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DESIGN OF WORKING CHAIR AND TABLE FOR BANGLADESHI GARMENTS WORKERS TO REDUCE FATIGUE AND DISCOMFORT

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ABSTRACT

Garments industries in Bangladesh is one of the biggest sectors in earning foreign currency. Not only that,, these factories have also absorbed lots of unemployed males and females. In garments industries workers have to work for eight hours almost uninterruptedly either by sitting or by standing in one position. So, undoubtedly stress developed in their musculo-skeletal system. An ergonomic approach to design the working chair and table has been described in this paper and also some suggestions for modification have been given, for the garments industries in Bangladesh.

Keywords: Ergonomic Design, Garments' manufacturing, Workspace design

1. INTRODUCTION

Garments industry is very labor intensive. The nature of work in the garments factory is a sedentary type involving repetitive work pattern. This kind of job results in fatigue, which causes different types of health problems to the workers. Work fatigue also results in the loss of productivity of the workers. Ergonomic design of the workspace looks into the cause of this fatigue and tries to develop a design, that would prevent or reduce the cause of fatigue.

Posture of the worker during the work is the key determinant of fatigue. Spinal curvature, joint angles and head, neck, arm, legs and trunk positions determine the postures. There are many studies relative different posture and health problems [Andersson, 1981; Andersson and Ortengren, 1974; Jmsson. et al., 1981; haeger, 1966; Ekland 1995; Lueder, 1985]. The reduction of postural stress is fundamental to workspace design in ergonomics. A person's working posture is a result of the requirements of the task, the design of the work space and personal characteristics. Considerations of all three components is needed in posture analysis and workspace design. Well designed work-station should be unobtrusive with respect to task performance. Therefore, in the design process task requirements as well as the anatomical, physiological and anthropometric characteristics of users are considered.

Garments industries in Bangladesh have, in general, very poorly designed workspace. Sewing desks, Inspection desks, sitting tool, limits of work space etc are designed without any ergonomic consideration. The industry owners are busy meeting quota based demands and very few cared the productivity and welfare of the worker. However, the situation is changing towards more responsible manufacturing. The industry has also to face an open competition from 2005 when workers productivity will be important to have price advantage. The major markets started emphasizing healthy work environment including workers safety and comfort.

This paper discusses the standards principles and parameters for ergonomic seat and table design. It presents the existing situation of the garments industries in Bangladesh. After critically analyzing the existing design, the paper suggests some additions and modification of the present seats in the industry. The suggested design is expected to improve the work condition of the worker reducing physical stress and fatigue and thus improving the productivity of the worker.

2. GENERAL PROCEDURE IN ERGONOMIC DESIGN

Designing work-space with ergonomic consideration involves the following steps

- Define the Tasks to be performed at the Workstation
- Determine the body dimension relevant in design
- Define the population to use the Workstation
- Determine the Principle to be applied
- Select the percentage of population to be accommodated with the Workstation

3. PRINCIPLES AND PARAMETERS OF ERGONOMIC WORK-SPACE DESIGN

3.1 General Principles Of Ergonomic Design

There are many studies on seat design [Mark S. Sanders and Ernest J. McCormic; R. S. Bridger1994].The problem in seat design is that nothing proves absolutely correct. There is no one best chair for

every one. A few principles of seat design is briefly discussed below to show, how individuals physical characteristics affect the design of a chair.

3.1.1 Promote Lumber Lordosis

When standing erect, the lumber portion of the spine (the small of the back, just above the buttocks) is naturally curved inward (concave), that is, it is lordotic. When one is sitting with the thighs at 90^o, the lumber region of the back flattens out and may even assume an outward bend(convex), that is, it becomes kyphotic. Lumber kyphosis results in increased pressure on the disk located between the vertebra of the spine[Sanders & McCormick,1993] It is seen that a 2 inch thick lumber support with a seat back rest angle of 90^o have a marked impact on maintaining lumber lordosis.

