International Journal of Manufacturing and Material Processing
Vol. 1: Issue 2
www.journalspub.com

Modified Sewing Machine Workstation Design by Using Taguchi Approach

*Shubham Ashokrao Netnaskar**
Department of Mechanical Engineering, Dr. Rajendra Gode Institute of Technology and Research, Sant Gadge Baba Amravati University, Amravati, Maharashtra, India

Abstract

The study was based on design of experiment using Taguchi Orthogonal Array with three parameters namely height of sewing machine table, angular movement of sewing machine table and sliding movement of sewing machine table considered for experimentation. An orthogonal Array of L9 experimental design was adopted & 3 angles namely trunk angle, head angle and neck angle was measured for each experimental run. Then the reading for female & male operator was separated & the qualitative analysis has been done on the basis of operator's opinion. From this qualitative analysis the optimize position for sewing machine operator has been determined so that operators can work longer without any stress or fatigue at back.(i.e. Risk of musculoskeletal disorder would be lower).

Keywords:

****Corresponding Author***
E-mail: netnaskarshubham@gmail.com

INTRODUCTION

Today, corporate work spaces are ergonomically designed, which simply means body friendly. Millions of dollars are spent each year on repetitive motion injuries, forcing companies to address the comfort and health of their workers. Ergonomics are very important when it comes to sewing since poor posture and awkward positions will result in early fatigue and pain in the neck, shoulders, and back. The purpose of this project was to look at conditions in the clothing industry to find out how these injuries start and how they can be prevented. Researchers identified many features in clothing plants that could be improved to prevent injuries including:

The project's final report brings together all of the information gained from this research. This report focuses on the potential ergonomic problems and solutions that were identified in plant. We hope this report can be used to initiate changes in the workplace by creating a starting point for discussion and stimulating ideas on how conditions in our plants can be improved.

What Is "Ergonomics"?

Ergonomics is a topic that affects us all; yet few of us have a good understanding of what the term actually means or realize how it affects us. Ergonomics is a science that focuses on designing a job for the worker. An ergonomically designed job would ensure that a taller worker had enough space to safely perform his or her job and also that a shorter worker could reach all of his or her tools and products without reaching beyond a comfortable and safe range. The opposite to this, and what typically happens in the workplace, is that a worker is forced to work within the confines of the job or workstation that is already in place. This may require employees to work in awkward postures, perform the same motion over and over again or lift heavy loads – all of which could cause work-related musculoskeletal disorders. These injuries often start as minor aches and pains but can develop into disabling injuries that affect our activities of daily living such as laundry, hobbies (knitting, golf, etc.) and even the ability to pick up our children. Ergonomics aims at preventing injuries by controlling the risk factors such as force, repetition, posture and vibration that can cause injuries to develop. Some fundamental ergonomic principals that should be followed in our workplaces are:

Use proper Tools

Tools should be appropriate for the specific tasks being performed. Your tools should allow you to keep your hands and wrists straight – the position they would be in if they were hanging relaxed at your side. Bend the tool – not the wrist! The tool should fit comfortably into your hand. If the grip size is too large or too small it will be uncomfortable and will increase the risk of injury. Tools should not have sharp edges, create contact stresses in your hand, or vibrate.

Keep Repetitive Motions to a Minimum

Our workstations or tasks can often be redesigned to reduce the number of repetitive motions that must be performed. Some tasks can be automated or redesigned to eliminate repetitive movements and musculoskeletal injuries.

Avoid Awkward Postures

Your job should not require you to work with your hands above shoulder height on a regular basis.

Arms should be kept low and close to your body. Bending and twisting of your wrists, back and neck should also be avoided.

Get Proper Rest

Need to rest your body and mind in order to prevent injuries. Give your muscles a rest during your coffee breaks, lunches and weekends by doing something different from what you do in your job. For example, if you stand all day while performing your job you should sit down to rest your legs and feet during your breaks. If you sit down when working you should stand up and walk around during your breaks to give your back a rest and to increase circulation in your legs.

The Scope of Ergonomics

In the same manner that a chemist can view the entire world in terms of chemist, the ergonomist can view virtually every human interaction as ergonomics. Anything that helps humans expand on capabilities or overcome limitation can be viewed as component of this field. This schematic summarizes the scope of ergonomics:

- **Motivating Factors**

Improving human well-being
(i) Safety
(ii) Comfort

Improve human performance
(i) Productivity
(ii) Quality
Reduce cost
(i) Injuries
(ii) Errors

Meet human resources trends
(i) Aging workforce
(ii) Slower growing labor pool
(iii)Rising employee expectations

Meet regulations
✓ Osha
✓ Ada

Sell better products

- **Contributing Disciplines**

(i) Engineering

(ii) Psychology
(iii) Medicine
(iv) Physiology
(v) Anatomy
(vi) Anthropology
(vii) Industrial design

- **The Process of Ergonomics**

(i) Task evaluation
(ii) Prioritization
(iii) Involvement
(iv) Problem solving
(v) Continuous improvement

- **Principal of Ergonomics**

(i) Physical
(ii) Cognitive

- **Applications**

(i) Tool, furniture, workstations
(ii) Production process
(iii) Display and control
(iv) Instruction
(v) Labels
(vi) Communication
(vii) Home appliances
(viii) Consumer product
(ix) Transportation system
(x) Sports and leisure activities

- **Results**

(i) Improved human well being
(ii) Increased efficiency
(iii) Reduced injuries
(iv) Fewer errors and accidents
(v) Lower cost
(vi) Innovation
(vii) Increased sales
(viii) Improved profits

What Are Musculoskeletal Disorders?

The Human Musculoskeletal System (also known as the Locomotors System) is an organ system that gives humans (and many animal species) the ability to move using the muscular and skeletal systems. The musculoskeletal system provides form, support, stability, and movement to the body. It is made up of the body's bones (the skeleton), muscles, cartilage, tendons, ligaments, joints, and other connective tissue that supports and binds tissues and organs together. The musculoskeletal system's primary functions include supporting the body, allowing motion, and protecting vital organs. The skeletal portion of the system serves as the main storage system for calcium and phosphorus and contains critical components of the hematopoietic system.

This system describes how bones are connected to other bones and muscle fibers via connective tissue such as tendons and ligaments. The bones provide the stability to a body in analogy to iron rods in concrete construction. Muscles keep bones in place and also play a role in movement of the bones. To allow motion, different bones are connected by joints. Cartilage prevents the bone ends from rubbing directly on to each other. Muscles contract (bunch up) to move the bone attached at the joint.

‘‘Musculoskeletal disorders’’ include a wide range of inflammatory and degenerative conditions affecting the muscles, tendons, ligaments, joints, peripheral nerves, and supporting blood vessels. These include clinical syndromes such as tendon inflammations and related conditions (tenosynovitis, epicondylitis, bursitis), nerve compression disorders (carpal tunnel syndrome, sciatica), and osteoarthritis, as well as less well standardized conditions such as myalgia, low back pain and other regional pain syndromes not attributable to known pathology. Body regions most commonly involved are the back, upper limb, lower limb, neck, shoulder, forearm, and hand, although recently the lower extremity (limb) has received more attention. While the back pain has several complex issues that have enough singular characteristics to be separately. Nevertheless, MSDs are the single largest category of work-related illness, representing a third or more of all registered occupational diseases in the

Nordic countries surveys of working populations have reported upper extremity symptom prevalence of 20 to 30% or even higher.

Sources or Factor Responsible For WMSDs

There are several factors which are responsible for WMSDs out of which some factors are mainly responsible for WMSDs are as follows.

Physical

There are some physical studies which are concerned with worker's body.

- Physical effect of various stresses and strains caused by environment factor like light, noise, heat humidity and atmosphere condition on human body and the extent to which it can interact
- Human stamina
- The speed, accuracy and force with which body movement can be carried out

Studies have mention that poor ventilation, low illumination and unbearable noise in industry results in loss efficiency, discontent and increased rate of accidents and sickness.

The knowledge of human stamina is useful in work organization, for instance, in determining the work and rest schedule.

The knowledge of the speed accuracy and force of movement of each body member helps jobs of machine to be designed so that heavy work is done by the big muscle, and light work by the small ones.

Physiology and anatomy are interrelated terms as anatomy deals with the study of internal details of human body.

Psychology

This is study concerned with behavior and human reaction under various working condition and under the influence of mental strain, fatigue, etc. The main contribution of psychology to ergonomics lies in the field of reactive information of human beings when they are at work or at rest; in fatigue or boredom and alert or inert conditions.

Awkward Postures

Often, because of the characteristic of the workplace or the methods adopted working have to use awkward or demanding posture. Inadequate work posture can constitute a risk factor. Conversely, posture can be inadequate for three types of reasons it is extreme if it is near the limits of the joints range of motion. Posture can be demanding if it can only be maintained by fighting gravity. Finally, certain postures are risky because the anatomical structure is placed in a position where they cannot function effectively. The pain caused by a posture will obviously depend on how far it is from a relaxed posture (this refer to amplitude of posture which is about the equivalent of intensity of posture), the frequency with which this posture is adopted, and its duration. Workers may sometimes adopt extreme posture because the material is poorly located, or because the work surface is not adequate.

Three Major Modulator

The seriousness of risk factor depends on three main characteristic intensity, frequency and duration.

