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Muscular-Skeletal Diseases Require Scientifically Designed Sewing Workstations

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The paper describes the adjustment of the sewing workstation with respect to working postures and workers' perceptions based on the results of a survey research carried out in 32 sewing workstations in different garment production factories in Slovenia. Poor posture of the trunk, neck and upper extremities, and the monotonous repetitive movements result in a high prevalence of musculoskeletal complaints affecting back, neck and upper extremities among sewing machine operators.

Several studies have confirmed that working postures are still a common problem in garment industry and ergonomically designed workstations can considerably reduce the above-mentioned problems. Therefore, the main purpose of the paper is to formulate all ergonomic recommendations for the modification of sewing machine workstations.

Keywords: dressmakers, working station, working postures, musculoskeletal diseases, prevention

0 INTRODUCTION

Nowadays, it is generally known that awkward and constrained postures result in musculoskeletal stress on the head/neck and trunk of seated operators [1] to [3] their critical literature overview about physical risk factors for neck pain Ariens et al. [2] ascertained that a positive relationship between neck pain and the following work-related risk factors exists: neck flexion, arm force, arm posture, duration of sitting, twisting or bending of the trunk, hand-arm vibration, and workstation design. Likewise, numerous previous studies report about considerable musculoskeletal problems due to the static postures of sewing machine operators, which have to be maintained during the whole working period, as well as those due to the highly repetitive manual tasks performed [4] to [6].

The sewing operation is characterized by a static sitting posture, a forward inclined posture of the head and trunk (Fig. 1), and relatively uncomfortable ankle and knee angles. The sewing task includes simultaneous hand and arm movements, and the continuous operation of foot pedals. Therefore, the working posture is constrained by the eyes for visual control of the work, the hands for directing the sewing material, and the feet for speedy control of the work.

Poor posture of the trunk, neck and upper extremities, and the monotonous repetitive movements result in a high prevalence of musculoskeletal complaints affecting the backs, necks and upper extremities among sewing machine operators [1], [4] and [5]. According to Herbert et al. [7] workers in the garment industry have higher rates of upper extremity work-related musculoskeletal disorders than those in many other industries. Similar findings, indicating that workers in machine sewing tasks have a much higher prevalence of persistent pain than e.g. hospital employees [5] and office workers [6] have been reported previously.

Sedentary work postures cause problems such as back and neck disorders [2], which cause absenteeism and significant medical costs. According to sources available from the Slovenian Institute for the Protection of Health, the rate of muscular and skeletal system diseases for the female population (in 2005) was 17.65% and is the highest in comparison to other diseases. Since then, sick leave in the Slovenian garment industry has been even higher, amounting to 23.2%, which is, for example, comparable to the findings written by Herbert et al. [7] for the USA. Several studies performed in Scandinavian countries [2], [8] and [9] also confirm that working postures are still a general problem in the garment industry and ergonomically-designed workstations can considerably reduce problems with back and neck disorders.

In our research we investigated and analyzed 32 sewing workstations in different garment production factories in Slovenia. We

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attempted to find out whether sewing workstations are designed in accordance with ergonomic principles or not and what are the body postures of operators at these workstations.

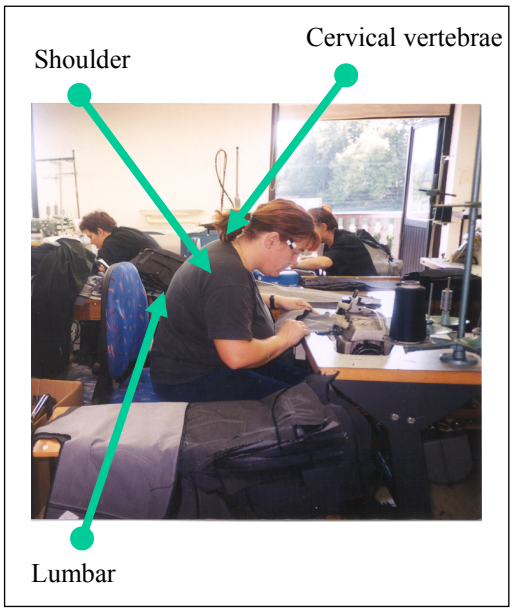

Fig. 1. *Working positions at sewing workstation*

From the studied 32 sewing workstations, a detailed analysis and workstation design of the selected sewing workstation for the technological operation of creating a side-seam for ladies' trousers is presented in detail. Taking into consideration workstation conditions, a proposal was made for ergonomic workstation re-design by considering the workstation adaptation and the working environment of the operator.

