ERGONOMIC ANALYSIS IN A COMPANY OF CLOTHING AND EVALUATION OF AN ERGONOMIC INDEX RELATED TO MSDs

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ABSTRACT
Industrial ergonomics systems are designed to improve productivity and the work environment. Different regulations are considered to protect the health, safety and to improve the conditions of workers. In the field of clothing, the working conditions are still painful and cause occupational diseases especially the musculoskeletal disorders. The main objective of this study is to analyze the ergonomic of garment manufacturing to applying the standard "ISO 11228-3". The risk of musculoskeletal disorders is determined then the risk index is deduced. According to a Nordic survey evaluated on the study population, the most frequent MSDs were at the back (78%), hand and wrist (76%), neck (52%), shoulders (48%). The OCRA index found varies from 8.75 to 26.41 and the proposed ergonomic index varies between 1.11 and 1.21 depending on the machine used.

KEYWORDS: *MSDs; ergonomic; stitching; posture, time.*

1. INTRODUCTION

The textile industry of clothing presented an important place in the Tunisian economy, it represents 26.6 % of the gross domestic product of Tunisia in 2015[1]. In spite of this importance, this sector causes professional diseases in particular the musculoskeletal disorders (MSDs). The diseases of MSDs can be located at the level of the hand, the fingers and the wrists, at the level of the elbow, of the shoulder, of the neck, of the back or still at the level of knee and of the ankle [2], [3], [4]. The diseases of MSDs are connected to a large number of physical constraints like repetitive work, uncomfortable posture; and psychology organizational like variable works, insecurity of employment [5]. The MSDs is the most recognized professional diseases affecting millions of workers every year [6], the MSDs represents 50 % of the professional diseases [7].

Tunisia inclines regulations and measures to set up to protect the health and the safety of the workers and to improve their working conditions. Logistic and legal structures govern the work such as the CSST (the committee of health and working safety), the CHSCT (the committee of hygiene, safety and the conditions of the work) and the CNAM (National Conservatory of Arts And Crafts) which manages the information relative to the occupational hazards. The working conditions remain painful and binding in several business sectors [8]. For the sector of clothing business, 67 % of the total of the professional pathologies were declared in 2013 [9]. The diseases of MSDs arethe most frequent; the carpal tunnel syndrome (CTS) presents 53 %.Among the declared MSDs, the tendinopathy which exceeds 70 %. Almost 80 % of the cases of the carpal tunnel syndrome are women working in the sector of clothing [9]. These diseases contribute essentially to the repetitive pain and to the fatigue during the execution of the work during the day what decreases the yield and the production. Thus, the application of an approach of the technical ergonomics is necessary to improve the productivity of the work, motivate the employees, reduce the absenteeism and improve the condition of the work [10]. Our study contributes to analyze the tasks in an assembly line of articles in a company of clothing by applying the standard ISO 11228-3 (2007). The essential purpose is to estimate the ergonomic constraints bound at the risk of the MSDs. The posts in a clothing company are chosen to doing the essay.

2. MATERIALS AND METHODS

This study is realized in a clothing company implanted in the region of Monastir. It was begun with an investigation based on a Nordic questionnaire [11] and the standard ISO 11228-3. The study is made in a specialty chain in the manufacturing of man jackets, compound of 50 workers (47 woman and 3 men). Among them, thirty work at the post of a simple machine, ten at the post of ironing and the rest work respectively at the posts of buttoning, overcasting, the checking, the cleaning the peeling and the control. The simple and overlock machines had the following characteristics: 1.2 m in length, 80 cm in width and 80 cm in height. The chain was composed of 3 lines with an S-shaped implantation, supply and evacuation of packs of pieces is done by means of a rail with hangers and tweezers pending on the rail. During the study, the same classic model is manufactured, and then the yield stays constant. The company works fifty hours per week. The cycle time for each operation was measured by the timing method. For each task, 20 records were taken. The analysis was carried out throughout the chain using ISO 11228-3. The organization of the post and the layout were not the same for all posts. Indeed, there were posts that consisted of a single machine and other posts containing two machines. For each position the working time was 570 minutes per day. A Nordic questionnaire is used to collect socio-demographic information (age, genre, and seniority in the company, the weight, the size, the hand dominant, working time, the professional state and the health). The results collected to an ergonomic gone deeper into analysis by using the standard ISO 11228-3.The analysis allowed knowing the level of risk of MDSs by the assessment of OCRA index.

