2003] wood [Jones and Kumar 2007], fish processing [Quansah 2005] clothing factories [Forcella et al. 2012], steel industry, electronics, automotive and chemical industries [Kee and Karwowski 2007, Lasota 2013a, Lasota 2013b, Lasota and Ścigaj 2013, Lasota 2014, Muthukumar et al. 2014, Sesek et al. 2004, Wang et al. 2014], etc.

Modern production systems featuring assembly lines and packing lines are often equipped with a conveyor belt for transport. The performance of such a system is determined not only by the technical subsystem, but also by the human subsystem. From an ergonomic point of view, a key element affecting workers and the efficiency of workflow is that of improper positions taken during work. In particular, this can be affected by excessive load. Discomfort in the human system can lead to problems associated with the provision of production, quality and an increase in costs related to sickness absence due to the negative impact of work on the health of workers. Hence, an essential element of ergonomic assessments is the detection of risks that require ergonomic intervention to improve the efficiency of the system.

This study focuses on one case relating to the packaging of furniture for positions located at the conveyor belt (Figure 1, Figure 2), which allowed for a detailed investigation on the interaction of employees with each element of the task. Due to the fact that employees perform the work manually, a set of methods was used including interview, task analysis and the OCRA checklist. The OCRA checklist is an observational technique which, in conjunction with the observation method, allows quick assessment of exposure of upper limbs in the work which is repetitive.

The aim of the study was to assess exposure of the upper limbs to MSD's in the process of sequential packaging of a product and conduct an analysis of risk factors.

2. RESEARCH DESIGN AND METHODS

2.1. RESEARCH DESIGN

This case study was carried out in the packaging section of an enterprise in the furniture industry located in western Poland. The study was limited to the packaging of a table as a final product. The evaluated system consisted of 5 stations located at the conveyor belt. Work took place in a standing position, in three shifts with a working time of 8 hours per shift. The sample consisted of 15 men with a mean age of 28.2 years, standard deviation (SD = 4.1) and years of work experience – 9.7 (4.1) years.

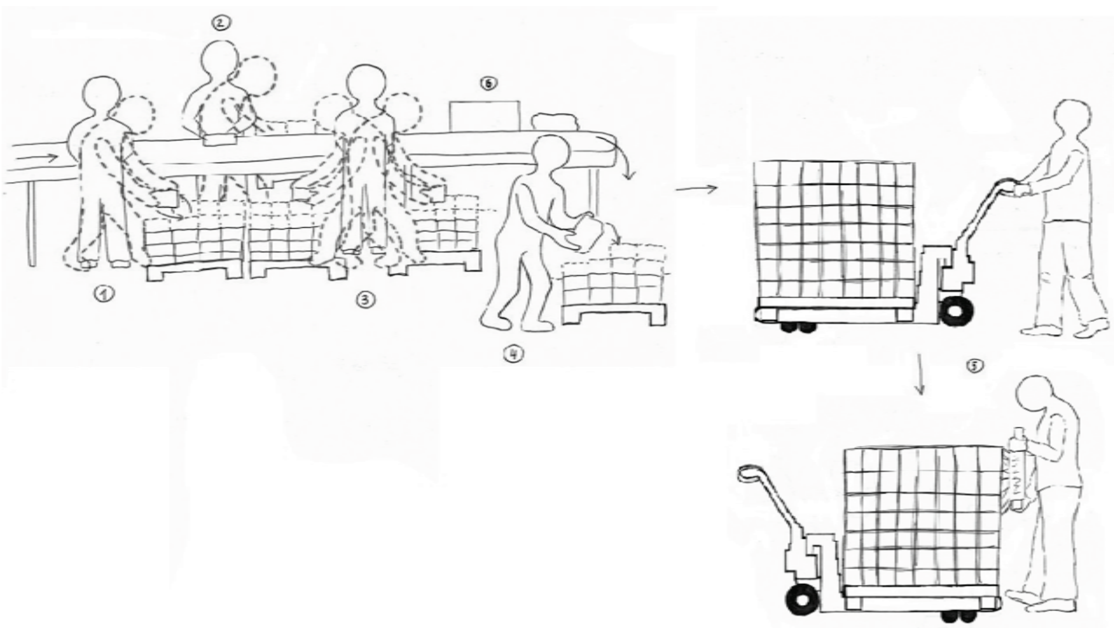

Fig. 1. The packing line – front view.