1 LITERATURE REVIEW

Given the complexity of modern industrial products, the intermediate verification and change processes require substantial time. This has a major negative impact on the development time and costs of the products [10] and [11]. Several suggestions about those sewing workstation features that cause problems with posture have been presented to date [1], [3] and [12] to [16]. Various researchers have suggested improvements to sewing machines (e.g. tilted sewing machines, adjustable swivel chairs, and sewing table height), inclined work surface, arm supports and adjustable foot controls. In 1984 Huoviala [13] reported a new sewing table designed at Finland' Reima Clothing Company. The major change was to tilt the sewing machine towards the operator. This modified sewing machine was tested on the production line and was shown to have success in making reductions in strain on the operator's neck, shoulders and back. Wick and Drury [14] prototyped an 11° inclined sewing workstation table, an upholstered swivel chair, an adjustable foot control and bench-mounted armrests. These changes were shown to reduce trunk forward flexion from 17 to 1° and head/neck inclination from 46 to 37°, as well as improving the posture of the lower extremities.

Yu et al. [16] investigated a work seat for industrial sewing operations with an adjustable pneumatic chair. The results showed that the most significant design features were the seat's height and the backrest distance for the seat pan to swivel freely. They recommended that the seat height should be adjustable between 510 and 610 mm, the backrest distance should be adjustable horizontally by about 50 mm, and its height should be fixed at 250 mm.

Delleman and Dul [3] studied design parameters for sewing table height, table slope and pedal positions. Based on their measurements of working posture and workers' perceptions, Delleman and Dul recommended that the table desk should be adjustable between 5 and 15 cm above elbow height in a seated posture, the table desk should be inclined at least 10° towards the operator and the pedal should be positioned as far under the table as considered comfortable (indication: pedal axis behind the needle).

The effects of inclined work surfaces have been studied for other tasks, mostly for those involving reading and writing. Hira [12] studied the slope of educational desks (testing adjustments of 0, 10, 15, 20 and 25°), and found that desk angles of 10 and 15° were preferred by most of the students, with an average value of 12.1°. Bendix and Hagberg [17] showed that the preferred slope changed with the task: a more horizontal desk slope was preferred for writing (0 and 22° were tested), but a steeper inclination (up to 45°) was preferred for reading material on the desk.

Other researchers have investigated slope work surfaces for assembly tasks in the electronic industry. Schuldt et al. [15] measured the level of

neck and shoulder muscle activity in a simulated soldering task and found that muscle activity was reduced when the work frame was inclined to 35°, giving a more upright posture.

2 METHODOLOGY

Since women in the Slovenian garment industry represent more than 90% of the employed, our research was limited to the female population. The analyses of the workstations included:

- **workstation analysis and evaluation;** analysis of the existent workstation dimensions with respect to working postures and workers' perceptions (the random sampling was conducted 10 days, every day, three times per hour, on 32 people, working at 32 sewing workstations in different garment production factories in Slovenia),
- **Ovaco Working Analysing System** (OWAS) to determine the postures that needs to be remedied (conducted 5 days, every day, 30 times per hour, 32 people). The extended OWAS method [18] was used to evaluate the strain caused by different operators' postures at seated sewing workstations.

Based on the results of the previously research, an ergonomic handbook written by Schmidtke [19] and recommendations of the DIN 33406, the theoretical seated workstation model was prototyped, aimed as the comparative sample for actual workstation evaluations. In Fig. 2 the examined dimensions of the theoretical model are marked.

Because no one from the 32 studied sewing workstations had a sloping table, we decided that this design aspect will not be included in our research.