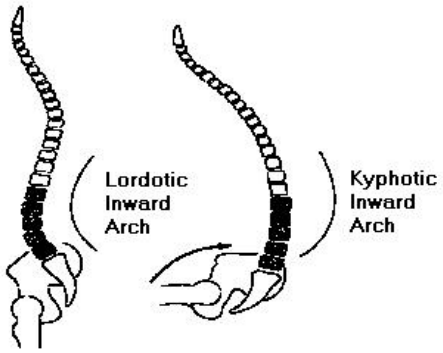

Fig 1.Lumber Lordotic and Kyphotic position

3.1.2 Minimize Disk Pressure

Excessive pressure can damage the disks between the vertebra. Unsupported sitting, i.e. not using a back rest, increases disk pressure considerably over that experienced while standing. Nachemson and Elfstrom (1970), for example, found that unsupported seating in an upright, erect posture(forced lordosis) resulted in a 40% increase in pressure compared to standing. Unsupported seating in a forward slumped posture increases pressure by 90% compared to stansding.

Andersson (1987) reports that using of a reclined backrest has a marked effect with considerable reduction in pressure by reclining backrest from vertical 90^o to just 100 to 110^o. Use of a lumbar support also reduces disk pressure as does the use of arm rest, but with a reclined back-rest the effect of arm-rest is negligible.

3.1.3 Minimize Static Loading on the Back Muscles

Andersson reports that muscular activity as measured by EMG (Electromyography) is similar when standing or sitting. In fact, EMG activity decreases when sitting in a forward slumped posture, this posture produces maximum pressure on the disks. Anderson and Ortengren (1974) found a reduction in muscular activity in the back when the backrest was reclined up to 110^o.

3.2 Parameters of Seat Design

3.2.1 Seat Pan Height and Slope

Figure 2 shows different parameters of sitting posture. Seat height should be low enough to avoid excessive pressure on the underside of the thigh. Such pressure can reduce blood circulation to the lower legs. Low seats results in more lumber flexion (an undesirable condition) than do high seats. In fact, people tend to set adjustable seats about 4 to 5 cm higher than their popliteal height taking into account their shoes and footrest if used.

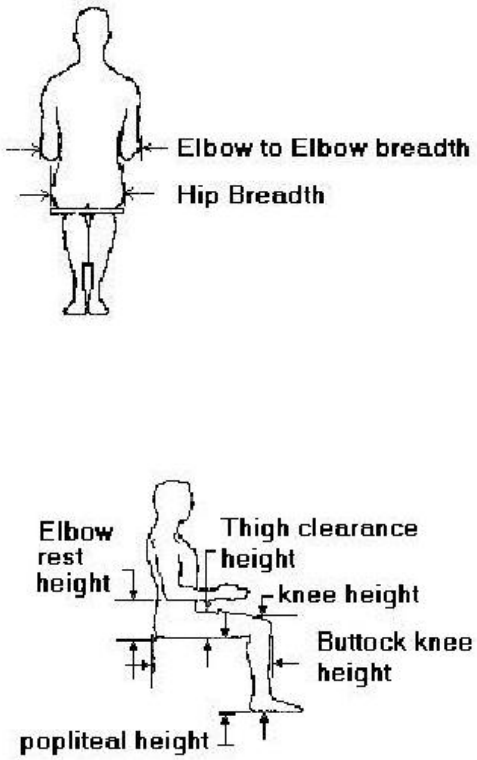

Fig 2. Parameters related to sitting posture

Usually the seat pan designed at the 5^{th} percentile female height.. ANSI recommends a minimum range of 40.6 to 52 cm. ANSI recommends seat pan angles of 0 to 10^o backward tilt. Mandal (1982) recommends 10 to 15^o of forward tilt. Compromising, Lueder (1986a), suggests 5 to 15^o tilt to 5^o backward tilt.

3.2.2 Seat Depth and Width

The seat depth shouldn't be too lengthy, then a small user either will not be able to use the backrest or his legs won't touch the floor. So,the seat depth should be the Buttock-Popliteal length of the 5^{th} percentile Female, sitting.

3.2.3 Back-Rest

Three parameters are needed to define the seat back.ANSI recommends a minimum range of 90^o to 105^o Seat back Angle with the seat pan, at least 30.5 cm Seat back Width in the lumber region. Lueder recommended Seat back Height should be minimum of 50 cm. ANSI

recommends a lumber Support that is 15.2 to 22.9 cm in height and 30.5 cm wide positioned 15.2 to 25.4cm above the seat reference point.

3.2.4 Contouring and Cushion

Human body has evolved in such a way that, when the body is seated, the primary weight of the body can best be supported by the Ischial Tuberosities of the buttocks. So, to reduce the pressure contoured seats should be used.