2.2. PROCESS AND TASK DESCRIPTION

The packaging process takes place in accordance with a technology card developed by the technologist in the following sequence: first, the tabletop is placed on the conveyor belt. Next, the legs are placed in position, followed by the fittings and boxes with screws. Then, the arranged elements are sent into a thermo-heating machine which shrink wraps the entire piece of furniture. The packaged product is removed from the conveyor belt and laid on a pallet. Following this, the pallet is protectively wrapped with cardboard corners and plastic foil. The system under assessment consisted of five stations located at the conveyor belt:

- positioning the table top: the job was to transfer a part (the tabletop) from the palette, check the quality and place it on the conveyor belt. The pallet with elements was situated on the floor. Initial handling height was approximately 1.3m (full range); as the number of elements decreased this was reduced to a level of 0.2m. Each tabletop weighs about 3 kg;
- placement of legs: the task of the worker was to check the quality of the legs, which were obtained from a palette, and then place them in a suitable manner on the conveyor belt, next to the tabletop. A palette with legs was provided for the employee. Initially, the height of handling was about 1.4m (full range); as elements decreased this was reduced to a level of 0.2m;
- placement of hardware: the work consisted of placing fittings and boxes of screws on the conveyor belt. Initially, the level of handling was about 1.4m (full range); as elements decreased this was reduced to a level of 0.2m. The employee checked the correctness of positioning of parts by the previous employee and their completeness;
- placement on the pallet: the job was to seal the finished, packaged table with tape and transfer it to the prepared palette, checking the quality of the previous product to ensure that the shrink wrap was undamaged;
- protective wrapping: for this task the employee had to obtain the pallet from the stack of pallets and place it at the end of the conveyor belt where the employee from the "Pallet loading" position placed packed tables. When the pallet was full, the worker moved it to the side using a hand forklift. The pallet was then secured by placing cardboard corners, laying a cardboard sheet on top of the set and sealing the whole consignment with plastic foil. After protectively wrapping, the pallet was moved to the designated place.

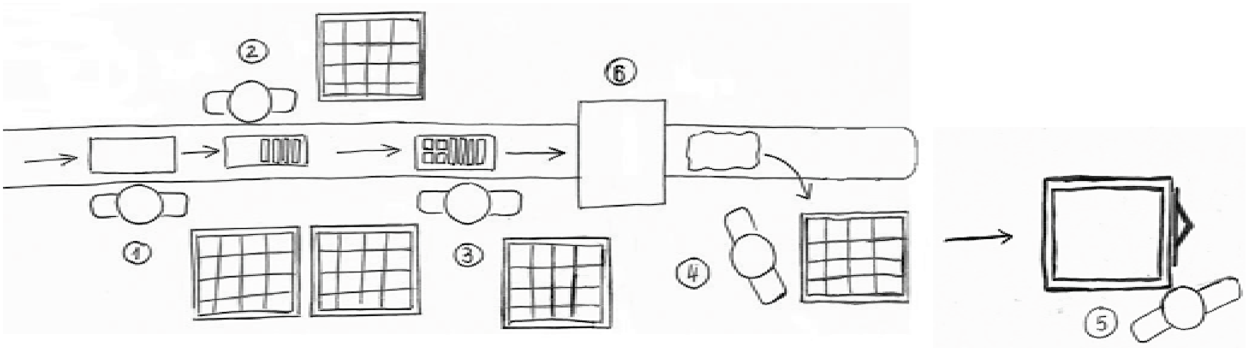

Fig. 2. The packing line – top view.

2.3. DATA COLLECTION

Several techniques were used to collect data in this study: observation, interviews, and task analysis and checklist evaluation.