3. RESULTS

1. Socio-Professional Characteristics Of The Workers

The ***workers*** are composed of 47 women and 3 men with an average age of 42 years ranging from 26 to 54 years. The age group between 26 and 35 years old accounted for 16% of the ***workers***. Forty-eight percent (48%) of the workforce is between the ages of 36 and 45. Whereas over 45 years represented 36%. Forty-eight (48) operators were right-handed and only two (2) left-handed. The average length of service in the company was 21 years, ranging from 4 months to 36 years. Twenty percent of employees in the study population had tenure of less than 10 years, 34% had seniority ranging from 16 years to 25 years and 46% had a seniority of more than 25 years. Forty-one (41) employees in this chain were permanent in this company and only 9 were casual. The mean size of the studied population was 163.6 cm, ranging from 153 cm to 175 cm. The mean weight of the population was 75.6 kg, ranging from 56 kg to 100 kg. Twenty of the workers had absences due to MSDs diseases.

According to figure 1, 20% of workers had a back strain or trauma in the lower back, resulting in long and successive absences and medical visits. Ten percent had wrist tendonitis. One case of carpal tunnel syndrome has been reported as an occupational disease and a case of cervico-brachial syndrome was declared as occupational disease. A case of epicondylitis was reported as an occupational disease. The painful episode was from one week up to two years in 28% of employees during low back pain symptoms. Forty percent (40%) of employees used the care (physician visit, physiotherapist ...). These diseases resulted in absenteeism in 40% of cases. According to the results, a detailed ergonomic analysis was performed using ISO 11228-3 to determine the causes of this symptomology and to assess the risk of MSDs by calculating the OCRA Index for left and right upper limbs.

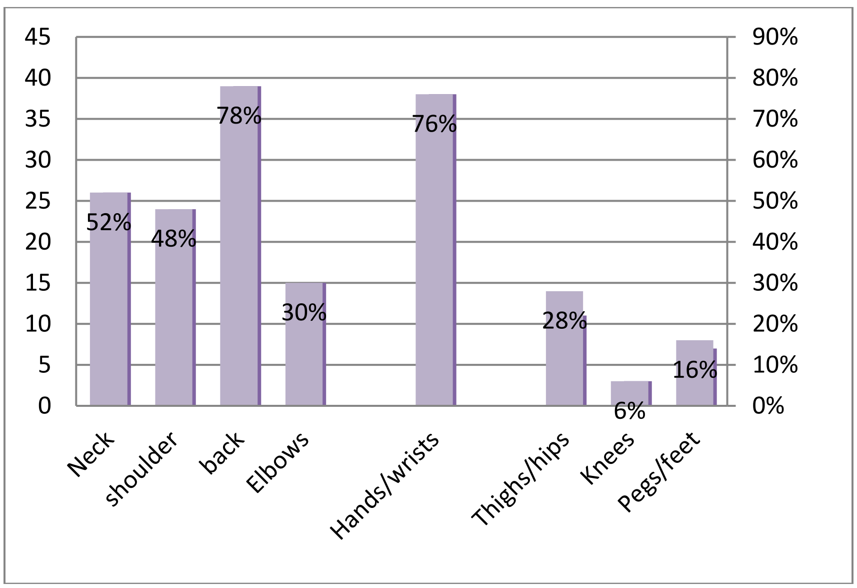

Figure 1. Distribution of MSDs according to the human body.