Therefore, to reach the main research aspects when considering the operators' forced positions during the sewing process, the following data were investigated:

1. Sewing workstation data (Fig. 2):
   -the height of the working table - A
   -the surface of the working table - B
   -the height of the chair - C
   -the chair support - D
   -the position of the pedal - E
2. Data to determine operators' postures at the workstation:
   -inclination of the head α,
   -movement of the eyeballs β.

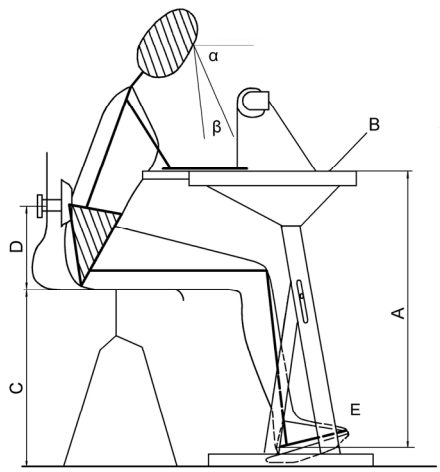

Fig. 2. *Examined dimensions of the operator at the sewing workstation*

In the second part of the research a detailed analysis of the selected sewing workstation was performed, where the workstation data and the operator's postures were measured again, together with all other important parameters needed to determine a completed workstation situation. The ergonomic recommendations were formulated for an ergonomic re-design [20] to [24] of a sewing machine workstation. Possible improvements of manufacturing systems' design can be studied using simulation modelling and analysis [25] and [26].

3 RESEARCH RESULTS

3.1 Present State Survey

3.1.1 Examined Dimensions of the Operators Regarding the Workstation Dimensions

Height of the working table - A

- corresponded to the height of the operator in four cases,
- too low in 28 cases, thus a proposal was made to increase the height.

Surface area of the working table - B

- in 20 cases the working surface area was too small and did not support one or both arms during sewing,

- in 5 cases the working surface area was too small for large patterned pieces,
- in 7 cases the working surface area was not studied in detail.

Height of the seat - C
- in 4 cases the height of the seat corresponded to the height of the operator,
- in 12 cases the height of the seat was set too high,
- in 16 cases the height of the seat was set too low.

Back support - D

The setting of the back support was studied in 26 cases:
- the setting of the back support corresponded to ergonomic requirements in one case, yet the operator did not use the support,
- in 25 cases the setting of the back support was inappropriate: in 14 cases the back support was adjustable, while in 11 cases it was not.

Position of the pedal - E

The position of the pedal was studied in 21 cases:
- in one case the position of the pedal and its use were appropriate (the operator could push the pedal with either foot),
- in five cases the position of the pedal was appropriate, yet the operator did not use the pedal correctly (she pushed the pedal using one foot only),
- in two cases the pedal was set so as to leave insufficient area for the legs,
- in 13 cases the inclination of the pedal was incorrect, which resulted in an incorrect angle between the sole and the shank.

It is clear from the above results that individual elements of some workstations meet ergonomic requirements. Analyses of the overall ergonomic workstation design, however, show that:
- not a single studied workstation met the ergonomic criteria completely,
- in 24 cases all 5 elements of the workstation were inadequately designed,
- in 7 cases only one element of the workstation was adequately designed (in three cases the height of a workstation, in three cases the height of the seat, and in one case the adjustment of the pedal),
- two elements of the workstation were suitable in only one case, i. e. the heights of the table and the seat.

3.1.2 Results from the Study of Operators' Postures

Measurements of the inclination angle of the head (α) and the inclination angle of the eyeballs (β) were taken in 27 cases out of 32. The results were as follows:
- angle α corresponded to the proposed values in only four cases out of the 27 measured,
- angle β corresponded to the proposed values in only one case out of the 27 measured,
- the sum of angles (α + β) corresponded to the proposed values in only one case out of the 27 measured.

When analyzing body postures determined using the OWAS method, special interest was taken in the percentage of individual seamstresses' postures at their workstations to find out where, due to the high percentage, correctional measures should be taken (Tables 1 and 2).

The analyses showed that at all 32 workstations, incorrect postures were such as to demand special measures be taken.

From the studied 32 sewing workstations the workstation design for the technological operation of creating a side seam for ladies' trousers is presented in detail.