2.4. OBSERVATIONS, INTERVIEWS AND TASK ANALYSIS

Observation of the tasks carried out by employees was preceded by an interview with the manager and employees to understand the process of work and the activities performed by employees. A hierarchical task analysis [Annett 2004] was used to identify the activities performed by the packers. Five tasks were identified in the activities performed by employees.

2.5. THE OCRA METHOD AND RISK EVALUATION

The occupational repetitive action method (OCRA) was developed in 1996 [Occhipinti and Colombini 1996], and in the following years was improved until in 2007 it became a standard [BS EN 1005-5, 2007]. The method exists in two versions; the OCRA Index and the OCRA Checklist. Both versions of OCRA methods are techniques of observation and are primarily intended for use by healthcare professionals: occupational health and safety operators, ergonomists, time and methods analysts, and sufficiently qualified production engineers, who have the knowledge of production processes necessary to apply the methods in preventing the occurrence of MSD's and improve production processes in this respect. In addition, both versions are designed to analyze the exposure of the upper limbs of workers performing various tasks and take into account risk factors such as: repetitiveness, force, awkward postures and movements, lack of recovery periods, and other factors, defined as "additionals". Additional risk factors include exposure to: vibration, precision movements, glove use, mechanical compression, and cold stress. OCRA generates a synthetic evaluation index, which should also be considered when developing the method of employee rotation for given positions. In addition, the OCRA index may be a harbinger of musculo-skeletal evaluation for upper limbs. The OCRA checklist is based on the OCRA index, and is easier to use, and generally recommended for the initial selection of the workstations featuring repetitive tasks [Colombini 2002]. The result is obtained by summing the indicators of frequency, force, posture, and additional factors. Weighting is added to the scores for lack of sufficient recovery and task duration variables, producing the OCRA Checklist. A summary of exposure scores estimates the actual exposure level (Table 1).

Table 1. OCRA checklist score.

Checklist Score	Exposure Level
<=7.5	no exposure
7.6–11.0	very low exposure
11.1–14.0	light exposure
14.1–22.5	medium exposure
>=22.6	high exposure

In particular, the OCRA checklist (see appendix 1) assesses the following risk factors: lack of proper recovery periods (Recovery), repetitiveness (Frequency), use of force (Force), awkward posture and movements (Posture) and other additional factors (Additional).

Recovery - presents six different scenarios to choose from with regard to breaks at work, wherein the assigned numerical indicator corresponds to each proposed scenario for breaks.

A scenario must be selected that suits best the actual conditions.

Frequency - offers seven scenarios with scores from 0 to 10. Each element describes the frequency of technical arm actions in time (slow, quite fast, fast , very fast) with respect to the possibility or impossibility of having short breaks (constant , or inconstant). A scenario must be selected that best suits the actual conditions.

Force – the coefficient of the "use of force" is grouped into three areas. The first group relates to handling and lifting operations for objects weighing more than 3 kg, or items that need to be raised with the hand in an awkward position (e.g. pinching), and whose weight is less than 1 kg. They also relate to the need to use body weight or body parts to perform the operation. Selection of a representative result is associated with the duration of operation in which the use of force occurred. The larger the time to exert force in a cycle, the higher the index value. The second and third group of questions contains a description of some of the most frequently performed tasks which require the use of intensive and moderate exercise, namely: to pull or push a lever, push buttons, close or open, press or handle components and use tools. For activities that require the use of intensive force, the result may be from 4 to 16, depending on how long the effort takes in relation to the length of the cycle. The forces associated with moderate effort indicator may range from 2 to 8, depending on the duration of exercise. The overall result, which is represented by force, is obtained by adding the results of the three areas.