2. Ergonomic Analysis Of Sewing Posts

The analysis was done in a chain making men's jackets for export. The model always contains front and back pieces, a collar that consists of a falling and a foot from the collar, two sleeves with a slit at the bottom and at the middle back. The jacket always contains a lining, with a heat sealin paper at the collar, parment and in the welt pocket. Each post should open the package of pieces to prepare and supply its post. Once the worker finishes his work, he must close the package and put it back in the hanger and on the rail. The position of the rail was to the right of each post along the chain. The seat was of adjustable height and each post is held by a table on the left for the evacuation of the pieces. For the ironing stations, the employees worked in an upright position. The procedure for each task consisted of the following:

- Act 1: Grip of the piece or pieces
- Act 2: Positioning of pieces
- Act 3: Engage and stitch pieces
- Act 4: Evacuation of the piece

Some posts have a waiting time and this is due to the poor balance between positions. In these cases, the duration of the repetitive task decreased and therefore the number of units per post decreased. Control times during an operation are negligible for most posts, which reduces the recovery time. The complexity of the task affected the frequency of technical actions per minute for the left and right upper limbs. Indeed, the task that requires fewer technical actions in its cycle gives a lower total number of actual technical action n_{ATA} and therefore the risk of MSDs is lower.

2.1. Force level analysis

The frequency of actions still influenced the force multiplier F_M, as the number of techniques increases, the force score increases, the force multiplier decreases. The stitching task requires the use of both hands all the time of the cycle; this implies an increase in the frequency of technical actions per minute. According to the analysis, the frequency can reach 60/min for most of the posts such as the assembly post for the front in front. The force multiplier also depends on the weight of the piece, the material used and the force exerted during the work. The force level of the piece was assessed at "1" for actions: take, position, engage, release. During stitching, the level of the force became "2". To open a package of 8 pieces, the force level was evaluated to "2". The ironing operation requires more force thus the level of the force was evaluated at "3" during the ironing action.

Table 1. Variation of the force level and the FM multiplier according to the type of operation or machine used.

Operation/machine	**Force level Y (min-max)**		**Force multiplier F_M (min-max)**	
	Upper right	Upper left	Upper right	Upper left
Simple sewing machine	1,17-1,85	1,18-1,868	0,81-0,67	0,81-0,67
Ironing	1,9-2,54	0,966-1,192	0,64-0,5	0,86-0,81
Overlock machine	1,49	1,57	0,75	0,74
buttonhole machine	0,66-1,07	0,66-1,112	0,96-0,84	0,96-0,82
button pressing machine	1,249	1,104	0,8	0,815
Zigzag Stitch machine	1,837	1,8	0,68	0,68
welt pocket machine	0,646-0,748	0,576-0,718	0,94-0,925	0,96-0,93
cleaning-pointing	0,956-1,11	0,906-1,09	0,86-0,845	0,865-0,854

According to the table 1, the force multiplier F_M differs in relationship with the type of operation or the type of machine used. Indeed, for the stitching operation using a single machine the multiplier F_M differs for the upper left and right limbs. This variation is due to the percentage of the stitching action in the cycle. When this percentage increases, the force level of will be higher and therefore the F_M lower. For the operation "Assembler jacket with lining", the cycle time was equal to 120 second and the percentage stitch action in the cycle was 86.6%. The F_M in this case was 0.67. The use of a chisel when performing the spot also affected the F_M since the force level was rated at level "2". For the ironing operation the force level for the right upper limbs was higher than that of the left upper limbs and this is due to the nature of the organization of the ironing station since the iron was always to the right of the operator and therefore its use is always done by the right hand. Then, that is due to the variation in the percentage of the ironing action in the cycle. To iron the front half of jacket, the cycle time is equal to 43 second and the percentage of the "ironing" action in the cycle is 74.4%.The strength level for the upper right limbs was found to be 2.545 and the F_M at 0.5. For the zigzag machine, the same principle applies as the percentage of the "stitching" action in the cycle increases, the force level also increases and the F_M decreases. For the buttonhole or button pressing machine, it should be noted that the F_M is higher than that for the simple machines and this is due to the "stitching" action for this type of machine is done automatically without the manual intervention for the Operator. The F_M for this type of machine also depends on the number of buttonholes to be executed during the cycle. The increase of the number of buttonholes or buttons per cycle implies that the F_M decreases. For the overcast machine, the multiplier force depends on the percentage of the stitching action in the cycle. For the welt pocket machine, the multiplier force for this machine is the highest and closest to the value 1 and this due to the stitching operation which is performed automatically, the worker must do only the following actions during the cycle; Take, position, engage, evacuate. For the manual operations "cleaning" and "pointing", the upper limbs are used during the cycle, the decrease in the level of the force is due to the absence of the stitching action during the cycle.