Intensity

Most of the time, contribution of the intensity of a risk factor goes without saying: the more intense the risk factor (the greater the effort or extreme the posture), the higher the risk. However, there are times the relationship is not that obvious. For example, saying that the complete and forced immobility of a body segment can contribute to the risk does not mean that its opposite uninterrupted mobility is desirable. The relationship here is a more complex one, where too little can be just as harmful as too much.

Frequency

Frequency refers to the number of times that a risk is present within a given time interval. Being exposed to vibration twice a day is a lower risk factor than being exposed two hundred times per day. The risk therefore increases most of the time with the frequency.

Duration

The third characteristics that affect the seriousness of risk factor is duration, a concept that has several meaning. It can be the amount of time spent in a given posture within the work cycle or the duration of the effort made within the cycle, such as the shoulder being flexed for 45 seconds in a two minute cycle. The longer the time spent in the cycle, the higher the risk factor. Duration can also mean the number of hours in a work shift when a worker is exposed to a given risk. Duration can also refer to a much broader scale. It this case, it may mean the number of years during which the worker has been exposed in his or her professional life. In all three cases, one simple principle generally stands out risk is proportional to duration of exposure.

Risk factor × Duration, intensity, = Scope of WMSD
Frequency
Risk

How Musculoskeletal Disorder Appears

The mechanism through which injurious occur are not well known given the current state of knowledge, the process can be link to black box. The starting is known over use to which many factors may contribute. The result is known; well identified illness such as tendonitis and bursitis. The different WMSDs have similar symptoms. The overloaded region is often pain full and sensitive when touched. Certain movement or efforts may cause pain which, in the most serious cases is felt even when the region at rest. There is often a swelling and sometimes numbness. Mobility may be limited by the swelling or the pain.

The First Symptom of WMSDs

By the time the illness is fully declared is already late to intervene. By that stage victim health has already been compromised and there may be permanent after effects. Most often, when a region of a body is over used, it generates negative consequences by the feeling of localized fatigue or discomfort. These manifestations are often considered as the early indicators of a more serious affliction.

This does not mean being alarmed at the slightest discomfort, which may occur especially when carrying out demanding and unaccustomed tasks. However more attention must be paid to aliment that do not disappear over time and that tends to worsen this may be an early signal of a situation that may degenerate into a WMSD if timely action is not taken.

Knowing How WMSDS Develop for Timely Intervention

The development of the first innocuous stage toward a clearly defined WMSD can be established. Action must be taken when the situation starts getting more serious, for example:

- When the ailment gets more intense or when there is pain
- When the ailment radiates from one very limited region to a bigger and diffuse region
- When discomfort is associated with increased movement or effort (e.g., at outset, the discomfort is felt only when pressure is applied to insert a piece)

- When the discomfort persists longer after work and recovery is very slow

Spinal Cord

The spinal cord is a long, thin, tubular bundle of nervous tissue and support cells that extends from the brain (the medulla oblongata specifically). The brain and spinal cord together make up the central nervous system (CNS). The spinal cord begins at the occipital bone and extends down to the space between the first and second lumbar vertebrae; it does not extend the entire length of the vertebral column. It is around 45 cm (18 in) in men and around 43 cm (17 in) long in women. Also, the spinal cord has a varying width, ranging from 1/2 inch thick in the cervical and lumbar regions to 1/4 inch thick in the thoracic area. The enclosing bony vertebral column protects the relatively shorter spinal cord. The spinal cord functions primarily in the transmission of neural signals between the brain and the rest of the body but also contains neural circuits that can independently control numerous reflexes and central pattern generators. The spinal cord has three major functions: as a conduit for motor information, which travels down the spinal cord, as a conduit for sensory information in the reverse direction, and finally as a center for coordinating certain reflexes.

Structure

The spinal cord is the main pathway for information connecting the brain and peripheral nervous system. The length of the spinal cord is much shorter than the length of the bony spinal column. The human spinal cord extends from the foramen magnum and continues through to the cones medullaris near the second lumbar vertebra, terminating in a fibrous extension known as the filum terminal (Figure 1).

Divisions of Spinal Segments

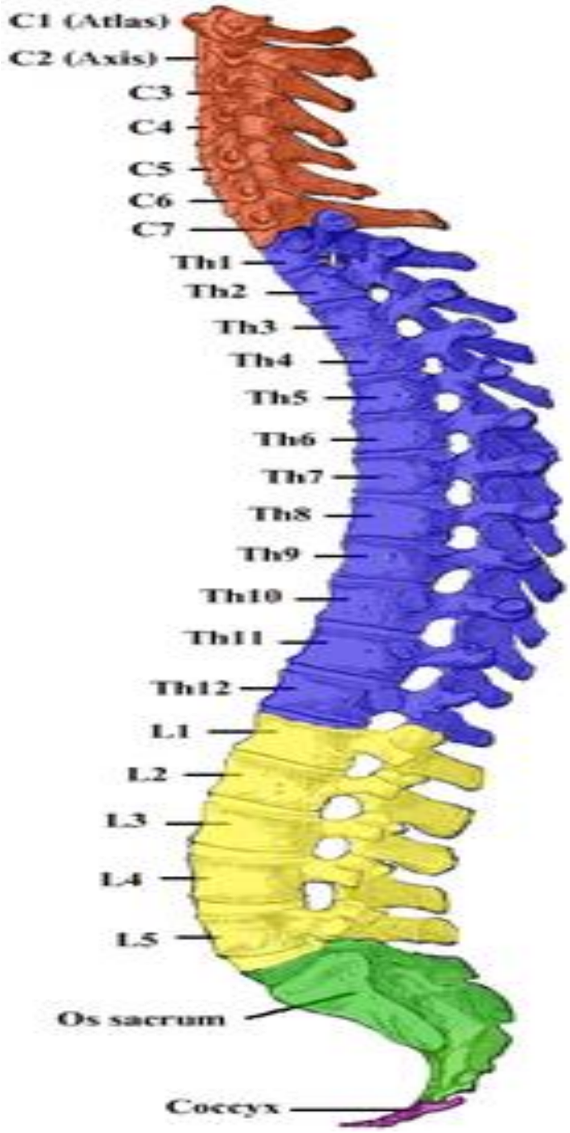


Fig. 1. *Spinal chord.*

It is about 45 cm (18 in) long in men and around 43 cm (17 in) in women, ovoid-shaped, and is enlarged in the cervical and lumbar regions. The cervical enlargement, located from C3 to T2 spinal segments, is where sensory input comes from and motor output goes to the arms. The lumbar enlargement, located between L1 and S3 spinal segments, handles sensory input and motor output coming from and going to the legs (Figures 2, 3).

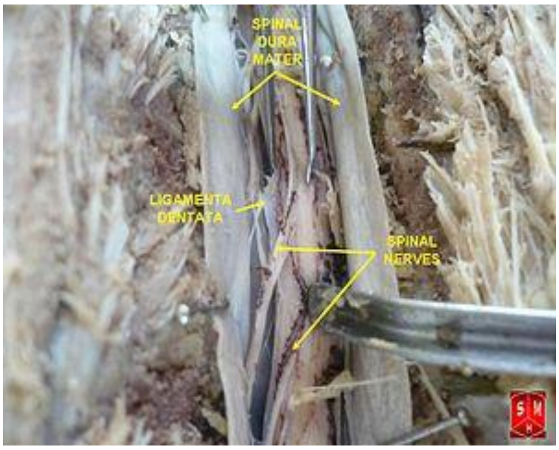


Fig. 2. *Internal structure of nerve system.*

Fig. 3. *Prototype of spinal chord.*

Different Types of Musculoskeletal Disorder

Lumbar Spinal Stenosis

Lumbar spinal stenosis (LSS) is a medical condition in which the spinal canal narrows and compresses the spinal cord and nerves at the level of the lumbar vertebra. This is usually due to the common occurrence of spinal degeneration that occurs with aging. It can also sometimes be caused by spinal disc herniation, osteoporosis or a tumor. In the cervical (neck) and lumbar (low back) region it can be a congenital condition to varying degrees. Spinal stenosis may affect the cervical or thoracic region in which case it is known as cervical spinal stenosis or thoracic spinal stenosis. In some cases, it may be present in all three places in the same patient. Lumbar spinal stenosis results in low back pain as well as pain or abnormal sensations in the legs, thighs, feet or buttocks, or loss of bladder and bowel control (Figure 4).

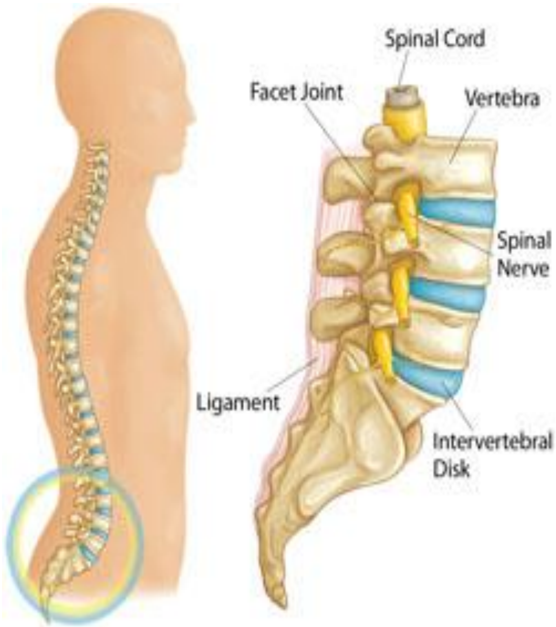


Fig. 4. *Parts of lumbar region.*

Causes

Spinal stenosis may be congenital (rarely) or acquired (degenerative), overlapping changes normally seen in the aging spine, "resulting from degenerative changes or as consequences of local infection, trauma or surgery". "Degeneration is believed to begin in the intervertebral disk where biochemical changes such as cell death and loss of proteoglycan and water content lead to progressive disk bulging and collapse. This process leads to an increased stress transfer to the posterior facet joints, which accelerates cartilaginous degeneration, hypertrophy, and osteophyte formation; this is associated with thickening and buckling of the ligament flatus. The combination of the ventral disk bulging, osteophyte formation at the dorsal facet, and ligament flatus hypertrophy combine to circumferentially narrow the spinal canal and the space available for the neural elements. This compression of the nerve roots of the caudal equine leads to the characteristic clinical signs and symptoms of lumbar spinal stenosis (Figure 5)."