3.2 Detailed Analyses Results for the Selected Sewing Workstation with a Proposal for an Ergonomic Re-design

The workstation for performing the technological operation of joining the side-seams of ladies' trousers comprises a sewing machine, a chair, a table on the left from which the operator picks patterned pieces, and a stand on the right for depositing the joined pieces (Figs. 4 and 5).

3.2.1 Ovaco Working Analysing System

The results obtained using the OWAS method (Fig. 6) show that corrective measures should be taken regarding the postures below:

Table 1. *Ovaco Working Analysing System table for observed operator's postures*

Part	Thoraxlumbal spine			Upper limb		Lower limb	Head	
	1.2	1.3	1.4	2.2	2.3	4.1	5.2	5.3
OWAS / %							>30° 	>30° 
10	□	□	●	□	□	□	□	□
20	□	□	●	□	□	□	□	□
30	□	●	●	□	□	□	●	●
40	●	●	▲	●	●	□	●	●
50	●	●	▲	●	●	□	●	●
60	●	▲	▲	●	●	□	▲	▲
70	●	▲	▲	●	●	□	▲	▲
80	▲	▲	▲	▲	▲	□	▲	▲
90	▲	▲	▲	▲	▲	●	▲	▲
100	▲	▲	▲	▲	▲	●	▲	▲

Table 2. *Percentage of individual postures at the sewing workstation*

OWAS posture	Changes – in near future		Changes – immediately	
	No.	%	No.	%
1.2 is bent backwards at an angle greater that 15°. A bent posture up to 30° means that the operator is bending in the lumbar-sacral area, while a bent posture above 30° means that she is bending the hips	13	40.6	5	15.6
1.3 is an upright posture with a torsion or side bow of the thoracic spinal part greater than 30°	4	12.5	3	9.4
1.4 is bent back with a lean greater than 15° and combined with torsion or side lean greater than 30°	7	21.8	1	3.1
2.2 is when one or both upper arms are actively stretched below the height of the shoulders	11	34.4	11	34.4
2.3 is with one upper arm above the height of the shoulders	2	6.3	0	0
4.1 is the way of sitting either physiological or non-physiological	28	97.5	0	0
5.2 is the head bent over the stomach by more than 30°	11	34.4	7	21.8
5.3 is the head bent sideways by more than 30°	2	6.3	1	3.1

- 1.2 bent posture, the bend is greater than 15°,
- 2.2 one or both upper arms are active and below the level of the shoulders,
- 4.1 sitting,
- 5.2 head inclined towards the stomach above 30°.

Legend for Table 1:

□ - changes are not needed

● - changes needed in near future

▲- changes needed immediately

3.2.2. Static and Dynamic Anthropometry

The anthropological measurements of the operator were compared to the dimensions of the table, chair and tool (Table 3).

The measurements of the inspected workstation are totally unsuitable. All measurements must be corrected to suit an operator's anthropological measurements.

A comparison of the actual arm reach with the required reach showed, that during sewing the operator keeps her arms within her motorial field or within an easily accessible field. When picking up and depositing patterned pieces, however, her arms reach outside the

easily accessible field. Patterned pieces should, therefore, be positioned so that the operator, when picking up and depositing them, stretches her arms outside the easily accessible field as seldom as possible [20].

