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Research Article

Musculoskeletal Disorders and Biomechanical Constraints in a Tunisian Manufactory

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ABSTRACT

Introduction: Assessment risks of musculoskeletal disorders of the upper limbs (MSDs-UL) and their prevention requires a good identification of constraints to better loosen them and preserve the well-being of operators.

Objectives: To quantify biomechanical risk factors of MSDs-UL among employees of an electronic industry in order to establish an appropriate preventive strategy.

Materials and methods: This study is conducted in an assembly industry of electronic parts involving 85 women. This is a descriptive survey followed by an ergonomic intervention.

Results: The middle age of the studied population was 35 years with an average of professional seniority of 14 years. In this company, 62% of workers are assigned at the assembly station, 26% at the control post and 12% at the welding position.

The clinical examination concluded that 33% of workers had MSDs of the neck and upper extremity, of which 50% affected the wrist and the hand. MSDs mainly affect women over the age of 36 and having a professional seniority more than 11 years. The welding station was the most provider of MSDs. Repetitiveness and inadequate postures are the two commonly constraints reported by participants. However, the deployed force is described as weak.

Observation analysis at the assembly station revealed a very high repetitiveness of postures in form of digital and lateral clamps.

The weld station has been shown to have high repeatability with extreme wrist extension for 58% of the overall time and tightening during the entire work. At the checkpoint, the right wrist flexion for 43% of the time, the use of the hand as a hammer for 42% of the time and the shaping of grasp for 44% of the time are postural constraints performed with high repetition.

Conclusion: The success of such prevention project must go beyond the medical framework to involve all partners in health and safety at work, especially the employer, operator and the ergonomist.

KEYWORDS: Musculoskeletal disorders; Assessment; Ergonomics; Prevention

INTRODUCTION

Musculoskeletal Disorders (MSDs) are an universal epidemic and a public health problem [1]. These diseases are the most frequent of occupational disease in many countries of the world. The significant increase in the incidence of work-related MSDs is closely related to the evolution of work. In developing countries, particularly in the Maghreb continent, tax benefits and the low cost of labor accounted for the relocation of manufacturing industries. In Tunisia, and because of a serious economic and political crisis, the April 1972 Law was promulgated to open the country to export-oriented foreign investors and project the country into the mundialization movement. While this transfer of technology has created an economic dynamism in the country with social and political stability, however, and since few years, we have noted a rapid increase in the number of occupational diseases, including upper limb MSDs which represent the first occupational disease [2]. That has increased from 135 cases in 1995 to 1334 cases in 2017 [3].

MSDs-UL represent a real problem of public health and work in Tunisia but also in several countries of the world as long as they also represent the first cause of occupational diseases recognized in French with an annual increase of 18% for 10 years. According to

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Eurostat, the statistics office of the European Communities, MSDs represent the most widespread and costly work-related health problem in Europe, affecting around 45 million workers [4].

The biomechanical origin of these affections is well documented. In order to measure this constraint at work, many tools have been developed ranging from checklist to analysis methods [5].

Aims: to quantify biomechanical risk factors of MSDs-UL among employees of an electronic industry in order to establish an appropriate preventive strategy.

MATERIALS AND METHODS

This intervention was carried out in an electronics assembly company, involving 85 women doing assembly, welding and control of electronic parts. This is a descriptive epidemiological screening study followed by an ergonomic study of the workstation.

The descriptive study is done using a questionnaire completed by the physician and a clinical examination targeting the musculoskeletal system.

The ergonomic study is an ergonomic analysis method proposed in two stages, according to Malchaire J. method. The first consists to determine of the most body area at-risk for MSDs; it is carried out thanks to a checklist. This checklist reviews all conditions and activities encountered at the workplace, such as inadequate postures, deployed forces, repetitiveness, mechanical stresses and other factors. Each question aims to assess the presence and / or duration of exposure to risk factors for the neck, shoulders, elbows, wrists and hands [6].

The second step is an observation analysis to quantify the level of effort, postures and repetitiveness of gestures focused on the upper limb area identified as most at risk during the previous step.

