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Anthropometric measurements related to the workplace design for female workers employed in the textiles sector in Denizli, Turkey

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Abstract

Because of working in a constant and iterative position, injuries occur in shoulders, necks, backs, and lower extremities of sewing machine operators. Holding the left upper arm up, bending the body and the head and ankle and knee at non-optimum angles causes these injuries or makes the situation more serious. This study aims at determining the anthropometric measurements related to the workplace design for female workers employed in large numbers in the textiles sector working in Denizli. In order to do this, a total of 18 anthropometric measures were collected at sitting (9) and standing positions (9) from 407 female workers in separate clothing plants, using the Harpenden type Anthropometer. The measurements taken in the sitting position are related to the aim to discover the optimum design of the workstation of the sewing machine whereas the measures at standing position were taken with the aim of determining the optimum height of the quality control and ironing units. In the study the descriptive and percentile values were calculated. Considering the anthropometric measurements required, suggestions related to workplace design were proposed.

Keywords: *Textile sector, women, anthropometric measurements, design of work place*

Introduction

Although there are a vast number of studies in industrialized countries which determine the anthropometric measurements of female workers employed in various sectors, the number of studies treating the anthropometric measurements of workers in the textile sector is limited. Among these studies, working posture of the sewing machine operators, configuration of workstation and perceptions of workers (Delleman and Dul, 2002), are factors that effect the sewing posture at the machine (Li et al., 1995), physical burden of workers (Vezina et al., 1992), shoulder and neck complaints of

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women in industrial workplaces (Blader et al., 1991; Fredriksson et al., 2000; Björksten et al., 2001), muscular-skeletal complaints (Vihma et al., 1982), and the evaluation of new chairs used in industrial working environments (Yu and Keyserling, 1989) can be mentioned. In Turkey, particularly in Denizli, a considerable number of working women serve in textile and apparel industries, and these women encounter many problems arising from the working environment. However, presently, there are no studies in Turkey that will solve these problems encountered by female workers in textile and apparel industries. No anthropometric nor design studies in this field exist. The anthropometric studies related to women are mostly intended for the kitchen (Gönen et al., 1990; Gönen et al., 1991; Kalınkara and Gönen, 1992), and clothing design (Şener, 1995).

A vast majority of women working in textile and apparel industries serve as sewing machine operators. Although the sewing process could provide a qualitative improvement and a flexible work style to the worker when it is treated as a whole, the individual in the workplace is limited by the simple and repetitive tasks because of highly advanced labour divisions. Although the activity at the sewing machine with its high motion sensitivity and difficult gripping positions, requires advanced sensomotor skills and configuration knowledge based on the nature of the fabric and the sewing steps, the activity remains qualitatively unskilled because of the highly advanced labour divisions. The physical burden in the sewing process is considerably high. Sitting in a fixed position constantly because of the sight requirements at the machine, leads to a static burden that threatens the health of the worker. This process not only effects the physical health but also leads to a permanent charge on the sense organs in psychological area, because it requires a constant control of vision and highly focused concentration (Erensal, 1987).

The studies that have been done so far show that the physical burdens lead to problems at the left shoulder, the neck, the back and in the lower extremities of sewing machine operators. These problems either arise from or become more pronounced when lifting the left arm, bending the head and body forward, and by the less than optimum ankle and knee angles while working for extended periods in a seated position. At the traditional sewing machine workstation, the position of the body is restricted by the sightlines required for the visual control of the task, by the hand motions required to orient the fabric, and by the foot motions required to control the speed of the machine. These restrictions related to body positions should be considered in quantitative proposals related to the configuration of workstations to improve the position of the body at work and decrease the number of complaints (Delleman and Dul, 2002).

Industrial sewing is an action that takes place in a seated position. The purpose of using a chair to sit is to decrease or eliminate physical energy consumption and tiredness. On the other hand, if the seated posture is not correctly supported, intense muscular-skeletal stresses will result. Muscular-skeletal stresses occur mostly around the waist, while sitting. When the individual changes his/her position from the standing posture to a normal sitting posture, the pelvis rotates backward. The rotation of pelvis causes the backbone to flatten approximately 25-38^{o}. The flattening of the backbone creates a stress on the lumbar discs, the posterior ligaments and the spinal nerves. When the spinal inclination flattens, the pressure on the lumbar discs increases approximately 35%, and the nucleus causes an opposite force on the lumbar discs. In the case of chronic charge, the combination of these two forces leads to a gradual internal trauma, and causes the fibers of connective tissue to sag then narrow (Yu and Keyserling, 1989).