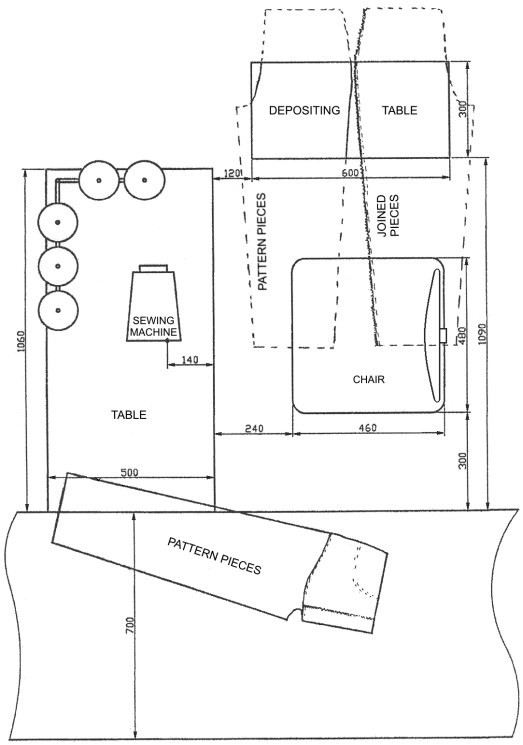

Fig. 4. *Lay-out of the workplace and positions of the patterned pieces*

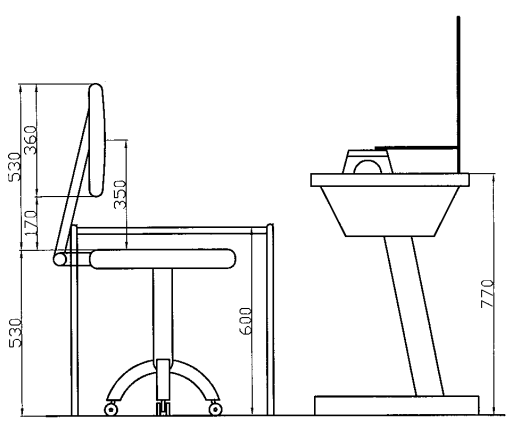

Fig. 5. *Side view of the workplace*

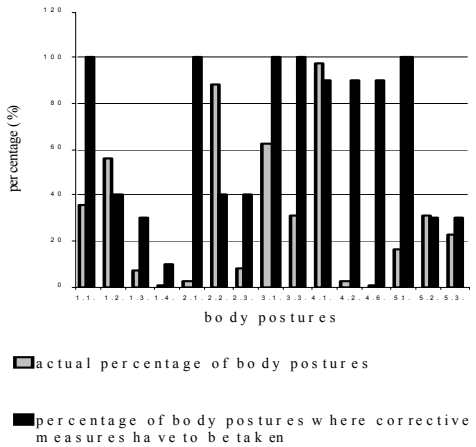

Fig. 6. *The histogram of the OWAS measuring method applied at the inspected workplace*

Based on scientific findings, an ergonomic design of the workstation is proposed by considering the results of the workstation analysis and a comparison of the results against the required values. The new dimensions of the machine adapted to the operator's measurements are shown in Figs. 7 and 8.

Dimensional changes:

- The height of the worktable is increased from 770 to 845 mm with respect to the height of the operator (780 – height of the operator + 45 – pedal + 20 – heel).
- The height of the seat is lowered from 530 to 495 mm with respect to the height of the operator and due to the incorrect sight inclination angle (α+β) (430 – height of the operator + 45 – pedal + 20 – heel).
- The chair is moved forward to the edge of the worktable so that the operator sits back and leans against the chair support. The dimensions of the present seat surface are too big, therefore replacement with a chair of seat dimensions 400 x 450 mm is proposed.
- The height of the chair support is reduced, with the centre at a height of 220 mm.
- The *optimum working methods* require that the sewing needle is located at a distance of 300 mm from the edge of the working table. Therefore, the width of the sewing table is enlarged from 500 to 660 mm. This also provides support to arms during sewing.

- Because the operator reaches outside the allowed and maximum area with her arms, a different layout of the patterned pieces is required. The table for picking up pieces is widened by 150 mm to a length of 650 mm.
- The stand for depositing patterned pieces is moved 130 mm closer to the operator for the same reasons as above.

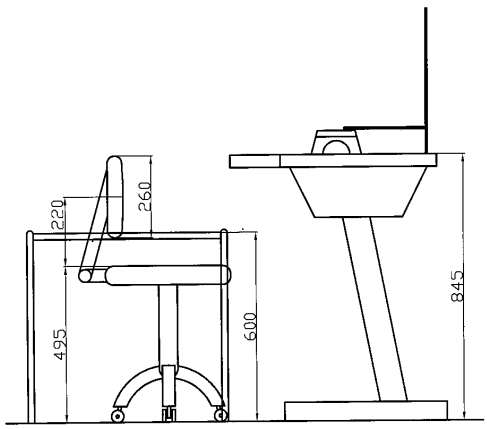

Fig. 7. *Side view of the workplace – proposal*

It is further convincing that the workstation meets ergonomic requirements if we compare the photograph showing an operator during sewing at a non-redesigned workstation with the photograph of an operator sewing at a re-designed workstation (Figs. 9 and 10)

The inclination angles of the head and the eyeballs are 37 and 9° respectively after re-design, which is very close to the required values.