2.2. Posture analysis

During the analysis of each post, the use of the left and right upper limbs varies between 60% and 100% of the cycle time. The posture evaluation shows that there are the following movements in the cycle;

- Wrist in flexion between - 40° and + 40 °.
- Elbows in flexion ≥60 °.
- The hands are pinched.
- The head is leaning forward.
- Rotating the neck to the right or left
- Back is leaning forward.
- Sitting position only standing position for ironing posts.

The posture multiplier is related only to the position of the wrist, elbow and hand. In the analysis, elbows were in flexion (≥60 °) between 80% and 92% of the cycle time, so the posture coefficient was set to 0.6. The wrists are flexed for 35% to 60% of the cycle time so the posture coefficient is set at 0.6. The hands are pinched for 23% to 40% of the cycle time; the posture multiplier is set to 1. Therefore the posture multiplier P_M is set at 0.6. Therefore, for the type of work performed on a stitching or ironing machine by applying the standard 11228-3 and evaluating the posture at the wrists, elbows and hands, the posture multiplier P_M is set at 0.6.

2.3. Evaluation of repetitiveness

During the analysis, the tasks are variable and the cycle time differs according to the complexity of the operating mode and the number of operations per post. The cycle time between the stations varies from 19.125s to 190s which is greater than 15s, so the repetitiveness multiplier R_{EM} is equal to 1.

2.4. Evaluation of recovery period

The company works from 7h30 to 12h without a recovery period, then from 12h30 to 17h00 without a recovery period. That is, employees work 4.5 hours without recovery period, so the multiplier R_{CM} is equal to 0.525.

2.5. Evaluation of the overall duration of manual repetitive tasks: duration multiplier: T_M

Working time during the day is equal to 540 minutes which is greater than 480 minutes, so the multiplier T_M is equal to 0.5.

2.6. Evaluation of the additional multiplier

Depending on the additional factors, it is noted that during the work cycle each task requires absolute precision and the pace is high. The presence of these two factors was throughout the cycle (more than 80%), in this case the additional multiplier A_M is equal to 0.8.

2.7. Evaluation of the OCRA Index

The ideal frequency of actions is estimated at 50 actions per minute. If all the multipliers are ideal, the OCRA index can take the following four cases:

- OCRA INDEX= 1,66 if F_M=P_M=1
- OCRA INDEX =2,8 if F_M=0,85 et P_M=0,7
- OCRA INDEX =2,38 if F_M=1 et P_M=0,7
- OCRA INDEX =1,96 if F_M=0,85 et P_M=1

In these cases, the OCRA index was in the green zone and there is no risk of MSDs.
According to figure 2, the OCRA index for the left upper limbs is higher than that for the upper right limbs and this is due to the frequent use of the left upper limbs since the shape of the post and the stitch simple machine requires the use of the left hand more than the right hand especially at the level of the supply and evacuation of the part (action releasing part of the machine). The OCRA index for the right upper limbs for the ironing operation is higher than that for the upper left limbs et that is due to the nature of the ironing post and the ironing action is always done by the right hand and Therefore the force multiplier F_M is lower and the number N_{RTA} is lower and therefore the OCRA index is higher and therefore the risk of MSDs is greater.
For the button pressing machine or buttonhole machine, the OCRA index is lower than that for the stitch simple machine and ironing because the multiplier F_M is higher, since the operation requires less of effort and less of the technical actions during the cycle. The welt pocket machine has the lowest OCRA Index, so the risk is lower because it is the only machine with the highest multiplier F_M. And this is due to the stitching action which is performed automatically without the manual intervention of the worker. According to these results, the sewing operations (stitching, overcasting, ironing, pressing buttonhole, pressing button, cleaning and pointing) have a high OCRA index (greater than 2.5) which implies a very high risk of MSDs.