In the apparel industry where the workers are generally female, it is not possible to guarantee that a workstation design suitable for men is also suitable for the female workers. Not only does the static position and seating characteristics in apparel industry cause muscle tiredness, but the faulty body position and seating characteristics, also, cause curvature of the spine, deformation of the discs between the vertebras, and consequently lead to problems in vascular, respiratory, central nervous system and visual functions (Kayış, 1989). In order to avoid these problems, workstation design should be required to be suitable for the user.

One of the most important biological variables that effects the physical characteristics of a human being is genetic structure. Gender is a factor that effects physiology, and body ratios show considerable gender differences. The differences between men and women cannot be accounted for in one design. Generally the anthropometric measurements of the male population are taken into account in design (Stoudt, 1982). The purpose of this study is to identify the anthropometric measurements of female workers in the apparel industry and to recommend the use of these measurements in workplace design to improve their health and productivity.

Methods used in the anthropometric survey

The purpose of this study is to identify the static anthropometric measurements of the female workers in the textile sector, a major area of employment in Denizli, to be used to improve workplace design. For this purpose, a total of 18 anthropometric measures in seated (9) and standing positions (8) and body weights were collected from 407 female volunteers from among machine operators employed in 7 different plants in the Denizli apparel industry who agreed to participate in this study (Figures 1 and 2). In order to determine the measurement points to be used in this study, the studies of Lohman et al. (1991) and Wang et al. (1999) were taken as the base.

Subject and measurement procedures

Because of the sensitive and repetitive nature of the tasks in textile and apparel works, the employees of the industry are composed of middle aged and younger women. Therefore, this study uses 407 female workers between ages 18-44 who accepted the application to volunteer. For this purpose a room was reserved in every plant for the measurement processes, and the measurements were taken in these rooms with groups including three employees. The measurements of the individuals were taken over thin clothing and barefeet. The measurements were made at the break (hour: 10.00-10.30) and meal (hour: 11.30-13.00) times. Considering the possibility of measurement changes during the day due possibly to either the individual or tiredness, no measurements were taken in the afternoons. In this way, there was no labor lost to the plants who provided the volunteers. Before the measurements, a researcher examined each female worker and recorded any complaints arising from the equipment on an individual questionaire. Then, the anthropometric measures were collected in the seated and standing positions. During the measurements, care was taken to be sure the individual was sitting upright and that her feet were perpendicular to the ground by using an adjustable chair.

Equipment and its use

Platform scales and an anthropometer of the harpenden type were used for the weights and anthropometric measurements of women, respectively. The measurements were made by experienced researchers, the authors of this article, who had experience with similar studies in the past. The research team was chosen from a group of anthropometrists and anatomists and the performance of the team was observed before the actual measurements by conducting preliminary measurements on many test subjects where the team worked together. Before the preliminary measurements, the anthropometers were calibrated. In this way, possible errors that could arise from the researcher and the measurement tool were minimized at the beginning of the study. During the applications, the measurements were recorded on the anthropometric data form prepared by the researchers.