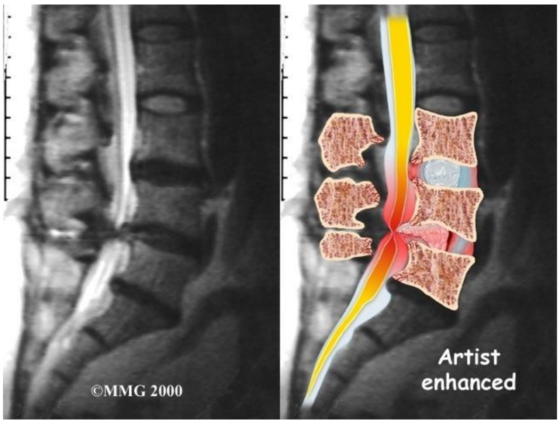


Fig. 5. *Herniation of disk.*

Spinal Disc Herniation

A Spinal disc herniation (prolapsus disci intervertebralis*)* is a medical condition affecting the spine in which a tear in the outer, fibrous ring (annulus fibrosus) of an intervertebral disc (discus intervertebralis) allows the soft, central portion (nucleus pulposus) to bulge out beyond the damaged outer rings. Disc herniation is usually due to age related degeneration of the annulus fibrosus, although trauma, lifting injuries, or straining have been implicated. Tears are almost always postero-lateral in nature owing to the presence of the posterior longitudinal ligament in the spinal canal. This tear in the disc ring may result in the release of inflammatory chemical mediators which may directly cause severe pain, even in the absence of nerve root compression.

Disc herniations are normally a further development of a previously existing disc "protrusion," a condition in which the outermost layers of the annulus fibrosus are still intact, but can bulge when the disc is under pressure. In contrast to a herniation, none of the nucleus pulposus escapes beyond the outer layers.

Most minor herniations heal within several weeks. Anti-inflammatory treatments for pain associated with disc herniation, protrusion, bulge, or disc tear are generally effective. Severe herniations may not heal of their own accord and may require surgical intervention.

The condition is widely referred to as a slipped disc, but this term is not medically accurate as the spinal discs are firmly attached between the vertebrae and cannot "slip (Figure 6)."

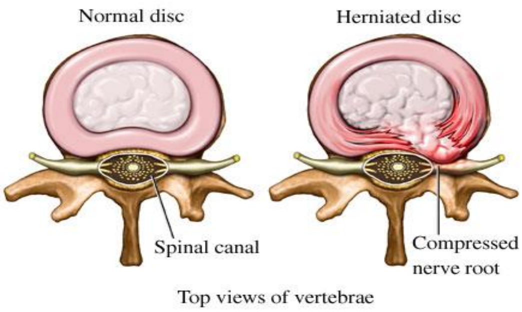


Fig. 6. *Vertebrae.*

Cause

Disc herniations can result from general wear and tear, such as when performing jobs that require constant sitting and squatting. However, herniations often result from jobs that require lifting. Minor back pain and chronic back tiredness are indicators of general wear and tear that make one susceptible to herniation on the occurrence of a traumatic event, such as bending to pick up a pencil or falling. When the spine is straight, such as in standing or lying down, internal pressure is equalized on all parts of the discs. While sitting or bending to lift, internal pressure on a disc can move from 17 psi (lying down) to over 300 psi (lifting with a rounded back) (Figure 7).

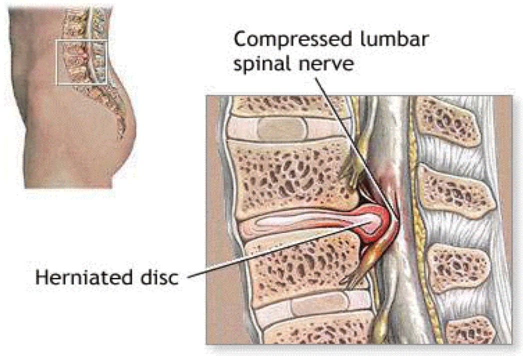


Fig. 7. *Herniation of disk.*

Carpal Tunnel Syndrome (CTS)

Carpal tunnel syndrome (CTS) is a median entrapment neuropathy that causes parenthesis, pain, numbness, and other symptoms in the distribution of the median nerve due to its compression at the wrist in the carpal tunnel. The path physiology is not completely understood but can be considered compression of the median nerve traveling through the carpal tunnel. It appears to be caused by a combination of genetic and environmental factors. Some of the predisposing factors include: diabetes, hypothyroidism, and heavy manual work or work with vibrating tools. There is, however, little clinical data to prove that lighter, repetitive tasks can cause carpal tunnel syndrome. Other disorders such as bursitis and tendinitis have been associated with repeated motions performed in the course of normal work or other activities.

The main symptom of CTS is intermittent numbness of the thumb, index, long and radial half of the ring finger. The numbness often occurs at night, with the hypothesis that the wrists are held flexed during sleep. Long standing CTS leads to permanent nerve damage with constant numbness, atrophy of some of the muscles of the thinner eminence, and weakness of palmer abduction (Figure 8).

Fig. 8. *CTS symptoms.*

Causes

Most cases of CTS are of unknown causes, or idiopathic. Carpal Tunnel Syndrome can be associated with any condition that causes pressure on the median nerve at the wrist (Figure 9).

Fig. 9. *Hands affected with CTS.*

Sciatica

Sciatica or lumbar radiculopathy is a set of symptoms including pain caused by general compression or irritation of one of five spinal nerve roots of each sciatic nerve or by compression or irritation of the left or right or both sciatic nerves. Symptoms include lower back pain, buttock pain, and pain, numbness or weakness in various parts of the leg and foot. Other symptoms include a "pins and needles" sensation, or tingling and difficulty moving or controlling the leg. Typically, symptoms only manifest on one side of the body. The pain may radiate below the knee, but does not always.

Sciatica is a relatively common form of low back and leg pain, but the true meaning of the term is often misunderstood.

Sciatica is a set of symptoms rather than a diagnosis for what is irritating the root of the nerve to cause the pain.

Treatment for sciatica or sciatic symptoms often differs, depending on underlying causes and pain levels. Causes include compression of the sciatic nerve roots by a herniated (torn) or protruding disc in the lower back (Figure 10).

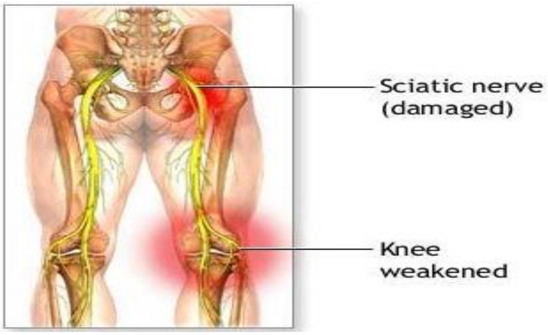


Fig. 10. *Scatia nerve.*

Causes

- Spinal disc herniation

Spinal disc herniation pressing on one of the lumbar or sacral nerve roots is the primary cause of sciatica, being present in about 90% of cases. Sciatica caused by pressure from a disc herniation and swelling of surrounding tissue can spontaneously subside if the tear in the disc heals and the pulpous extrusion and inflammation cease.

- Spinal stenosis

Other compressive spinal causes include lumbar spinal stenosis, a condition in which the spinal canal (the spaces the spinal cord runs through) narrows and compresses the spinal cord, caudal equine, or sciatic nerve roots. This narrowing can be caused by bone spurs, spondylolisthesis, inflammation, or herniated disc, which decreases available space for the spinal cord, thus pinching and irritating nerves from the spinal cord that travel to the sciatic nerves (Figure 11).

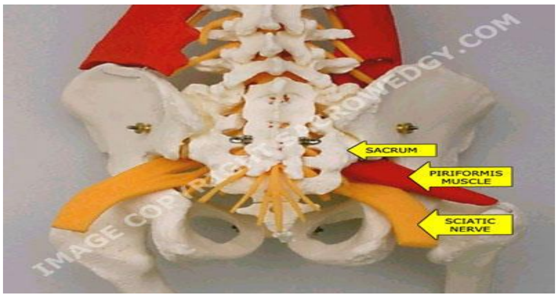


Fig. 11. *Representation of scatia structure.*

Tendonitis

As its name indicates tendonitis is an inflammation of a tendon. Tendons are structures that connect muscles to the skeleton. Biceps are attached to the shoulder and the forearm by the tendon. When this muscle contracts and shortens, it pulls on the tendon and causes the forearm to bend.