Posture - five blocks of questions describe awkward postures and movements. The first four blocks with letters from A to D describe a separate segment joint (shoulder, wrist, elbow, hand). The last group with the letter E, with a pre-assigned score of 3, describes the occurrence of "stereotypes" meaning the same movements are always repeated for more than 50% of the cycle time. If the cycle time is less than 15 seconds, the "stereotypes" is still 3. In addition, questions about the arms describe how long the arms are kept or moved in uncomfortable positions; wrist - its position and movements (extension, flexion, lateral deviation); elbow - movements (flexion-extension, prono-supination) or sudden movements are required; hand - the type of grip (pinch grip, and palmar grip, or a hook grip). For each scenario, the type of joint or extremity and proportion of task time is taken into account. From the results from each group (A, B, C, D) only the highest score is taken and should form an accumulated result with E category "stereotypes" to form the final result for posture.

Additional – Additional factors are divided into two groups: physical and mechanical (eg. Inappropriate gloves, vibration, pressure, etc.), along with the pace of work, which takes into account whether it is partially or fully imposed by the machine. Subtotals provide additional final result.

Final score. To obtain the final result concerning the assessment of the workplace the partial results obtained for each of the risk factors must be added: recovery, frequency, force, posture and additional.

The tasks carried out by the operators were assessed during routine daily work. In turn, positions taken by each of the workers were evaluated several times. The most unfavourable postures taken by the packers were taken into account.

3. RESULTS AND DISCUSSION

An evaluation was carried out using the OCRA checklist (see Appendix 1), the results of which are shown in Table 2.

Table 2. OCRA checklist score on the packing line.

Work place	Recovery	Frequency	Force	Posture							Additional	Checklist score	Exposure Level
				Shoulder	Site	Wrist	Elbow	Hand	Stereotypy	Tot. Posture score			
1	6	1	8	1	both	0	2	4	3	7	1	23	high
2	6	1	6	1	both	0	0	4	3	7	1	21	medium
3	6	3	0	1	both	0	0	4	3	7	1	17	medium
4	6	1	8	2	both	0	2	4	3	7	1	23	high
5	6	0	6	0	both	0	2	2	0	2	2	16	medium

where workplace:
1 - placing the tabletop; 2 - placement of legs; 3 - placement of fittings; 4 - placement on the pallet; 5 - wrapping the consignment protectively

For all positions, the rating for recovery reached 6 points (from a maximum of 10), since the system of work was such that employees had only one break for lunch during the 8-hour shift. Another factor was the frequency of arm activities: placing the tabletop, legs and placing the complete pack onto a pallet adopted a value of 1 because the arm movements were relatively quick (about 30 movements per minute), however short breaks were possible. In contrast, the position of placing fittings – arm movements were quite fast (about 40 movements per minute), although short breaks were still possible (score 3). In turn, the protective wrapping position adopted a score of 0, because the arms movements were slow (about 20 movements per minute) and short breaks were possible. The force factor for the tabletop placement position and placing the product on the pallet reached a value of 8, as operators manipulated weights greater than 3 kg once every cycle and used of intense force for approximately half the time. When placing the legs and securing the complete set on a pallet, the rate reached 6, because the work required the use of mean force for more than half of the cycle. Only employees in the position of stacking fittings did not use considerable force to lift the elements, therefore in this case the ratio is equal 0.

The assessment of body composition of the employee consists of: shoulder, wrist, elbow and hand, and also takes into account stereotypes and limbs with greater involvement. In this study both upper limbs were involved in the tasks in all workplaces. In the case of the first four positions: placing the tabletop, legs, and hardware on the conveyor belt and placing the packaged product on the pallet, posture was rated as 7 (Total posture score = the highest score from: shoulder, wrist, elbow, hand; + stereotypes), affected by the position of the hands – 4 points, which were kept in an incorrect position during the execution of tasks, and stereotypes which reached a value of 3, as the cycle was shorter than 15 seconds. For the position of securing the pallet, the cycle was almost a minute, therefore frequency has a value of 0, and the indicator of body composition was rated with a score of 2, because the elbows and hands worked in awkward positions but not for long durations. The last element of the assessment was additional factors, which for workers in the first four positions was 1 because the pace of work was set by a conveyor belt. For employees in position 5, the value was 2 as tools caused compression of the skin.