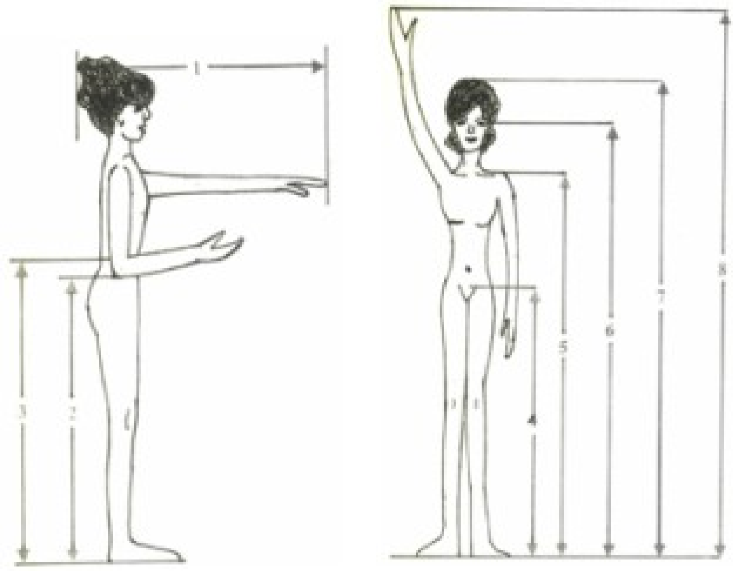

Fig. 1. Anthropometric measurements of the female workers in a standing position

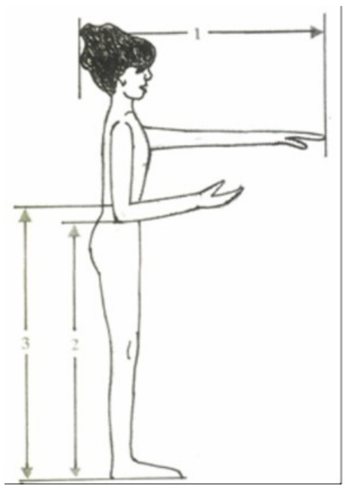

Fig. 2. Anthropometric measurements of the female workers at sitting position

Measurements in the seated position relate to the optimum design of the sewing machine workstation, and the measurements in standing position relate to the determination of the optimum heights in quality control and ironing units. In the study, in addition to the descriptive values, the 1st, 5th, 50th, 95th and 99th percentile values. Based on the anthropometric measurements, optimum values of workplace height were determined. In this determination related to the workplace design in apparel industry, the 1st, 5th, 50th, 95th and 99th percentile values were taken into account.

Results

General information about women

The women included in the study are between the ages 18 and 44 years. Of these women, the 15% are below or at the age 20 years, approximately 1/3 rd (34.3%) are between the ages 21 and 25 years, the 27.2% are between 26 and 30 years, and the remaining 23.6% are older than 30 years. The majority of the women (75.6%) have the primary education. The percentage of having secondary education is 24.4%. There is not any one among these women who has higher education. The majority of the women (70.5%) are married, and the others are bachelor (26.0%) or divorced/widower (3.5%). The 74.0% of them have children. The number of births varies 1 and 6 among the the women with children. The 81.9% of married women have one or two children. The 1/5 th of the women have been working for a year or shorter. The percentage of women who have been working for years between 2 and 5 is 41.0%, between 6 and 9 is 22.0%, and the remaining 16.9% have been working for longer than 10 years in a related job.

All of the women work at the machine. More than the half (55.5%) of the women have problems arising from the working environment and the equipment. The women who have problems mostly complain from the waist (51.1%), the back (30.5%), the neck (27.0%) and the shoulder (15.6%) aches. These problems are followed by the foot, the leg and the arm aches. When the complainants were also asked for the reasons of their problem, and they have stated that they had no "*problems arising from the improper equipment/working heights.*" The factors arising from the nature of the task like the task requires "*sitting constantly*" (59.5%) and "*bending forward*" (54.9%) are the first two among the reasons for problems. These reasons are followed by "*improper foot pedal*" (10.3%), "*improper sitting material*" (4.4%), and "*task requires bending towards one side*" (2.8%). The women were also stated that the distance between the eyes and the object worked with is not proper, and that they have problems (the factors like dust, noise, temperature, etc.) with the working environment. When the research data are considered, it is seen that the problems of the individual like the waist, the neck, the shoulder and the back aches are the problems arising mostly from sitting constantly, bending forward and unadjustable sitting materials.

The Scheffe analysis shows that the problems of the women stemming from the work increase with the increasing age ($F = 5.415$, $P<0.001$) and service period ($F = 4.354$, $P<0.002$). It was observed that the waist, the back, the neck and the shoulder aches increase considerably particularly after the age 25 and servicing for more than 10 years.

The anthropometric measures of women related to design

The descriptive and percentile values of the anthropometric measures related to the working environment and the equipment, of the female workers in apparel industry were determined and given in Tables 1 and 2.