The tendon "works" each time the muscle is overburdened, for example, by considerable and repeated effort that the tendon may be overused. If the tendon is injured and theories abound that WMSDs are caused by an accumulation of microscopic injuries the body may try to repair it. This is when inflammation occurs, with signs of swelling. If the overuse persists, an injured tendon, swollen by inflammation, may be even more vulnerable to overload. This produces tendonitis (Figure 12).

Fig. 12. *Tendonitis occurring in knee and elbow.*

REVIEW OF LITERATURE

The purpose of this project was to look at conditions in the clothing industry to find out how these injuries start and how they can be prevented. Researchers identified many features in clothing plants that could be improved to prevent injuries including:

The clothing industry is generally seen as a safe place to work. Compared to other industries, there are relatively few serious accidents in clothing plants. The hazards we face are different. The major health risks in this industry do not arise from immediate, potentially fatal hazards. Instead, the risks that clothing workers face come from more subtle hazards whose effect accumulates over time.

Several studies have shown that operators of sewing machines report discomfort in the left shoulder, the neck, the back, and the lower extremities. These complaints may be caused or aggravated by the seated working posture which is characterized by an elevated left upper arm posture, a forward inclined posture of the head and trunk, and unfavorable ankle and knee angles, respectively. At a traditional sewing machine workstation, the body posture is constrained by the eyes for visual control of the work, the hands for directing the sewing material, and the feet for control of the machine. In order to improve the working posture and reduce the number of complaints, quantitative recommendations for the adjustment of the workstation are needed.

Many research shows that sewing machine operators face a substantially higher risk of muscle pain and injury than workers in other jobs. Studies also show that the frequency of persistent neck and shoulder injuries increases with years of employment. One report found that sewing machine operators experience as many cases of repetitive strain injuries as data entry keyers and secretaries combined. These injuries lead to long-term health effects. This is why we wanted to look at the working conditions that can lead to such high rates of disability for clothing workers.

Research has consistently found that the physical characteristics of the job are an important risk factor for muscle pain and injury. The risks for sewing machine operators have been linked to conditions such as poor workstation design and chairs, and organizational factors such as the piecework system.

Factors such as repetition, force, posture and vibration are associated with higher rates of injury. But you can't look at the workstation alone to understand these injuries. There is growing evidence that other factors are linked to injuries.

These include:

- High work pace
- Lack of control over the job
- Workload
- Co-worker support
- The general work environment

On the other hand, researchers have identified factors that relate to reduced injury rates. These factors include empowerment of the workforce, delegation of safety activities, greater seniority of the workforce, good housekeeping and an active role of top management. Few studies, however, have investigated physical and organizational risk factors at the same time in more than one workplace.

Scientists and Their Research

Some scientists had done research on sewing machine and its operations and recommended further changes that can be made in the design for improving the performance.

Nico J. Delleman and Jan Dul

Nico J. Delleman & Jan Dul observed that the sewing machine operators had to face many difficulties while performing operations on workstation. So they decided to do research and improve the design of the model. For that, they used different kind of methods and performed different experiments.

Methods

In the laboratory ten sets of experimental conditions were tested. Test subjects worked for a certain amount of time at each set of conditions. Working posture and workers' perceptions were measured.

At a traditional adjustable sewing machine workstation, the operators performed their normal sewing task in ten experimental sessions of 45 min followed by breaks of 15 min. In each session one of the ten sets of experimental conditions was presented. The first day consisted of three sessions and the following two days of either three or four sessions. The order of presentation of the sets of experimental conditions was balanced over subjects, days, and sessions. Prior to the first session each operator selected a seat height at which pedal operation was comfortable.

For this, visual cues from the desk and the sewing machine were hidden by a blanket. The individual seat height and pedal inclination were constant during the experiments, but the operator was free to choose the fore/aft position of the chair.

Conclusions by Wick and Drury

Concerning the hypotheses and experimental conditions tested for sewing machine operation, the following conclusions were drawn.

1. The desk should be adjusted between 5 and 15 cm above elbow height.
2. The desk should be given a slope (indication: 0°–10°).

Research by Andrej Polajnar and Marjan Leber (1991)

Same as Wick and Drury, two Slovenian scientists Polajnar and Leber, professors from University of Maribor, Slovenia, done further research on musculoskeletal diseases and sewing machine operations.

Conclusion by Andrej Polajnar and Marjan Leber

It can be conducted 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.

Ibrahim H. Garbie

The experimental study conducted by Ibrahim H. Garbie to investigate the effects of assembly of a product on operator performance. A fully adjustable ergonomically designed assembly workstation (smart workstation) was used for the experiment. In the study the subjects were randomly assigned into three experimental conditions for table adjustment, chair adjustment and the gender) performed the assembly task. Performances of the participants assembling a product are: operator production rate representing the output i.e. products assembled per unit time (units/hour). The regression model was built measure the operator performance by using Minitab Software. In the result is known those females are more productive than male.

PROBLEM IDENTIFICATION

The clothing industry is generally seen as a safe place to work. Compared to other industries, there are relatively few serious accidents in clothing plants. The hazards we face are different. The major health risks in this industry do not arise from immediate, potentially fatal hazards. Instead, the risks that clothing workers face come from more subtle hazards whose effect accumulates over time.

Many research shows that sewing machine operators face a substantially higher risk of muscle pain and injury than workers in other jobs. Studies also show that the frequency of persistent neck and shoulder injuries increases with years of employment. One report found that sewing machine operators experience as many cases of repetitive strain injuries as data entry keyers and secretaries combined. These injuries lead to long-term health effects. This is why we wanted to look at the working conditions that can lead to such high rates of disability for clothing workers.

Research has consistently found that the physical characteristics of the job are an important risk factor for muscle pain and injury. The risks for sewing machine operators have been linked to conditions such as poor workstation design and chairs, and organizational factors such as the piecework system.

Factors such as repetition, force, posture and vibration are associated with higher rates of injury. But you can’t look at the workstation alone to understand these injuries. There is growing evidence that other factors are linked to injuries.

These include:

- High work pace
- Lack of control over the job
- Workload
- Coworker support and
- The general work environment

On the other hand, researchers have identified factors that relate to reduced injury rates. These factors include empowerment of the workforce, delegation of safety activities, greater seniority of the workforce, good housekeeping and an active role of top management. Few studies, however, have investigated physical and organizational risk factors at the same time in more than one workplace.

We focused on identifying good practices that are in use in the industry. My goal in creating this report is to share these good practices so that injuries can be reduced across the industry.

Why Ergonomics Is Important for Sewing Machine Operator?

Sewing machine operator has number of problem while working on sewing machine. These problems are as follows:

- Pain, numbness, or tingling in the shoulders, neck, back, and hands affect many sewing machine operators. These symptoms may be related to their job.
- Symptoms may start gradually and many people try to ignore them at first. But if anybody ignores them, symptoms can get worse and become harder to treat.
- These symptoms may indicate a serious injury that can interfere with your work and personal activities. They can even lead to permanent disability (Figure 13).

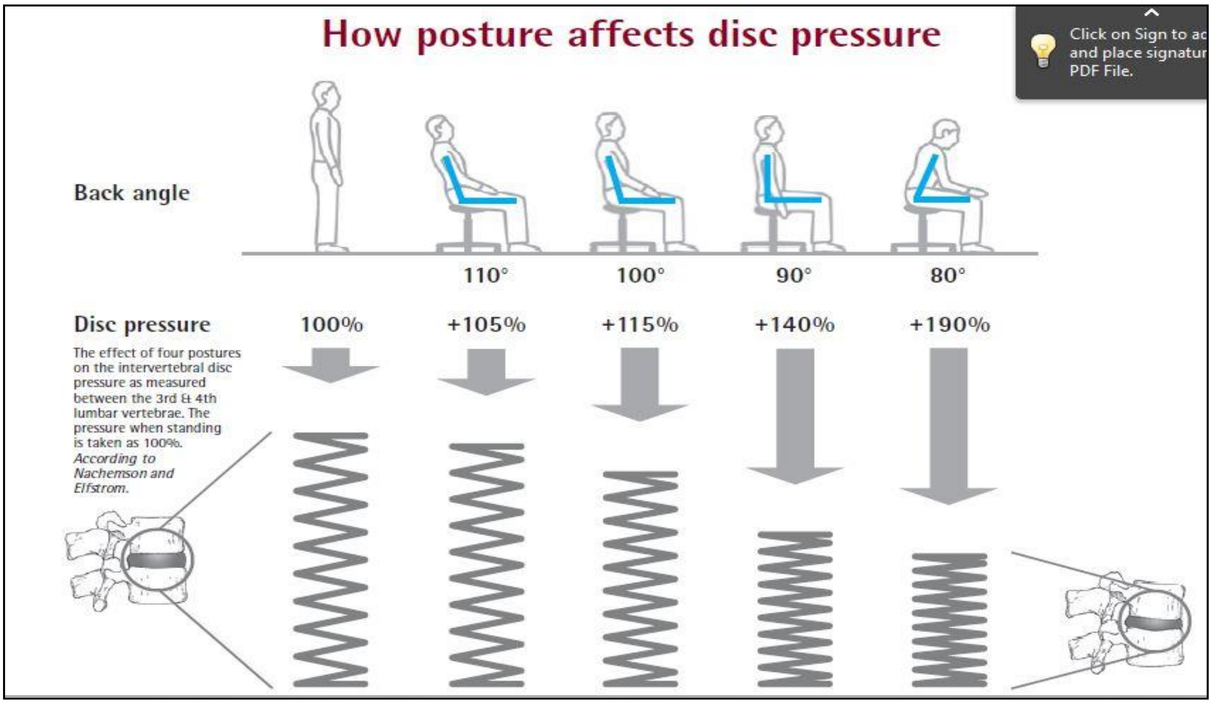


***Fig. 13.** Posture affects the disk pressure.*

Figure 13 shows how the posture affects the disk pressure. As shown in the figure as the angle is less the more disk pressure acts, as the angle increases the disk pressure goes on decreasing.