The density and thickness of the seat pan cushion affects pressure distribution, as does contouring. It is generally recommended that seat cushion thickness ranges from 4 to 5 cm (Lueder, 1986a).

3.3 Parameters of Table Design

3.3.1 Work Surface Height

Work surface height is simply the height of the upper surface of the table, bench, desk, counter etc. measured from the floor. Figure 3 shows different parameters related to table design. If a work surface is too low, the back may be bent over too far; and if it is too high, the shoulders must be raised above their relaxed posture, which cause shoulder and neck discomfort.

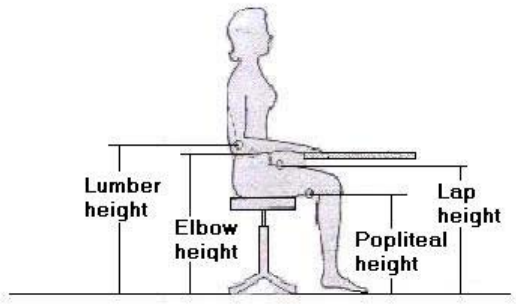

Fig 3. Different dimensions in table design

3.3.2 Table Height and Arm Posture

Recent studies have shown that reducing work surface heights, generally to permit relaxed posture of the upper arm with respect to working height. Working with relaxed upper arm and elbows at 90^{o} provides comfort and helps maintain straight wrist

3.3.3 Table Height and Thigh Clearance

Table height is also influenced by the seat height, the thickness of the work surface and the thickness of the thigh. The clearance between the seat and the underside of the work surface should accommodate the thighs of the largest user. *ANSI* (Human Factor Society, 1988) recommends 66.5 cm as the minimum height as the underside of the non-adjustable seated work surface. Such table can cause problems to the small users. They usually have to raise their seats so that their elbow height is equal to the working height. In so doing often their feet cannot touch the floor. When this occurs a foot rest is needed to support their feet.

3.3.4 Tilting of the Table

The slanted work surface results in less bending of the neck, more upright trunk and less trunk flexion than does the horizontal surface. Figure 4 shows such 2 kinds of work surfaces in different trunk positions.

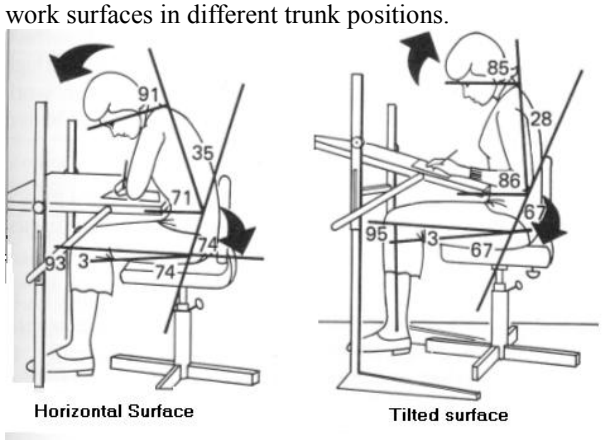

Fig 4. Different trunk posture with table tilting

4. Work Space and Task Requirements in Garment Manufacturing

Typical work-space in a garments factory comprises a sewing table, a tool, a work-in process inventory holder etc. The surface area of a work station having a table and a tool is about $1m^2$. Typical tasks at a sewing station are taking the cloth, seeing the sewing instructions, matching the thread, sewing the cloths; store that at a bin etc. An inspection worker has to inspect the finished dresses by standing before a big table, most of the times for all day long. From this brief scenario it can be well understood that how much tedious the works are and how much work space a person needs to move freely. Though there are isles between the workplaces, but it seems the work-spaces are somehow congested. Lighting facility in work area is average. But, room temperature is much higher than comfortable range

5. WORKSPACE DESIGN FOR THE GARMENTS WORKERS IN BANGLADESH

Use of anthropometric data for designing a work-space should be reasonably representative of the population that would use the space. So, 44 anthropometric data of 11 males and 11 females have been collected from a garment industry, which will be used for the design phase. A summary of only the necessary data are given in the Table-1 given below.

There are three principles for applying anthropometric data to specific design problem. Each applies to a different type of situation - design for extreme individual, designing for an adjustable range, designing for average. In the garments industries in Bangladesh both male and female workers are working. So, the design will be for the average workers.