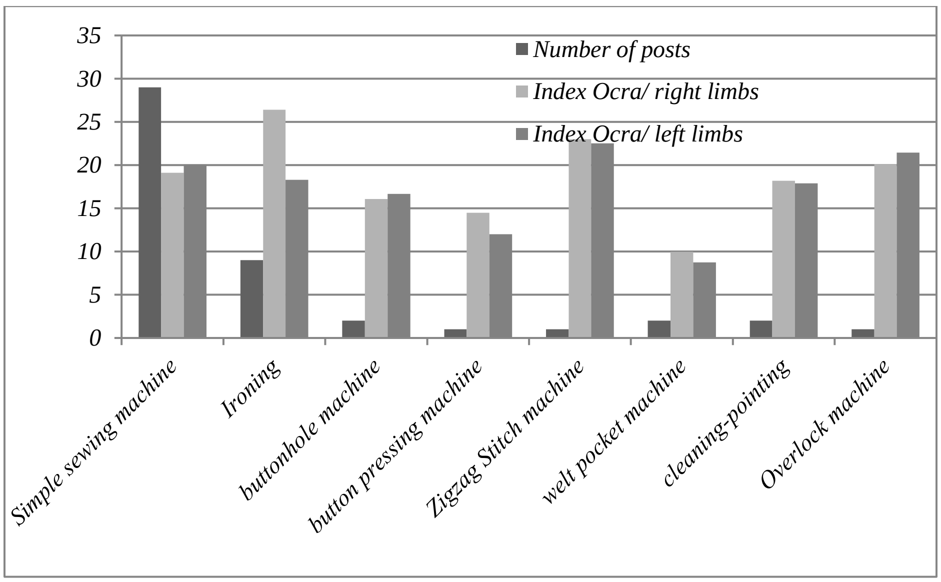

Figure 2: Variation in the average index OCRA for the right and left upper limbs for each type of machine or operation

3. Ergonomic Index Linked To The Risk Of Musculoskeletal Disorders Msds:

Following the result obtained by applying the ISO 11228-3 standard, we proposed an ergonomic index linked to the risk of MSDs according to the OCRA index found according to the type of each machine studied. To estimate the ergonomic index, a score is given for each multiplier (F_A, F_M, P_M, R_{EM}, R_{CM}, T_M and A_M), the score is determined according to the effect of each multiplier over the OCRA index calculated in the previous section and compared with the ideals multipliers (OCRA index without risk in the green zone).Table 2 summarizes the estimated points for each multiplier depending on the type of machine or operation.

Table 2. Variation of score for each multiplier according to the type of machine or operation and evolution of the ergonomic index.

Machine/operation	**Score**							**Ergonomic index**
	F_M	**F_A**	**P_M**	**R_{EM}**	**R_{CM}**	**T_M**	**A_M**	
Stitching	+2	+1,2	+2,7	0	+4,75	+5	+2	1,176
Ironing	Droit :+5,25 Gauche : +1	+1,8						Droit : 1,215 Gauche : 1,17
overcasting	+1,8	+1,7						1,18
Zigzag stitch machine	+3	+1,7						1,19
Welt pocket machine	-0,25	-3,3						1,11
cleaning/pointing	+1,3	+1,6						1,17
Pressing buttonhole machine	+0,4	+0,4						1,15
Pressing button machine	+1,2	-2,1						1,13

The ergonomic index is calculated as follows:

$$Ergonomic\ Index\ = 1 + \frac{\sum F_M + F_A + P_M + R_{EM} + R_{CM} + T_M + A_M}{100} \quad (1)$$