Why Sewing Machine Operators Have These Problems?

- An uncomfortable work position:
  Sewing work may force you to hold your body in the same position for long periods. If so, pain and injury can result.
- Repeated or forceful motions:
  Repeated or forceful motions such as reaching, stitching, pinching, and pulling hundreds of times a day can cause small injuries to muscles and joints.
- Hard edges:
  If the edges of your chair, work table, or table legs press into your body for long periods, it can damage nerves or soft body parts.
- Long work hours and few breaks:
  Long work hours and few breaks mean less time for muscles and joint injuries to heal. Almost all the problems that are faced by sewing machine operator can be eliminated with the help of ergonomics. Hence ergonomics is very important for sewing machine operator.

DESIGN AND DEVELOPMENT

Several studies have shown that operators of sewing machines report discomfort in the left shoulder, the neck, the back, and the lower extremities. In order to improve the working posture and reduce the number of complaints, quantitative recommendations for the adjustment of the workstation are needed.

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. According to Herbert et al. workers in the garment industry have higher rates of upper extremity work-related musculoskeletal disorders than those in many other industries. By studying all the papers for sewing machine operations by Wick and Drury (1986) and for musculoskeletal diseases by Andrej Polajnar and Marjan Leber, it is concluded that, there are still some problems associated with the sewing machine operations.

According to their research, following conclusions were made:

- The desk height should be adjusted between 5 and 15cm above elbow height.
- Inclination of 10° should be given to the desk.
- The pedal position should be repositioned from 5° to 15°.

But according to the changing ergonomic conditions, nature, behavior, diseases and mostly because of the difference in culture, now a days a need raised to make some extra changes in the design and adjustments of the sewing machine (Figure 14).

Fig. 14. *Traditional design of sewing machine.*

Proposed Changes for Sewing Machine

After further research it is concluded that following changes can be made in the sewing machine design to make it comfortable enough for both the men and women in the garment industry.

Newly Recommended Sewing Machine

The machine is modified on recommendation which were proposed while surveying.
For the first time we have tried to make the machine having angular motion in context of one parameter i.e. working area. The main reason to have angular motion is to allow the operator to take back support was achieved in this machine.

The adjustments which were made in the machine are as follows:

- The first and the most important is adjustment of wooden board due to which operator can able to take back support.
- The second and also the most important adjustment are to move working table in angular motion.
- The next adjustment is the height adjustment the height of the working table can be increase or decrease according to operator requirement.

Specification of the Recommended Sewing Machine

- Inclination of working table

As working table was fixed in existing machine operator has to bend forward for operation. To avoid this we decided to bring the table towards the operator by inclining it up to 10 degree as per requirement. The working table can be inclined to various angle up to 10 degrees this also allows operator to take back support and to minimize the risk of musculoskeletal disorder (Figure 15).

Fig. 15. *Inclination of working table.*

- Height adjustment

When operator sit he thinks to have machine should well-operated according to his/her height. So we intended to have height increment or decrement parameter for the operator convenience. For which height can be increased or decreased from about 30–32 inch due to which operator will be able to focus on machine in correct way and he/ she will not be force to bend in front towards the machine for performing operation. The inclination of the work table will be minimum for the operator working with height adjustment. It will allow the operator to work efficiently by taking back support in will also lower the risk of disorder of neck, eyes, etc.

Fig. 16. *Height adjustment of working table.*

- Horizontal adjustment

When operator sit he thinks to have machine should well-operated according to his/her comfort. So we intended to have horizontal increment or decrement parameter for the operator convenience. For which horizontal distance can be increased or decreased from about 0 to 14 cm due to which operator will be able to focus on machine in correct way and he/she will not be force to bend in front towards the machine for performing operation. It will allow the operator to work efficiently by taking back support in will also lower the risk of disorder of neck, eyes, etc.

Fig. 17. *Horizontal adjustment of working table.*

Construction Details

Developing such a machine is a big task we first started with support stand & remaining step by step procedure is as follows.

- Step 1: We took 4 rectangular pipe of length 12 Inch and having diameter 1 Inch.
- Step 2: We took 4 rectangular pipes of 12 inch length and diameter 0.75 inch on which we made a drill of diameter 1 cm at distance of 1 inch.
- Step 3: the 4 rectangular pipes of large diameter were welded on the 4 corners of the stand and then we had inserted a small diameter pipe inside the large diameter pipe, which makes the height adjustment.
- Step 4: Thereafter we took the four angles of L shape which we fitted on rectangular pipe.
- Step 5: Then we took the two CI strips which we fitted on the L shape angles through the nut bolt arrangement.
- Step 6: After that we had fixed up the sliding of length 10 inches.
- Step 7: After that we had made 3 drills on the wooden board at a distance of 0,7,14 inches in order to provide horizontal displacement.
- Step 8: After assembly of all parts pulley was introduced to maintain tension in wire connecting flywheel and machine at different position of height and sliding of working table.

DESIGN OF EXPERIMENTATION

After developing the machine it was found that most studies were depend on the comfort condition but the relationship of ergonomic parameter with the productivity is not evaluated yet the purpose of this study is to evaluate the influencing parameter to improve the productivity of sewing machine operator.

The design is given below. Following are the details of the different position.

Experiment Setup

Adjustable Sewing Machine

The machine has different adjustable parts as follows:

- Vertical displacement
- Angular displacement
- Sliding table

Subject

s mentioned above previously we have 3 different arrangements i.e. Vertical, horizontal and angular arrangement. In order to do the experiment we have different number of combinations, so it is not possible to do experimentation on all the combinations.

So, in order to check the particular combinations we used the Taguchi Array(L9 Array).

***Why L9 Array*?**

As we have 3 independent and 3 dependent control factors because of this we choose the array L9 from above matrix of Taguchi.

Independent Factors

1. Vertical Arrangement
2. Horizontal Arrangement

3. Angular Arrangement

Dependent Factors
1. Trunk Angle
2. Neck Angle
3. Head Angle

The control factors for the experiment are as follows in Table 1–4:

Table 1. *Selected factors and their levels.*

Control factors	Level		
	1	2	3
Horizontal	0 cm	7 cm	14 cm
Vertical	30 inch	31 inch	32 inch
Angular	0^0	5^0	10^0

The standard L9 ARRAY is given below:

Table 2. *L9 orthogonal array.*

Experiment no.	Control factors		
	1	2	3
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	3
5	2	2	1
6	2	3	2
7	3	1	2
8	3	2	3
9	3	3	1

Now as per above mentioned control factors, the array of this experiment is given below:

Table 3. *L9 orthogonal array for experiment.*

Experiment number	Control factors		
	1 (cm)	2 (inch)	3 (degree)
1	0	30	0
2	0	31	5
3	0	32	10
4	7	30	10
5	7	31	0
6	7	32	5
7	14	30	5
8	14	31	10
9	14	32	0

Now with the help of this array, we did experimentation and checked the behavior of 3 angles i.e. trunk, neck and head angle at 9 different combinations of each operator.
We took the readings of 9 operators.

Procedure
Step 1: From L9 array the first combination is 0-30-0 which means that 0 is horizontal displacement, 30 is height from ground level and 0 is angular displacement.
Step 2: In this step we kept horizontal displacement 0, height from ground level 31 and angular displacement 5 and allowed the operator to operate the machine for 10 minutes.
Step 3: In this step we kept horizontal displacement 0, height from ground level 32 and angular displacement 10 and allowed the operator to operate the machine for 10 minutes.
Step 4: In this step we kept horizontal displacement 7, height from ground level 30 and angular displacement 10 and allowed the operator to operate the machine for 10 minutes.
Step 5**:** In this step we kept horizontal displacement 7, height from ground level 31 and angular displacement 0 and allowed the operator to operate the machine for 10 minutes.
Step 6:-In this step we kept horizontal displacement 7, height from ground level 32 and angular displacement 5 and allowed the operator to operate the machine for 10 minutes.
Step 7: In this step we kept horizontal displacement 14, height from ground level 30 and angular displacement 5 and allowed the operator to operate the machine for 10 minutes.
Step 8: In this step we kept horizontal displacement 14, height from ground level

31 and angular displacement 10 and allowed the operator to operate the machine for 10 minutes.

Step 9: In this step we kept horizontal displacement 14, height from ground level 32 and angular displacement 0 and allowed the operator to operate the machine for 10 minutes.

Readings

Thus by following the above 9 steps we allowed the 5 female and 4 male operators to operate the modified sewing machine for several time (approx. 15 min.) and their measurement of different angles (i.e Neck angle, Head angle & Trunk angle) are as given below.