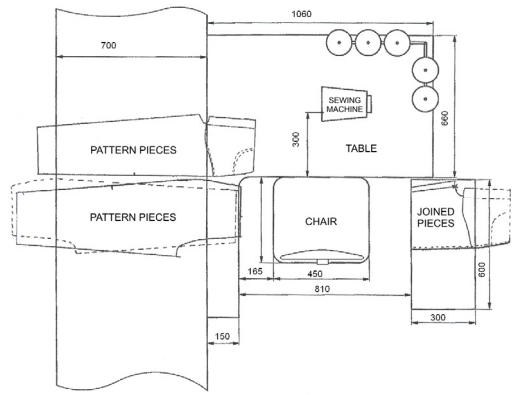

Fig. 8. *Overhead view of the workplace – proposal*

The inclination of the back after re-design is only 6°, while it is 16° before re-design.

Even more important is the inclination of the head that is bent forward by 41° before re-design and only 25° after re-design. When observing the operator during sewing at a re-designed workstation, it was noticed that the worktable was slightly too high and had to be lowered. The front edge of the table should have a somewhat concave design with respect to the larger figure of the operator.

4 DISCUSSION

In the sewing process stresses are induced by:

- anthropometric measurements (body postures, body measurements),
- working tasks,
- working environment, and
- work organization.

Table 3. *The comparison of actual workplace dimensions with the required workplace dimensions (according to OWAS)*

Workplace dimensions	Actual dimensions [mm]	Required dimensions [mm]
Height of the working table	770	780+45+20=845
Height of the chair	530	430+45+20=495
Dimensions of the chair	480 x 460	450 x 400 (max.)
Dimensions of the chair support	360 x 420	220 x 300 (minim.)
Distance of the chair support centre from the seating area	350	220
Height of the table for depositing pieces	600	600
Distance of the sewing needle from the edge of the working table	140	300

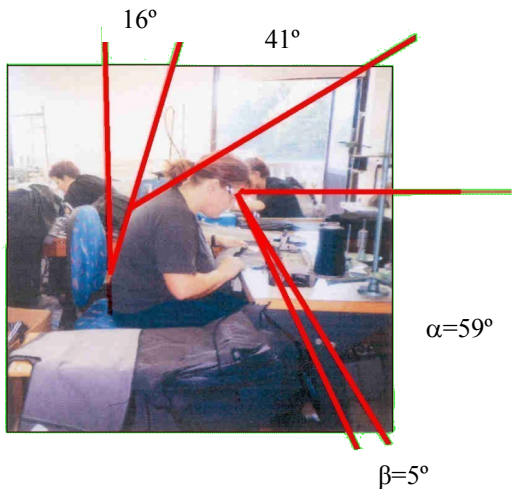

Fig. 9. *Operator in her posture during sewing at a non-redesigned workstation*

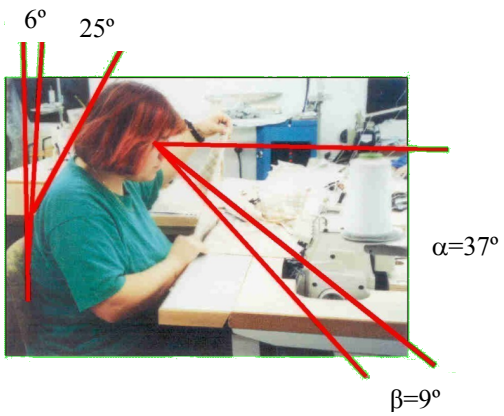

Fig. 10. *Operator in her posture during sewing at an ergonomically designed workstation*