Table-1: Garments workers' anthropometric data

Dimension	Female (cm)		
	5th %ile	Mean	95th %ile
Elbow Height, Standing	87.9	93.55	99.21
Sitting Height,	72.52	77.01	81.51
Sitting Elbow Height	18.08	22.29	26.51
Sitting Thigh Height (Clearance)	11.24	13.4	15.57
Sitting Popliteal Height	38.37	41.22	44.08
Abdominal Depth, Sitting	11.78	14.78	17.79
Buttock-Knee Depth, Sitting	43.05	47.46	51.88
Buttock-PoplitealDepth, Sitting	35.15	39.72	44.3
Dimension	**Male (cm)**		
	5th %ile	**Mean**	**95th %ile**
Elbow Height, Standing	91.3	99.91	108.52
Sitting Height,	78.91	83.48	88.06
Sitting Elbow Height	21.17	24.71	28.26
Sitting Thigh Height (Clearance)	9.18	11.55	13.93
Sitting Popliteal Height	40.74	43.88	47.03
Abdominal Depth, Sitting	15.15	19.75	24.36
Buttock-Knee Depth, Sitting	47.45	51.73	56.02
Buttock-Popliteal Depth, Sitting	37.75	41.91	46.08

5.1 Sewing chair design

5.1.1 Seat pan height and Slope

In Bangladesh almost all of the garments workers are female.There is a trend to design the seat pan height as the 5th percentile female popliteal height. But at that height a female of near 95th percentile could feel discomfort, so the height could be 95th percentile female height. But, that height may be irritating for a short user. Because if the seat pan is higher, those users are unable to touch the floor by the feet. But fortunately most sewing machines come with a pedal. An operator have to put his feet on that while sewing. So, there shouldn't be any problem of foot-keeping. So, 95th percentile Female popliteal height (44.08 approximately 44 cm, from Table-1) should be a good design choice and this dimension is within the ANSI recommendation (40.6 to 52cm).

If forward tilted seats are used, no doubt that bio-chemical advantages will be available. The advantages, however, do not accrue to everyone. Such seats appear to be most beneficial when used with a slanted work surface. That would also cover the mean range of the male.

5.1.2 Seat Depth and Width

This phenomena may affect the short users. Chairs with deep seats may look comfortable, but if the seat depth exceeds the users' buttock knee length (buttock to the popliteal fossa), the back rest cannot be used properly. So, 5th percentile female buttock to popliteal lenth (35.15 cm approximately 36cm, from Table-1) should be a right design.

The width should be set to be suitable for large persons .As, female have higher hip breadth than male, so, 95th percentile Hip Breadth Female, sitting (32.89, from Table-1) is considered as perfect.

5.1.3 Seat back

While designing seat back, the factor of supporting the lumber vertebras comes first. But, the location of the lumber support with respect to the level of lumber spine (L1-L2 or L4-L5) does not seem to be of importance (Andersson, 1986). This finding suggests that a height adjustable lumber support is not necessary since the height of a fixed lumber support can be optimized to contact the lumber spines of a wide range of users. So, ANSI recommendation for the lumber support can be followed.

The support should be 16 to 22cm in height (ANSI recommendation is 15.2 to 22.9 cm), which will work both as lumber and lumbo-thoracic support, 30cm in width (ANSI recommendation is minimum 30 cm) and should be 16cm (ANSI recommendation is15.2 to 25.4cm) above the seat reference point.

ANSI recommended seat pan angle range is 90^o to 105^o. More than 90^o angle should be only used when used with a tilted work-surface. Because, in garments industries workers have to work being in forward tilted positioned. So, seat back angle more than 90^o will not be useful.

Correct lumber support can be achieved by using extra cushioning to form a lumber pad (slight softer than the seat pan cushion) or, by contouring the back rest. Back rest should be protruded to 4 to 5 cm forward to support the lumber region perfectly. So, a 4cm thick non-contoured cushion serves just as perfect and at the same time cost saving.

5.1.4 Hand rest and foot rest

No hand rest is needed as the hands are always at the work surface, which is just as the elbow height. Again foot rest is also not needed as working table provides a pedal (to operate the sewing machine by foot), that automatically serves the purpose of foot-rest.