4. DISCUSSION

The body regions affected by MSDs are the neck, shoulders, back, wrists, hands and elbows. They express themselves through pain, weakness and loss of strength. MSDs are a major health problem in the workplace and especially in the garment sector and represent the leading cause of occupational diseases. The major causes of TMS are: physical exertions, repetitive movements and awkward positions [12]. Other studies have shown that MSDs are due to organizational and psychosocial factors in work; 70% of the workers confirm that the various causes are related to the following factors that machine incidents, machine breakdowns, the high rate of work and lack of autonomy, the level of concentration and the level of competence required [2]. Other studies in the garment field shows that the nature of the sewing machine usually requires a sitting posture and the assembly task requires pushed to the right and the left hand [13]. So for a reason of this conception of the body and the needle of the machine, many researchers such as HIVMA and others (1982) have indicated that the repetitive nature of the stain lead to awkward positions that can be among risk factors contributing to MSDs. According to a study of employees worked on the sewing machine, the rate of pain due to MSDs is high in the back (upper back (24.8%), lower back (23.9%)) , The neck pain rate was 50.5%, shoulders 50.2%, wrist (18%), hand and fingers (12.7%), and lower limbs (12%) [14]. This study was done to analyze the positions in a clothing manufacturing line, the application of a Nordic questionnaire showed the following results; MSDs are a major problem in most of the population, 78% of the workforce have problems with the lower back, 76% in the hands and wrists, 52% in the neck and 48% in the shoulders. The application of ISO 11228-3 for a thorough ergonomic analysis has shown the root causes of MSDs hazards:

- The frequent use of left and right hands throughout the cycle, which increases the frequency of technical actions per minute.
- The percentage of the stitching action in the cycle, when this percentage increase the force level becomes higher and MSDs risk increase.
- The use of tools such as scissors and pliers increases the level of the force and therefore the risk increases.
- The ironing station with its construction and the heavy weight of the iron and the repetition of the task increases the level of the force and the risk for the right hand.
- The operating mode of the task affects the OCRA index; indeed, when the number of action in the cycle increases the OCRA index.
- The posture influences the OCRA index, the more uncomfortable the posture predicate the more OCRA index and the risk increases.

According to these factors and according to the type of each machine studied or the operation carried out, an ergonomic index linked to the risks of the MSDs has been evolved. The most important ergonomic index is the ironing operation, since the OCRA index for this operation is the highest. The variation of the ergonomic index between the stitching machine, the overlock machine, and the zigzag stitch machine, is due to the variation of the operating mode during the execution of the task and the nature of the machine. The aim of introducing an ergonomic index over time in the work cycle is to reduce the effect of the MSD risk factor. The ergonomic index is proposed to increase the base time of each cycle, in fact the index found must be used to calculate the time of a cycle of such an operation by increasing the base time by the proposed index. This will increase the basic time of the operation so that the worker can work with a lower rhythm. The ergonomic indexes found (11% -21.5%) are quite high compared with the ergonomic index for the automotive field which varies according to the manufacturer between 7% and 10% [7]. To reduce this ergonomic index, it is necessary to introduce the culture of technical ergonomics in the sector of germent, to apply the methods of ergonomic analysis which are; OWAS, checklist, RULA, NIOSH, Lifting Equation, PLIBEL, The Stain Index, OCRA, QEC, Manuel Handling Guidance L23, REBA, FIOH Risk Factor Cheklist, ACGHI TLVs, LUBA, Upper Limb Disorder Guidance, HSGGO, MAC [4]. Other research has focused on the ergonomic design approach to reduce risk factors for MSDs. The home should be between 5 and 15 cm above the elbows and the work table should have a 10° slope and the pedal should be placed away from the work station (pedal shaft behind the needle) [15]. Repetitive cycles if the basic time of an operation is less than 30 will be the cause of the fatigue where the concentration and the use on the hands and wrists are more important. It is therefore necessary to minimize the time of the operation which has a high number of cycles. For sitting position, the position of the head and neck depends on the design of the chair which must be adjustable and to improve the position of the elbow [16].

5. CONCLUSION

The Tunisian clothing sector is the most important source of occupational diseases, especially MSDs, despite its importance in the economy sector. This study was done to evolve an ergonomic index related to MSD risk factors. According to the results found, the existing MSDs diseases are at the level of the lower back, hands and wrists, shoulders and neck. These symptoms are due to several factors: Mainly biomechanical factors such as repeatability of the task, frequency of technical actions. Other socio-organizational factors such as awkward posture, high work rhythm, work rate, high level of concentration.

The proposal for an ergonomic index related to these risk factors for MSDs is a solution to minimize these risks, which the index varies between 1.11 and 1.215 according the machine used and the type of the operation.

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