Details of the operators

Table 4. *Details of operator.*

Operator no.	Name of operator	Age	Weight	Height(cm)
A	Krupali Shriwas	21	50	159
B	Radhika Joshi	20	48	158
C	Payal Badge	23	45	160
D	Khushbu Shilpkar	20	46	158
E	Surbhi Shilpkar	18	45	159
F	Shubham Netnaskar	20	62	180
G	Swapnil Patil	21	61	181
H	Ankush Taywade	20	68	175
I	Akshay Parate	21	60	176

Thus by following the above 9 steps we took the reading of 9 operator and measurement of different angles are given below.

I. Female Operators

1. Krupali Shriwas

Trunk angle	12.01	12.96	9	-2.82	8.3	9	1.33	-6.33	3.16
Neck angle	58.43	41.59	39.1	33.45	40.11	29.92	52.4	31.3	36.78
Head angle	29.65	13.3	7.38	7.38	14.15	0	33.85	11.84	10.44

2. Radhika Joshi

Trunk angle	6.83	11.74	7.14	-7.82	9.95	8.97	-8.86	-2.33	3.89
Neck angle	35.21	43.07	34.94	32.11	36.58	34.14	34.35	33.81	38.46
Head angle	14.93	12.25	6.89	15.17	8.16	10.85	15.96	9.11	5.91

3. Payal Badge

Trunk angle	8.23	6.86	6.96	3.66	9.46	8	-5.02	-5.49	3.89
Neck angle	40.02	41	37.03	36.81	36.56	44.82	45.34	34.43	47.71
Head angle	4.04	4.29	0	6.21	0	0	8.34	0	4.98

4. Khushbu Shilpkar

Trunk angle	7.05	12.05	11.61	8.09	12.67	8.61	10.29	-4.62	-1.85
Neck angle	54.95	69.87	53.46	52.44	50.52	50.42	63.43	35.36	45.91
Head angle	20.86	19.16	14.57	14.57	10.84	15.08	21.99	4.28	14.42

5. Surbhi Shilpkar

Trunk angle	7.34	9.67	5.72	5.09	5.22	8	4.31	-3.11	7.34
Neck angle	36.85	34.83	22.51	34.25	29.9	32.32	40.42	28.86	36.85

Head angle	12.05	3.31	0	6.16	0	2.54	5.5	8.38	12.05

II. Male operators

1. Shubham Netnaskar

Trunk angle	8.24	14.77	8.13	10.07	16.02	10.4	16.36	-11.1	0.93
Neck angle	55.72	57	52.73	60.71	64.83	57.78	82.34	40.5	41.38
Head angle	35.22	32.75	21.04	35.03	35.03	24.58	44.79	21	22.33

2. Swapnil Patil

Trunk angle	9.94	9.96	5.55	6.46	13.09	11.73	-13.19	-3.51	9.33
Neck angle	48.85	39.61	32.72	54.49	48.9	52.81	56.28	37.99	45.11
Head angle	16.55	9.87	7.01	16.89	9.98	10.32	22.88	11.94	13.6

3. Ankush Taywade

Trunk angle	8.27	12.06	12.27	4.11	5.22	2.5	-11.09	-3.11	3.75
Neck angle	32	51.28	44.44	35.56	42.75	27.72	32.95	31.88	40.7
Head angle	19.24	11.33	0	14.02	10.08	5.68	4.35	5.93	7.38

4. Akshay Parate

Trunk angle	16.51	9.32	9.36	10.77	11.59	7.53	-3.86	-3.42	6.83
Neck angle	73	60.67	56.72	56.8	62.71	52.23	47.37	49.04	57.75
Head angle	26.19	21.54	21.21	22.05	28.69	21.55	16.16	19.67	26.25

QUALITATIVE READINGS

Qualitative Readings are nothing but the readings which we cannot measure directly of certain scale OR with respect to certain standard scale. So this results of this readings are based on the opinion of an operator.

The scale for reading is given in Table 5.

Table 5. *Opinion and rating.*

Sr no.	Opinion about comfort	Rating
1	High ↑	4
2		3
3		2
4		1
5		0
6		-1
7		-2
8		-3
9	↓ Low	-4

After experimentation we took the opinion of different operators, on their experience the opinion on the different positions are given below in tabular form.

Operators

Krupali Shriwas

Experiment no.	Positions	Rating
1	0-30-0	0
2	0-31-5	-1
3	0-32-10	-2
4	7-30-10	4
5	7-31-0	-1
6	7-32-5	1
7	14-30-5	1
8	14-31-10	3
9	14-32-0	1

Radhika Joshi

Experiment no.	Positions	Rating
1	0-30-0	0
2	0-31-5	-1
3	0-32-10	-2
4	7-30-10	4
5	7-31-0	0
6	7-32-5	-1
7	14-30-5	2
8	14-31-10	3
9	14-32-0	1

Payal Badge

Experiment no.	Positions	Rating
1	0-30-0	0
2	0-31-5	1
3	0-32-10	-1
4	7-30-10	3

5	7-31-0	-1
6	7-32-5	1
7	14-30-5	2
8	14-31-10	4
9	14-32-0	1

Khushbu Shilpkar

Experiment no.	Positions	Rating
1	0-30-0	0
2	0-31-5	-1
3	0-32-10	1
4	7-30-10	2
5	7-31-0	1
6	7-32-5	-1
7	14-30-5	0
8	14-31-10	4
9	14-32-0	2

Surbhi Shilpkar

Experiment no.	Positions	Rating
1	0-30-0	0
2	0-31-5	-1
3	0-32-10	-2
4	7-30-10	4
5	7-31-0	0
6	7-32-5	-1
7	14-30-5	2
8	14-31-10	3
9	14-32-0	1

Shubham Netnaskar

Experiment no.	Positions	Rating
1	0-30-0	-2
2	0-31-5	-3
3	0-32-10	-1
4	7-30-10	1
5	7-31-0	-1
6	7-32-5	2
7	14-30-5	-1
8	14-31-10	4
9	14-32-0	3

For 1st operator

Swapnil Patil

Experiment no.	Positions	Rating
1	0-30-0	0
2	0-31-5	1
3	0-32-10	2
4	7-30-10	3
5	7-31-0	-1
6	7-32-5	0
7	14-30-5	1
8	14-31-10	4
9	14-32-0	2

Ankush Tayawade

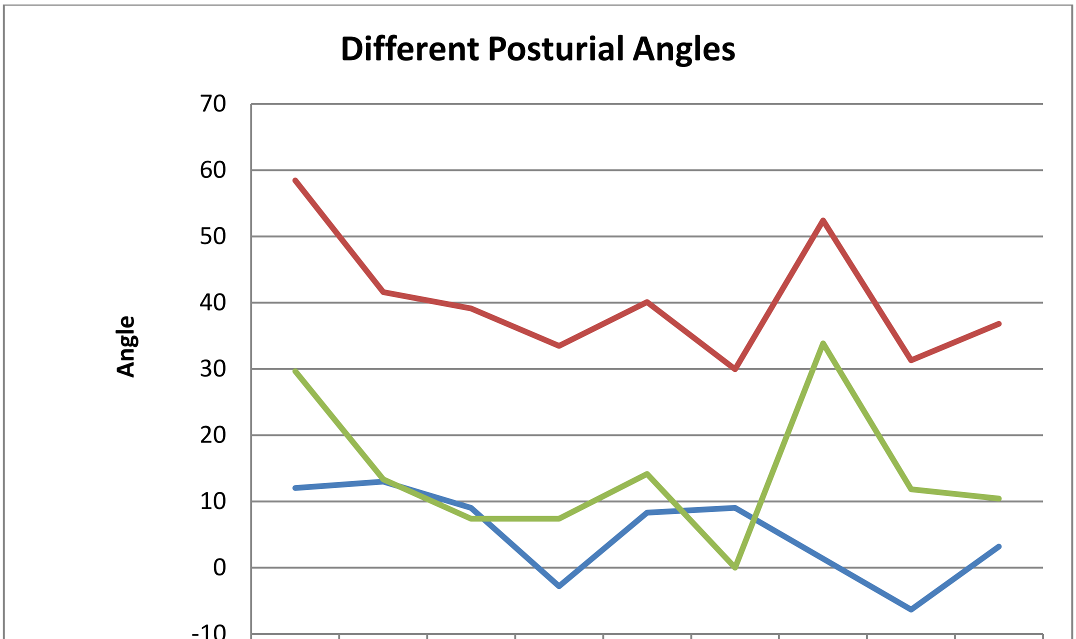
Experiment no.	Positions	Rating
1	0-30-0	0
2	0-31-5	-1
3	0-32-10	1
4	7-30-10	1
5	7-31-0	2
6	7-32-5	3
7	14-30-5	4
8	14-31-10	4
9	14-32-0	-1

Akshay Parate

Experiment no.	Positions	Rating
1	0-30-0	0
2	0-31-5	-1
3	0-32-10	-2
4	7-30-10	1
5	7-31-0	2
6	7-32-5	1
7	14-30-5	2
8	14-31-10	4
9	14-32-0	-1

RESULT AND DISCUSSION

After conducting the experimental study, the results of the experiments are represented in tabular and graphical form.



	1	2	3	4	5	6	7	8	9
Trunk Angle	12.01	12.96	9	-2.82	8.3	9	1.33	-6.33	3.16
Neck Angle	58.43	41.59	39.1	33.45	40.11	29.92	52.4	31.3	36.78
Head Angle	29.65	13.3	7.38	7.38	14.15	0	33.85	11.84	10.44

Fig. 18. *Comparative position of angle for 1st operator.*

From Figure 18, it seems that all three angles (i.e. head angle, neck angle and trunk angle) are less at the position number 8 i.e. the position 14-31-10 (i.e. 14 Horizontal, 31 vertical and 10 angular displacement).