5.1.5 Contouring and Cushion

For the perfection in design contoured seat should be used. But, that demand a high cost. A cushion of 4-5cm thick with slight hollow in the buttock area serves very well. This hollow prevent user's pelvic from sliding forward. A figure below shows a model based on data derived above

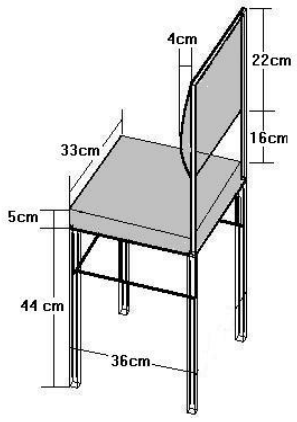

Fig 5. a model of chair for sewing worker .

5.2 Sewing table design

5.2.1 Table height

From the discussion of section 3.3.3, for the common height, sewing table height should be sitting elbow height plus sitting popliteal height of 95th percentile male

(47.03+28.26=75.3, from Table-1). Bex (1971) suggested that the height should be reduced by 4cm.

5.2.2 Tilting

Sewing Table should be 15^o tilted towards the worker (ANSI recommended) so that the he or she can maintain the correct trunk posture. This is also helpful to get relief from neck and lower back pain.

Sewing Table width and length is not concerned in the discussion, as the machine position is fixed in the table and operator has only put his hand there for sewing.

5.3 Inspection table design

Inspection worker does the inspection standing before a table for a long time. Of course there are advantages of standing work position such as- reach is greater in standing than seating, requires less legroom than seated workers, standing can be maintained with muscular activity, trunk muscle power is twice as great in standing etc. But, prolonged daily standing is known to be associated with low back pain.

5.3.1 Table Height

Work surface height should be at Standing Elbow Height of 5th percentile Female (87.9 cm, from Table-1*)*. As this is a light work if the surface is below the elbow height, it will be more comfortable. So, even the 95th percentile or above Male workers won't feel any difficulties. But, as in almost every garments industries Male workers does the Inspection. So, if it is Standing Elbow Height of 5th percentile Male which is 91.3 cm, from Table-1 should be fine.

5.3.2 Table tilting

Inspection table should be tilted up to 15^o. As, the whole dress has to be seen at a time, it needs a large surface area to be observed by the inspector. So, he needs to be bent time to time. If the table is tilted, then whole area can be observed even maintaining the straight trunk posture.

5.3.3 Foot-Rest

It is known that people who do have to stand for long periods use standing aids. Such aids indicates that if standing is to be prolonged, it should be tri-pedal rather than bi-pedal, the third leg providing opportunity to rest each of the other. So, it is recommended that a 4 to 6^o slanted foot rest should be used to allow less fatigue to grow in the body.

6. CRITICAL ANALYSIS OF EXISTING SETUP

Several garments industries in Dhaka City have been visited. Most of these industries have almost same chair and table dimension and no where right posture is maintained. Here chairs are called 'Bench' or 'Tool' have been made in a conventional measurement. Three of these garments industries' Sewing Chair-Table and Inspection Table Dimension were measured and given below in Table-2.

Table 2: Dimensions of existing set-up

Sewing Chair				
Factory ->	**X**	**Y**	**Z**	**Average**
Height (cm)	46	43.18	46.99	45.39
Width (cm)	30	27.94	29.21	29.05
Length (cm)	45.72	43	91.44	60.05
Sewing Table				
Height (cm)	77	76.2	76.2	76.46
Width (cm)	54	53.34	48.26	51.87
Length (cm)	106	91.44	101.6	99.68
Inspection Table				
Height (cm)	102	83	91.44	92.12
Width (cm)	89	91.44	89.9	90.11
Length (cm)	120	182.88	203.2	168.69

Actually for designing an ergonomic chair seat height, breadth and width are the key factors. In these factories seat height is very close to the proposed measure, Depth is lower than standard and width is more than needed. For table design height and thigh clearance are the major concern. These factory sewing table heights are close to the proposed measure but some factories' tables don't provide enough thigh clearance. The following common drawbacks were observed.

6.1 Sewing Chair

Most of garments factory provide no back support, no cushion and no provision for adjustability of seat and Work-surface height.