In addition to the artihmetic mean and standard devition values of the anthropometric measures, the 1st, 5th, 50th, 95th and 99th percentile values were determined, and the deformity and flatness values of the measures were calculated.

When the anthropometric measures related to workplace design of the women in apparel industry were examined, it was observed that the body weight varies between 41 and 115 kg, and the statures of the women vary between 1381 and 1778 mm (range = 368 mm). Anthropometric studies about women are very limited in Turkey. Among these studies conducted by Gönen et al. (1991) it was found that the average height of the women is 1565±54 mm (1416-1686 mm) and the average body weight is 67.4±1.34

kg (41-111 kg) at the same age group. Although the studies are performed in different regions, results of both groups are close to each other.

Table 1: Anthropometric data female workers employed in the textile sector (n = 407)

Body dimensions*	Mean	SD**	Range
Weight (kg)	60.4	12.2	41-115
1.Functional forward reach	610	59	320-796
2.Elbow height	1019	79	777-1164
3.Waist height	991	63	795-1140
4.Knuckle height	747	61	600- 898
5.Shoulder height	1292	66	1076-1505
6.Eye height	1454	73	1236-1643
7.Stature	1548	66	1381-1778
8.Functional overhead reach	1844	104	1596-2119
9.Thigh clearance	192	21	114-253
10.Eye height	1212	36	1059-1348
11.Sitting height	1328	33	1235-1458
12.Functional overhead reach	1609	56	1377-1799
13.Elbow-to-fist length	364	47	281-475
14.Knee height	465	26	363-559
15.Seat height	388	20	277-441
16.Buttock-knee length	518	41	396-694
17.Buttock- popliteal length	472	53	356-594
18.Leg length	933	53	680-1190

*All linear dimensions are in mm
**SD = Standard deviation

Table 2: Anthropometric data female workers employed in the textile sector (n = 407)

Body dimensions	P1*	P5	P50	P95	P99
Weight (kg)	42.0	45.0	58.0	82.8	99.9
Standing position					
1.Functional forward reach	510.0	530.0	600.0	705.6	759.2
2.Elbow height	802.3	844.4	1038.0	1120.6	1149.0
3.Waist height	823.3	864.0	998.0	1085.2	1115.5
4.Knuckle height	608.4	643.8	758.0	839.2	873.5
5.Shoulder height	1146.4	1172.8	1295.0	1394.6	1447.8
6.Eye height	1280.2	1325.2	1458.0	1571.8	1614.0
7.Stature	1399.2	1429.2	1558.0	1642.6	1709.0
8.Functional overhead reach	1614.6	1672.8	1841.0	2018.4	2076.0
Sitting position					
9.Thigh clearance	144.1	157.4	190.0	229.0	245.8
10.Eye height	1139.2	1157.4	1210.0	1274.8	1308.9
11.Sitting height	1261.1	1274.4	1326.0	1388.2	1414.0
12.Functional overhead reach	1486.2	1528.0	1603.0	1714.8	1774.4
13.Elbow-to-fist length	287.2	307.4	343.0	441.0	460.6
14.Knee height	380.9	427.0	464.0	507.0	532.8
15.Seat height	324.3	324.3	388.0	419.0	432.9
16.Buttock-knee length	428.3	442.8	526.0	526.0	575.9
17.Buttock- popliteal length	369.2	399.0	461.0	564.6	573.0
18.Leg length	801.0	847.0	930.0	1002.0	1068.4

*P1, P5, P50, P95, P99 denote 1st, 5th, 50th, 95th and 99th percentile values

When it is considered that all of these women work at the machine, it will be clear that these women having different physical characteristics can not use the same equipment/sitting material should required to be adjustable in order to increase the productivity and health problems.

Workplace design

An ergonomically appropriate working environment designed by the needs of the workers are taken into account determines the conditions that require minimum power for the task by minimizing the forces on the user. On the other hand, improperly designed equipments cause the aches and symptoms around the shoulder, neck, nape and waist, and to the problems with the muscle and skeleton systems (Kalınkara et al., 2001). These equipment originated problems arising from the routine works in apparel industry will be able to solved by rearranging the working environment, and the productivity will be able to maximized as a result of providing more confortable conditions to the worker. It is possible to give examples of this situation by considering the results of this study.