Also, all the angles are low at position number 4 than remaining 7 positions i.e. the position 7-30-10 (i.e. 7 horizontal, 30 vertical and 10 angular displacement).

Comparative Study of Different Angles for Female Operators

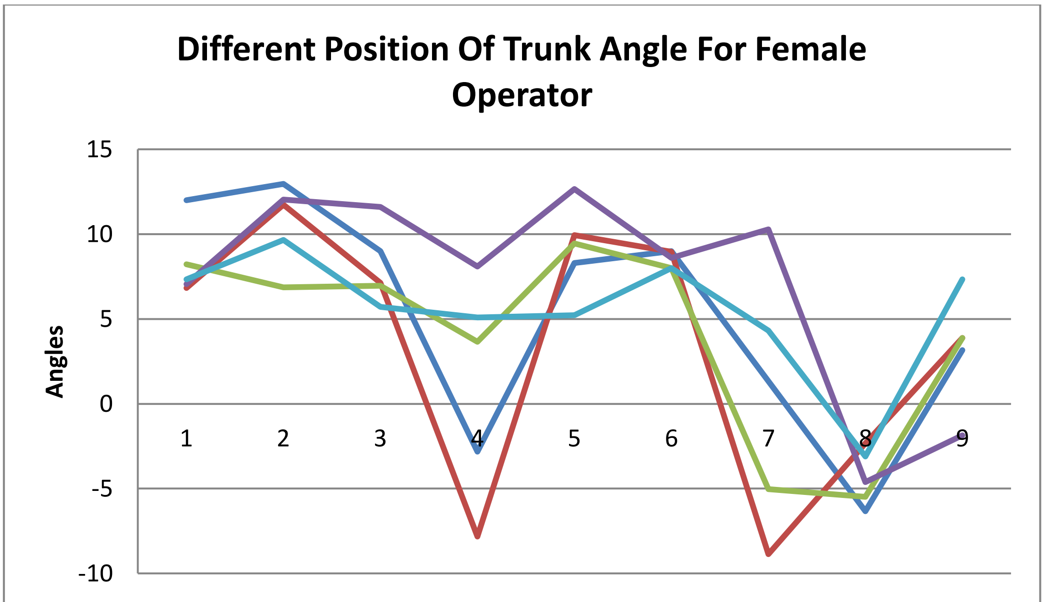


Fig. 19. Different position of trunk angle for female operator.

From Figure 19 it seems that the trunk angle for female operators is less at position number 8 i.e. 14-31-10 (i.e. 14 horizontal, 31 vertical and 10 angular displacement) and also at position number 4 i.e. 7-30-10 (i.e. 7 horizontal, 30 vertical and 10 angular displacement).

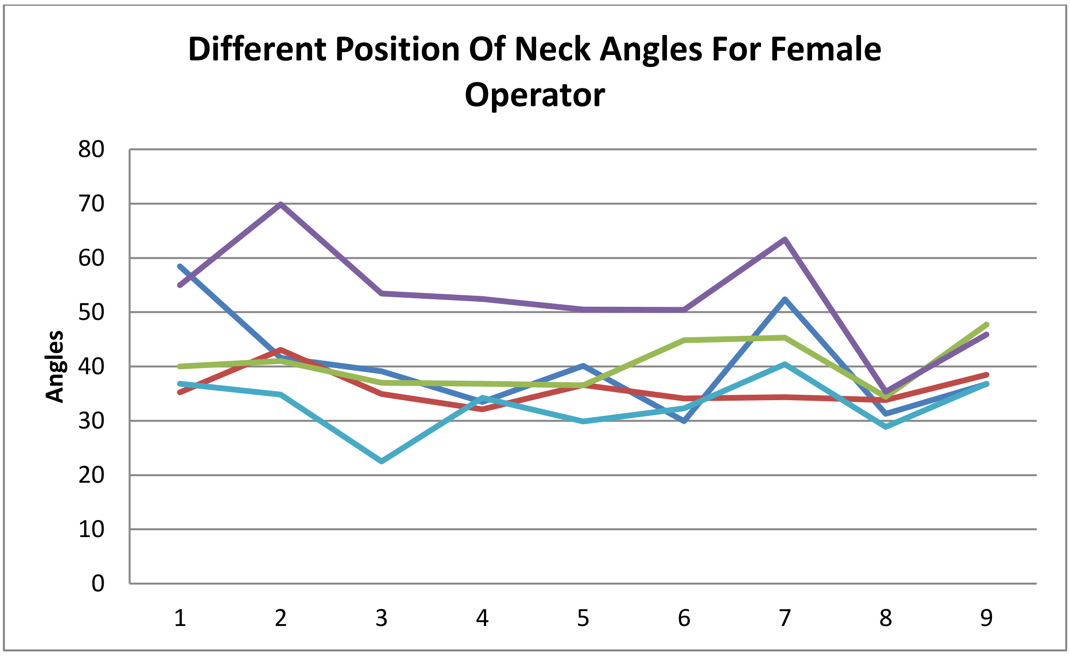


Fig. 20. Different position of neck angle for female operator.

From Figure 20 it seems that the neck angle for female operators is less at position number 8 i.e. 14-31-10 (i.e. 14 horizontal, 31 vertical and 10 angular displacement) and also at position number 4 i.e.7-30-10 (i.e. 7 horizontal, 30 vertical and 10 angular displacement).

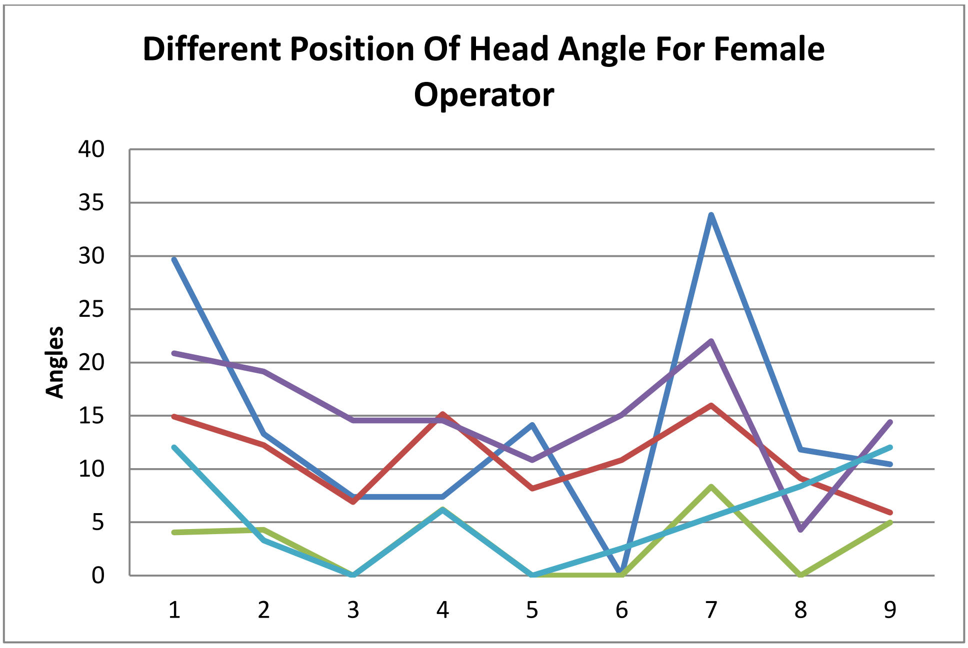


Fig. 21. *Different position of head angle for female operator.*

From Figure 21 it seems that the trunk angle for female operators is less at position number 8 i.e. 14-31-10 (i.e. 14 Horizontal, 31 vertical & 10 angular displacement) and also at position number 4 i.e.7-30-10 (i.e. 7 horizontal, 30 vertical and 10 angular displacement).

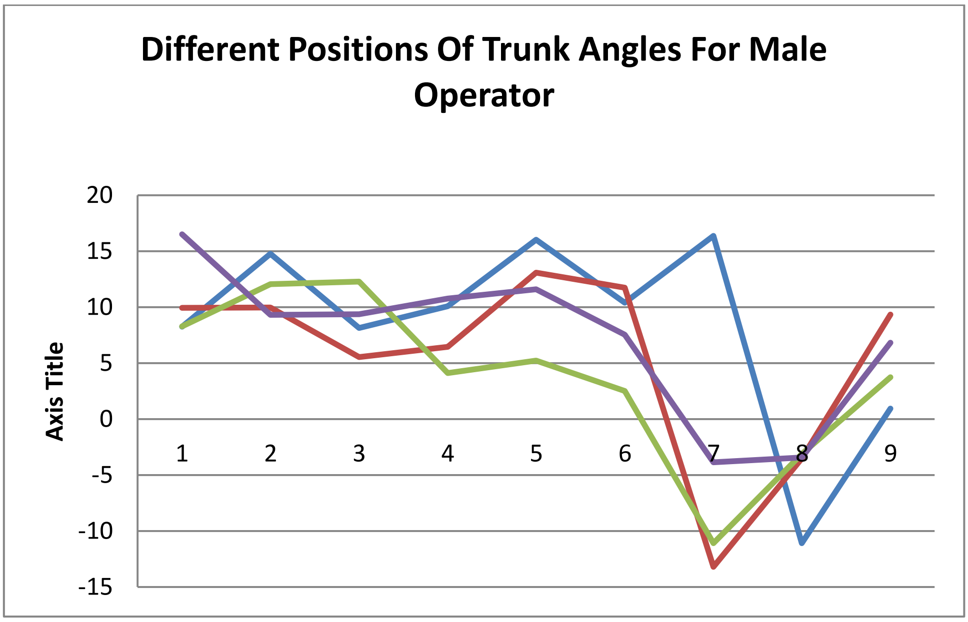


Fig. 22. *Different position of trunk angle for male operator.*

From Figure 22 it seems that the trunk angle for female operators is less at position number 8 i.e. 14-31-10 (i.e. 14 horizontal, 31 vertical and 10 angular displacement).