The results obtained show that at two positions: placing of the tabletop and protective wrapping of the set, exposure is high, mainly due to the manipulation of heavy elements weighing more than 3 kg, which required employees to use considerable force. For the other three positions exposure is medium. An aspect of significant importance was the fact that there was only one break, which in relation to the shift is insufficient for adequate rest. Also stereotypes due to the short cycle times (<15 seconds) had a significant impact on the final result.

4. CONCLUSIONS AND RECOMMENDATIONS

An important element in production systems, in addition to the physical elements, is the human factor which affects performance, cost and quality [Istota inżynierii produkcji 2012]. The improvement of manufacturing systems should not only cover the technical sphere, but also the realm associated with the environment and ergonomics. The aim of the study was to assess exposure to MSD's of the upper limbs in the process of sequential packaging of a product and conduct an analysis of risk factors.

Of the five positions located at the conveyor belt, two positions were evaluated as high risk and three as medium.

The main risk factors influencing the negative evaluations were:

- insufficient number of breaks preventing an adequate rest;
- short working cycle – less than 15 seconds;
- force, due to the manipulation of the objects.

The positions studied were associated with a significant exposure of the upper limbs of workers to health problems, consequently further research and changes in the positions should be carried out. Production engineers and specialists in the field of health and safety should pay particular attention to the organization of the packaging process and:

- Assess the packaging process using the OCRA Index for more accurate identification of sources of irregularities;
- Develop and implement a rotation system taking into account the load of the upper limbs.

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APPENDIX 1 (based on Colombini 2002)
OCRA CHECKLIST – A shortened procedure for an identification and assessment of the main risk factors for upper limb in repetitive tasks.

TYPE OF WORK INTERRUPTION (WITH PAUSES OR OTHER VISUAL CONTROL TASKS) Choose one answer. It is possible to choose intermediate values.

- 0 - There is an interruption of at least 5 minutes every hour in the repetitive work (also count the lunch break).
- 1 - There are two interruptions in the morning and two in the afternoon (plus the lunch break), lasting at least 7–10 minutes on the 7–8 hour shift, or at least four interruptions per shift (plus the lunch break), or four 7–10 minute interruptions in the 6-hour shift.
- 3 - There are two pauses, lasting at least 7–10 minutes each in the 6-hour shift (without lunch break); or, three pauses, plus the lunch break, in a 7–8-hour shift.
- 4 - There are two pauses, plus the lunch break, lasting at least 7–10 minutes each over a 7–8 hour shift (or three pauses without the lunch break), or one pause of at least 7–10 minutes over a 6-hour shift.
- 6 - There is a single pause, lasting at least 10 minutes, in a 7-hour shift without lunch break; or, in an 8-hour shift there only is a lunch break (the lunch break is not counted among the working hours).
- 10 - There are no real pauses except for a few minutes (less than 5) in a 7–8-hour shift.

Score ____**RECOVERY**

ARM ACTIVITY AND WORKING FREQUENCY WITH WHICH THE CYCLES ARE PERFORMED (IF NECESSARY, INTERMEDIATE SCORES CAN BE CHOSEN) Choose one answer (state whether left or right arm is involved the most).

- 0 - Arm movements are slow, and frequent short interruptions are possible (20 actions per minute).
- 1 - Arm movements are not too fast, are constant and regular. Short interruptions are possible (30 actions per minute).
- 3 - Arm movements are quite fast and regular (about 40), but short interruptions are possible.
- 4 - Arm movements are quite fast and regular, only occasional and irregular short pauses are possible (about 40 actions per minute).
- 6 - Arm movements are fast. Only occasional and irregular short pauses are possible (about 50 actions per minute).
- 8 - Arm movements are very fast. The lack of interruptions in pace makes it difficult to hold the pace, which is about 60 actions per minute.
- 10 - Very high frequencies, 70 actions per minute or more. Absolutely no interruptions are possible

____**FREQUENCY**

PRESENCE OF WORKING ACTIVITIES INVOLVING THE REPEATED USE OF FORCE IN THE HANDS/ARMS (AT LEAST ONCE EVERY FEW CYCLES DURING ALL THE TASK ANALYSED):