The types and magnitude of stresses greatly depend on the working environment or individual enterprise. One common point to all workstations in the sewing process is the stress induced by the forced position of the operator because, due to the nature of work, the operator is in a sitting position for the whole time. The stress is still greater because workstations are inadequately designed, i. e. unadapted to the operator's measurements. This research has shown that none of the analyzed workstations were designed in accordance with ergonomic requirements:

- none of the analyzed workstations met the ergonomic requirements completely, which means that not a single workstation shows any agreement with all the studied elements (i. e. height and surface of the worktable, height of the seat, inclination of the seat support and position of the sewing machine pedal) with ergonomic requirements,
- in 75%, all five elements are inadequately designed,
- in 21.9%, only one element is adequately designed,
- in 3.1%, two elements are adequately designed.

The non-ergonomic workstation design results in the following incorrect body postures:

- the back is bent, with a bend greater than 15°,
- one or both forearms are active and stretched below shoulder height,
- sitting is non-physiological,
- the head is inclined over the stomach by more than 30°.

Due to this, corrective measures should be taken.

A comparison of the results shows that incorrect operator posture results from an incorrect workstation design:

- incorrect positions of the back and head result from a table and chair set too high or too low (in 87% of all workstations the heights of the worktable and chair were inadequate; 84% of operators showed at least one incorrect posture of the head or back),
- posture 2.2 – one or both forearms actively stretched under shoulder height – this is due to incorrectly designed and insufficient work surfaces that do not support the arms during sewing. This posture is so frequent that corrective measures must be taken (in 62.5% of workstations the surface of the worktable is too small; the posture 2.2 is above the allowed limit in 68.8% of cases).

An important sign that operators are excessively stressed and strained at their workstations are besides tiredness, injuries, occupational diseases and handicaps, enhanced sick leave due to diseases of bodily locomotion.

A detailed analysis of the selected sewing workstation showed that:

- the workstation is badly designed or not designed at all: the operator selects her own method of performing a sewing operation, as she thinks fit,

- ecological stresses meet the allowed or required values, with the exception of the excessive contrast between the work surface and the patterned piece;
- the results obtained using the OWAS method and a comparison of an operator's body measurements with the dimensions of the workstation, showed that the operator's posture was not in accordance with ergonomic requirements;
- the nature of the work itself makes the work stressful: the work psychically affects the operator.

The results obtained with the above analyses are sufficient to re-design the workstation according to ergonomic requirements. To adapt the dimensions of the workstation and machine driving parts to the operator's body measurements, and thus to reduce static and dynamic stresses or strains due to incorrect body postures, it is necessary to:

- increase the height of the table to 845 mm,
- lower the height of the chair seat to 495 mm,
- replace the old chair with a new one having seat dimensions of 400 x 450 mm,
- move the chair to the edge of the table and instruct the operator to sit in a correct position,
- decrease the distance from the seat to the centre of the seat support 220 mm (move the seat into the lumbar part),
- widen the table for picking up pieces by 150 mm at a length of 650 mm from the edge of the worktable,
- support the operator arms during sewing to reduce the proportion of OWAS 2.2 posture (one or both arms actively stretched and below shoulder level).
- move the stand for depositing pieces 130 mm nearer to the operator.

5 CONCLUSION

It can be concluded that:

- sick leave in the Slovenian garment industry is very high,
- workstations for performing the sewing operation are not adapted for operators,
- incorrect body postures causing severe stresses and strains which increase with years of service.

The inadequate postures of operators during sewing at non-designed workstations and a high proportion of sick leave due to illnesses of the muscular-skeletal tissues show that workstations in the garment industry urgently need re-designing in accordance with ergonomic requirements and special features of the sewing operation. Special care should be paid to the design of the table and chair or to the adaptation of their height to the height of the operator, because the operator is in a sitting position during sewing.

The aim of workstation design is to provide a more humane and successful working environment. As shown by the results of the analyses, this aim can be reached with a correct approach, which considers scientific findings, as well as with the cooperation of experts from different fields (physiology, ecology, work study, technology of work, safety at work, and medicine). The ergonomic recommendations are presented for a typical sewing workstation, however, the same recommendations, regarding working postures, can be used for any other workstation.

6 ACKNOWLEDGEMENT

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