The procedure is based on the Occupational Work Analysis Systems (OWAS) method, which is based on instant observation at regular time intervals. It consists of:

- Identify a representative work period,
- Real-time video recording during this representative period,
- Break down the work into elementary operations,
- Evaluate the level of strength of each operation,
- Perform the encoding of the operations and postures observed at each freeze,
- Analyze and process the result using a computer program called MSDs.

RESULTS

Descriptive study

The average age of the studied population was 35 year-old with extremes ranging from 19 to 46 years. The average of professional seniority was 14 years. The distribution of workers according to the position shows that 62% of them are assigned to the assembly station, 26% to the control post and 12% to the welding position.

The clinical examination concluded that 33% of the workers had MSD of the neck and upper extremity, of which 50% affected the wrist and the hand. Carpal tunnel syndrome is the most common clinical diagnosis of MSDs (24%). These disorders affected worker over 36 years-old of age with a seniority more than 11 years. The objective clinical examination of tendonitis and ductal wrist syndromes was noted respectively at 6% and 8% of workers assigned to the assembly station.

The largest provider of MSD is the welding position with 90% of women affected, including 40% of CTS. At the control post, 18.1% of workers have ductal syndrome and 9% tendinitis of the wrist.

Observation analysis

Assembly station: Tasks at the assembly station were broken down into five basic operations: lubrication of the base; installation of the spring; placing the pusher; establishment of the contact and inserting the lid.

The contact placement operation (operation 4) takes up half of the overall work time at the assembly station. It is carried out in the whole of time in pliers digital in a very repetitive way (index: 0.92).

The operation of pedestal lubrication (operation 1) is carried out by lateral gripping in 100% of its time. This operation is carried out in extreme extension of the right hand in 54% of his time, with a repeatability qualified as very high (index: 0.92). This operation occupies only 13% of the overall assembly work time (Table 1).

Welding station: The tasks at the welding station have been broken down into six basic operations: installation of electromagnets; placing of turntables; welding of the electromagnet and platinum; opening the lid; taking and storage of parts.

The welding operation (operation 3) is clearly distinguishable from the others. It is obviously the most restrictive because it occupies more than half of the working time at the welding position, or 52% of the overall work time. The wrist is in extreme extension during the entire welding operation, far exceeding the exposure limits by 25% of the time with a high repetitiveness index. The grip is in the form of a lateral gripper throughout the operation, with a high index of repetitiveness, evaluated at 0.6 (Table 2).

Control station: Tasks at the control station were broken down

Table 1: Biomechanical constraints in the assembly station operations.

	Operations					Globale	Limite
	1	2	3	4	5	100	
Duration (% of time work)	13	17	8	47	15	100	
Angle:							
-Extension>45°	54	11	12	13	20	19	25%
-Flexion>45°	0	0	0	0	7	1	25%
-Extreme radial deviation	0	11	12	0	0	3	25%
-Extreme ulnar deviation	0	6	0	2	0	2	25%
Taken:							
- Finger tong	0	94	50	100	40	73	
- Side clamp	10	0	0	0	0	13	
- Fingerprint + pressure	0	6	50	0	60	14	
-Total	100	100	100	100	100	100	
Force=Score de BORG	2	2	3	2	4	Mean: 2.4	
Repetitiveness:				Indice			
-Flexion/Extension				0.47			
- Deviation				0.12			
- Prises Index	0,92						

into five basic operations: activation of the lever n° 1; placement of the piece; handling lever # 2; release lever # 1; storage.

In this station, operation 1 (Leverage # 1) is clearly distinguishable from other operations. It is obviously the most restrictive because it occupies a duration of 35% of the overall work time; it occurs in 94% of its time in extreme flexion of the wrist with a hammer-shaped (hypothenar eminence) and in a repetitive way exceeding the limits of exposure.

Operation 3 (manipulation of lever 2) is also restrictive; it occupies 27% of the total time of the control task, including 93% medial Grasp taking, with a high repetitiveness index evaluated at 0.75.