More than one answer can be ticked: add up the partial scores obtained. If necessary, choose intermediate scores, and then add them together.

this working task implies: _ The handling of objects weighing over 3 kg _ Gripping between forefinger and thumb and lifting objects weighing over 1 kg (in pinch) _ Using the weight of the body to obtain the necessary force to carry out a working action _ The hands are used as tools to hit or strike something	1 - once every few cycles 2 - once every cycle 4 - about half of the cycle 8 - for over half of the cycle
The working activity requires the use of intensive force for: _ Pulling or pushing levers _ Pushing buttons _ Closing or opening _ Pressing or handling components _ Using tools	4 - 1/3 of the time 6 - about half of the time 8 - over half of the time (*) 16 - nearly all the time (*)
The working activity requires the use of moderate force for: _ Pulling or pushing levers _ Pushing buttons _ Closing or opening _ Pressing or handling components _ Using tools	1/3 of the time 4 - about half of the time 6 - over half of the time 8 - nearly all the time

____FORCE

PRESENCE OF AWKWARD POSITIONS OF THE ARMS DURING THE REPETITIVE TASK

_ RIGHT, _ LEFT, _ BOTH (mark the limb with greater involvement):

1 - The arm/arms are not leaning on the workbench but are a little uplifted for a little over half the time 2 - The arms have nothing to lean on and are kept nearly at shoulder height for about 1/3 of the time 4 - The arms are kept at about shoulder height, without support, for over half of the time 8 - the arms are kept at about shoulder height, without support, all the time **__ A**
2 - The wrist must bend in an extreme position, or must keep awkward postures (such as wide flexions or extensions, or wide lateral deviations) for at least 1/3 of the time 4 - The wrist must bend in an extreme position, or must keep awkward postures (such as wide flexions or extensions, or wide lateral deviations) for over half of the time 8 - The wrist must bend in an extreme position all the time **__B**
2 - The elbow executes sudden movements (jerking movements, striking movements) for about 1/3 of the time 4 - The elbow executes sudden movements (jerking movements, striking movements) for over half of the time 8 - The elbow executes sudden movements (jerking movements, striking movements) nearly all the time **__C**

_ Grip objects, parts, or tools with fingertips with constricted fingers (pinch) _ Grip objects, parts, or tools with fingertips with the hand nearly open (palmar grip)	2 - for about 1/3 of the time 4 - for over half the time 8 - all the time **__ D**
_ Keeping fingers hooked	

PRESENCE OF IDENTICAL MOVEMENTS OF SHOULDER AND/OR ELBOW, AND/OR WRIST, AND/OR HANDS, REPEATED FOR AT LEAST 2/3 OF THE TIME (please cross 3 also if the cycle is shorter than 15 seconds) **Stereotypes _3_ E**

Use the highest value obtained among the four groups of questions (A, B, C,D) only once, and add to that of the last question **E.**

____POSTURE

PRESENCE OF ADDITIONAL RISK FACTORS: only choose one answer per group of questions.:

2 - Gloves inadequate to the task are used for over half of the time (uncomfortable, too thick, wrong size, etc.) 2 - Vibrating tools are used for over half of the time 2 - Tools employed cause compressions of the skin (reddening, callosities, blisters, etc.) 2 - Precision tasks are carried out for over half of the time (tasks over areas smaller than 2 or 3 mm) 2 - More than one additional factor is present at the same time and, overall, they occupy over half of the time 3 - One or more additional factors are present, and they occupy the whole of the time (i.e.,……………………….)
1 - Working pace set by the machine, but there are "buffers" in which the working rhythm can either be slowed down or accelerated 2 - Working pace completely determined by the machine

_____ADDITIONAL

CALCULATING THE CHECKLIST SCORE FOR ONE TASK/WORKPLACE

To calculate the task CHECKLIST SCORE, add the values in the 5 boxes: Recovery + Frequency + Force + Posture + Additional

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