6.2 Sewing Table and Inspection Table

There are problems with table height, table tilting and in thigh clearance in the existing set up. However, some garments industries have tilted inspection table.

A verbal survey was carried out to both male and female workers. It was found that they feel some common problems (though they can't define those correctly). These are: i) Lower back pain (due to the Kyphotic position of the lumber vertebra) ii) Numbness in the buttock (as there is no cushion, excessive pressure at the Ishchial-tuberosities and blocking of blood circulation) iii) Swelling at the Calf-muscle (due to excessive under-Thigh Pressure) iv) Neck pain (due to not maintaining the Lordotic shape of the Cervical vertebra) v) Muscular fatigue

7. MODIFICATION SUGGESTED FOR EXISTING SETUP

7.1 Sewing Chair

7.1.1 Back Support

A back rest should be added with the existing set-up, which will support the lumber region of the operator. It can be made at a low cost by bending a pipe to a desired shape, which have a cushion of approximately 4cm thick attached with it and then by attaching the structure with the existing set-up. A suggested model is shown in the figure 6 in detail anthropometric dimensions in it.

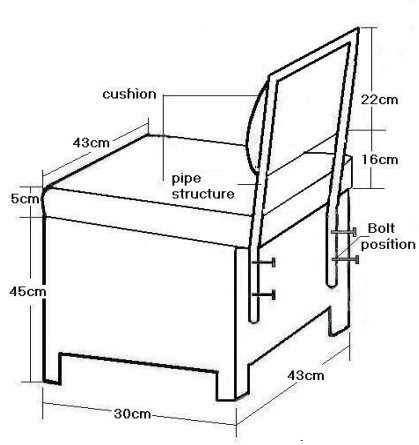

Fig 6. Pipe structure and cushion added with the existing set-up.

7.1.2 Cushion

An approximate 5cm thick cushion should be provided over the existing tool. Actually cushion making cost is very low as a lot of scrap is produced everyday in Garment industries.

7.1.3 Table Tilting

Sewing table can be tilted up to 15^o by inserting wedge shaped blocks or by using strips under the legs of the table.

7.2 Sewing Table and Inspection Table

7.2.1 Foot Rest

In the inspection table the foot rest facility is there but cannot be used due to less thigh Clearance. It will be useful if it is lowered a little (approximate height is 75cm, as fine works demand that standing work surface should be lower than standing elbow height) and an extra slanted ($4\text{-}6^o$) foot-rest is provided.

7.2.2 A Standing Height Chair

A standing height chair with lumber support could be provided in which seat pan is almost at the standing elbow height of 5^{th} percentile male (91.3 approximately 91cm from Table 1) as most of the inspection workers are Male in most of the garments industries). This will give the lumber support to maintain the correct posture, help working for a long time and reduce the muscular fatigue of the inspector.

7.2.3 Tilting

Sewing table should be tilted up to 15^o by inserting wedge as shown in the figure 7, resulting a good trunk posture reduce back pain. The figure also shows other features as suggested for modification after using anthropometric dimensions.

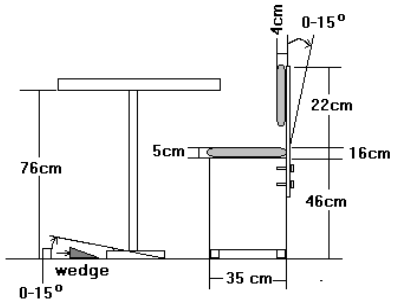

Fig 7. A modified model of existing set-up.

8. CONCLUSION:

The main theme was here to reduce the stress while working. The human body is simply not made to sit in one position for long periods of time. The disks between the vertebra depend on changes in pressure to receive nutrients and remove waste products. Discs have no blood supply; fluids are changed by osmotic pressure. Sitting in one posture, no matter how good it is, will result in reduced nutritional exchanges and in the long term may promote degenerative processes in the discs. The best defense against postural fixity, however is to periodically stand up and work the kinks out by flexing and bending the back and the legs. Scientists and even normal peoples are now thinking about the stress relaxation and less fatigue growing while at work. Correct body posture helps a lot in relaxing stress in body. Entrepreneurs, who are going to start new garments industries, can follow the design instruction described in this paper to relax their worker from postural stress. Existing garment industries can modify their design investing very marginal amount of money and it's very simple. But, the effect to the workers will be very rewarding.

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