Operation 5 (storage) is characterized by occupying 25% of the overall time of the control task. The socket is in the shape of a medial Grasp occupying 60% of the time with high repeatability. Ultimate ulnar deviation affects 56% of the time with low repeatability (Table 3).

Table 2: Biomechanical constraints in welding machine operations.

	Operations						Global e
	1	2	3	4	5	6	100
Duration (% of time work)	14	16	52	3	9	6	100
Angles:							
-Extension>45°	0	12	100	22	33	0	58
-Flexion>45°	21	0	0	0	0	0	3
-Extreme radial deviation	0	0	0	0	0	0	0
-Extreme ulnar deviation	36	50	0	0	22	83	20
Taken :							
- Digitale pince	79	82	0	0	78	100	37
- Lateral pince	0	0	100	100	22	0	57
-Pince digitale + pression	21	21	0	0	0	0	6
Force=Score de BORG	1	2	2	2	2	2	Mean : 1.2
Repetitiveness:	Indice						
-Flexion/Extension	0.60						
-Deviations	0.35						
-Prises	0.66						

Table 3: Biomechanical constraints in control post.

	Operations					Global e
	1	2	3	4	5	100
Duration (% of time work)	35	5	27	8	25	100
Angles:						
-Extension>45°	6	80	0	12	16	11
-Flexion>45°	94	0	7	75	8	43
-Extreme radial deviation	0	0	22	0	0	6
-Extreme ulnar deviation	0	0	0	0	56	14
Prises:						
-No prise	6	100	0	13	24	14
- Medial Grasp	0	0	93	0	60	40
-Digital Grasp	0	0	0	0	16	4
- Martinar	94	0	7	87	0	42
Force=Score de BORG	3	2	2	3	2	Mean : 2.4
Repetitiveness:	Indice					
-Flexion/Extension	0.78					
-Deviations	0.20					
-Prises	0.75					

DISCUSSION

In this study a significant increase in the incidence of MSDs after age 36 was noted, that reflect a correlation between age and musculoskeletal affections. These results are in agreement with the study of MC CORMACK et al who considers that the age of onset of MSD is around 40 years and that employees over 40 are at risk [7].

LADEPECHE found a correlation between MSDs and job tenure, especially after 20 years of work [8]. Our results confirm these findings when 60% of women with seniority greater than 20 years had at least one musculoskeletal affection. However, HASCHER has shown that the occurrence of MSDs-UL is sometimes very early. Indeed cases of CTS and epicondylitis appeared 4 to 6 years after professional exposure [9].

In this study, 33% of workers had MSDs of the neck and upper limb. This prevalence is higher than that reported by ABDELMONEM [10] among a car seat manufacturing company's workers (20%). Such is the case of many scientific studies; CTS represent the frequent affection among workers (12%) [10,11].

To better understand risk factors of biomechanical constraints in different post, an objective analytic method was used. So that, the progressive ergonomic strategy of semi-quantitative analysis of musculoskeletal disorders proposed in two stages by Malchaire J in 1997 was adopted [6] with a strong emphasis on prevention which requires an analytical vision of results, rather than epidemiological studies, which consist only on superficial evaluation [12].

Biomechanical constraint on the musculoskeletal system is proved as a function of the force deployed, articular postures and the frequency of the gestures [6].

The definition of repetitiveness differs from authors. In this study the definition described by J Malchaire was adopted: repetitiveness is considered to be the number of passages per unit time from a neutral posture to an extreme posture [6]. It is quantified by an index of gestural variability. It varies from zero to one. If its value is zero, the posture is maintained continuously, whereas if its value is equal to one, the posture is very changeable and the movements are extremely repetitive.

Despite differences in the definition and quantification of repetitiveness, the literature has found an association between harmfulness of this factor and the occurrence of MSDs in general and that of the wrist in particular [13].

In the current study, gestural variability in taking object is the most important, particularly at the assembly station (index: 0.92). It is less important in flexion/extension, whereas it is relatively weak in deviations [14].