To determine the height of the seat, 5 th percentile distribution characteristics of the shortest findings of the statistical data are used. Thus, the thighs are prevented to cut by the front side of the sitting material by ensuring that there remains enough space under the thighs of the sitting person (Kalınkara, 1995). The minimum height of the sitting material should be 379.5 mm, when a 25 mm shoe height is added to the 5 th percentile value (354.5 mm) of the height of the back of the knee of the individual. A setting range between 379.5 and 447.3 mm will ensure the suitability for the 90% of the workers. The optimum height should be determined by adding the pedal height of the machine, and also the wheel height if the machine has wheels, to this height. However, in two plants included in the study and also in most of the plants in apparel industry, the sitting materials are not adjustable. This situation causes the individual with different anthropometric measures to have problems in using the sitting material. Similarly, classical sitting materials also cause various aches because they don't support the waist and the back.

In the textile sector, the workplace and the workflow are changed, rearranged continuously according to the scale orders. In order to make these changes more rapidly, the machines are attached with wheels which increase the work height about 50 mm. This situation prevents the relation between the individual and work height because of the constant height of the sitting material. Generally the individual on the sitting material raises herself by using a pad or something similar to set up on optimum balance with the work surface, since the height of the sitting material is low and it is not adjustable. For the short individuals, however, increasing the height of the work surface creates important problems, and forces the individual considerably. Similarly, the pedal angle of the machine affects the sitting style of the individual so that increasing angles leaves the individual away from the working point or makes the individual to slide towards the front side of the sitting material, that prevents to support the waist.

Tasks which are performed in standing position like ironing, cause tiredness because they require more human power. These kind of tasks in apparel industry should be performed by male workers in order to further utilization of human resource. However, in three of the plants included in the study the ironing process is performed by woman. If the women are required to be employed in this process, the work height should be related to the elbow height of the women and the leisure breaks should be increased. For the heavy processes like ironing which has an energy consumption of 4 kcal/min, the height of the working surface should be 200 mm lower than the elbow height. When it is considered that the elbow height in standing position varies between 993.8 and 1132.3 mm (+25 mm shoe height), the height of the ironing table can be adjustable between 818.8 and 857.3 mm. The height of the units around the area that will be used for storing purposes should not exceed 1735.0 + 25 mm and should not be lower than 705.5 + 25 mm in order to prevent bending.

(a) (b)

Fig. 3. A constant sitting material is the source of various aches for the employees of the apparel industry (a), an adjustable sitting material, however, avoids most of the problems and provides a more comfortable working environment (b).

Conclusion

The qualification of a workplace can be measured by the standards like the steps of the task, the distance and the type of the action, and the usage comfort of the tools and the equipment. However, these are not the most important factors in deciding the quality of the workplace. Designing the workplace according to the individual who performs the task is generally much more affected. Such an application, on the other hand, is not economic for the environments where the employee density is high and for the plants that have employees from different sexuality. For this reason, adjustable working mechanisms should be developed, by determining the upper and lower limits with the consideration of the anthropometric measures. For a proper design, one of the heights of the workbench/machine, the sitting material and the pedal should be constant, and the other two should be adjustable. Presently, adjustable sitting material is the alternative generally encountered in practice. However, although there is not any plant included in the study and in the industry that fully matches the situation, some of them have adjustable sitting materials.

The high machines which are started to be used to sew trousers in standing position in some plants, also create health problems and tiredness. These machines can be advantegous for short term work, but for the long term static works, they will create important health problems. The anthropometric measures determined in this study will be useful for the design of workplace arrangements, and for the design of ergonomic products and means in the areas like health sector, office management, etc where female workers are hired intensively. The arrangement of the workplace in accordance with the individual properties will increase the productivity and the life quality by decreasing the tiredness in tasks performed either in standing or sitting positions. As the data obtained with this study is benefical in the workplace design in textile plant, can also be applied to other sectors where the women are employed. With this characteristics the study can constitute an anthropometric database for women.

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