Several biomechanical arguments confirm that extreme postures are factors in the occurrence of MSDs [10,15,16]. The association between the extreme movements and the grips in the form of digital forceps increases the risk of the appearance of the MSDs of the wrist and the hand [10,11,16].

The study of postures in our work concluded on the importance of extreme extensions (welding), extreme flexions (control) and demanding grips (all positions).

At the welding station the postural constraints are described as very high. Indeed, during the 52% of the working time, the wrist is in extreme extension far exceeding the limits of exposure of 25% of the time. The presence of extreme cubital deviations (20% of the time) and the shape of lateral or digital forceps throughout the duration of the task are noted. Thus, the welding station is the most restrictive in terms of unfavorable postures. The comparison of these results with the data from the clinical examination shows that the prevalence of hand and wrist MSDs is higher at the welding position than other positions.

Work at the control post requires extreme flexion movements (43% of the overall task time), use of the base of the hand as a hammer (42% of the overall time) and a medial deviation shaping Grasp (40% of the overall time). These constraints are proved as risk factor to CTS and Guyon syndrome [16,17]. Indeed, 18% of the women working at the control post have these canal syndromes.

At the assembly station, the only postural constraint is the digital gripper shape, which is associated with a very high gestural variability index (0.92% of the time). This catch has been described as a factor in the occurrence of tendonitis of the hand and CTS [10,11,17]. In fact, 6% and 8% of women working at the assembly station present tendinitis and ductal syndromes of the wrist and hand, respectively.

The force deployed during the execution of the work has been widely described in the literature as a factor that increases the risk of developing MSDs [6,18].

According to RODGERS, the degree of harmfulness of the force depends on the momentary hold time and the activation frequency per minute of each muscle [19]. The amount of force needed to perform a given task is a function of the weight that is manipulated, the position of the object in relation to the axis of the body and the restrictive postures adopted.

Several methods had been adopted to measure the level of force applied and thus to quantify the importance of the risk of MSD: recording of the electromyographic activity of the muscles, the measurement of the external weights manipulated, the subjective scale of Borg, which is commonly used. The worker indicates the level of effort estimated from zero to ten. This method was adapted in our study to measure the level of force during work. It is an easy method that does not sophistical equipment and estimates for each body zone a value of the strain in relation indirectly to employee physical capacity [6].

In the present study, the force factor is not a biomechanical constraint since the average strength level estimated on the BORG scale is low for the different tasks in the company. It is 2.4; 1.2 and 2.4 respectively at assembly, welding and control stations.

ERGONOMIC SYNTHESIS AND RECOMMENDATIONS

Specific preventive measures were predicted to reduce biomechanical constraints. Technical corrections concerning the design and supply procedures of the posts; therefore, the modification of the brush shape of the greasing is desirable in order to replace the rectilinear form of the latter with a shape not requiring the extreme extension and lateral clamp association. The post rotation system in all cases is desirable.

Welding operation imposes immediately because of its binding nature, the modification of the shape of the welding rods in order to respect the neutrality of the wrist axis. The change of the design of the welding station is necessary to minimize the ulnar deviations during the feeding and the storage of the parts on both sides of the operator. The rotation system of the posts is desirable.

In order to avoid the assumption hammer hypothenar and to reduce the extreme flexion of the wrist during the setting in action and the release of the lever No. 1, in control post, it's necessary to modify the design of the level. Therefore, the modification of the rounded shape of the lever 2 imposing the medial Grasp taking is indicated.

In addition, some general action must be concerned to success this ergonomics intervention, such as the automation of some very repetitive tasks; introduction of breaks and reduction of cadences. A rotation system is one of the possible solutions to reduce the risks of repetitive work. Also, it's necessary to inform and training workers in terms of proper postures

CONCLUSION

At the end of this ergonomic study and thanks to a quantitative analysis, biomechanical risks are well objectified in the various workstations. However, even more in-depth studies considering other risk factors, especially psychosocial constraints, deserve to be done to successfully prevent work-related MSDs.

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