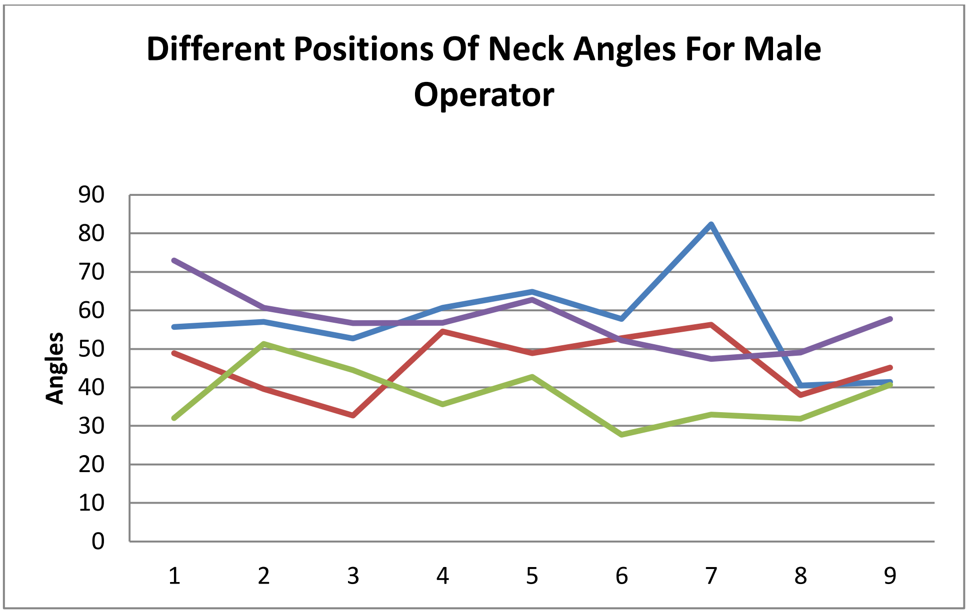


Fig. 23. *Different position of neck angle for male operator.*

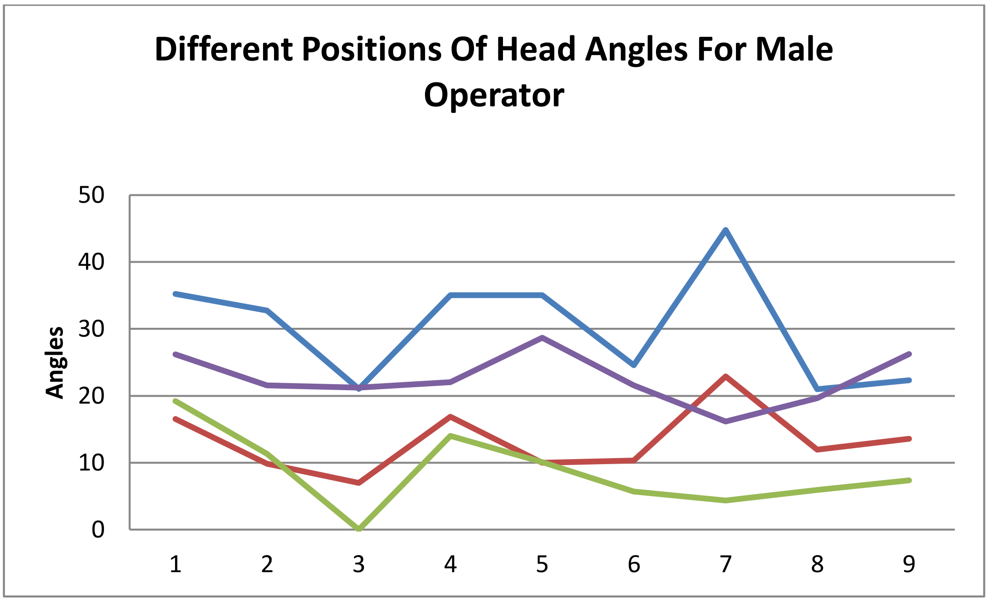


Fig. 24. *Different position of head angle for male operator.*

From Figure 23 it seems that the trunk angle for female operators is less at position number 8 i.e. 14-31-10 (i.e. 14 horizontal, 31 vertical and 10 angular displacement). From Figure 24 it seems that the trunk angle for female operators is less at position number 8 i.e. 14-31-10 (i.e. 14 horizontal, 31 vertical and 10 angular displacement).

Qualitative Analysis

The average of all opinion of the female operator is given below in Table 6.

Table 6. *Average rating of female operator.*

Experiment no.	Average rating
1	0.4
2	-0.6
3	-1.2
4	3.4
5	-0.2
6	-0.2

7	1.4
8	3.4
9	1.2

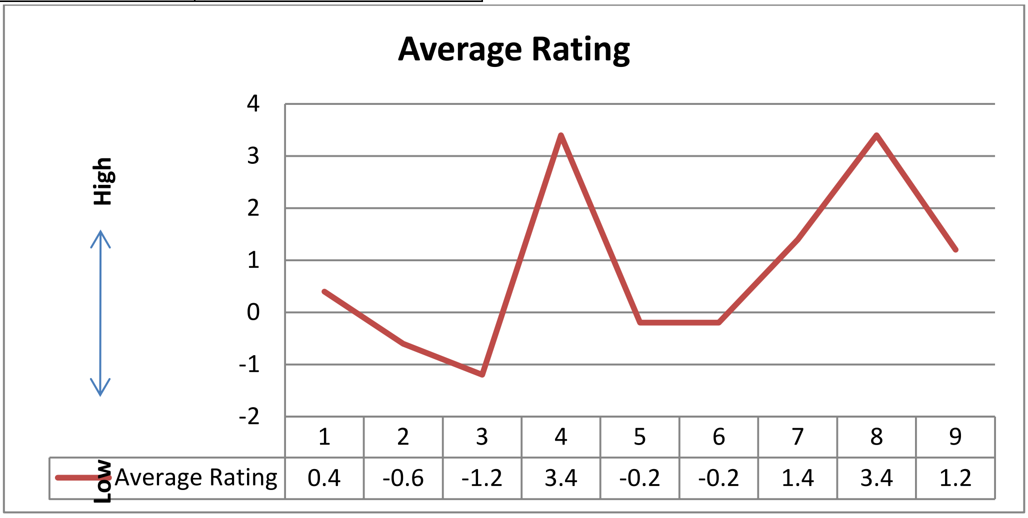


Fig. 25. *Graph for average rating of female operator.*

From the it is found that position number 4 & 8 are the comfortable positions.

The average of all opinion of the male operator is given below in Table 7 (Figure 25).

Table 7. *Avg. rating of male operator.*

Experiment no.	Average rating
1	-0.2
2	-0.8
3	0
4	1.2
5	0.4
6	1.2
7	1.2
8	3.2
9	0.6

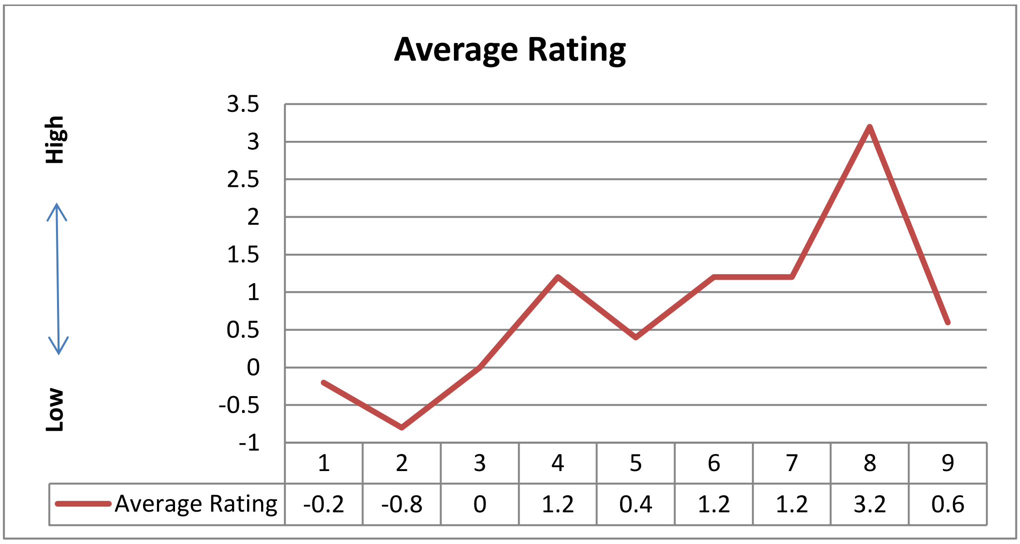


Fig. 26. *Graph for average rating of male operator.*

From the it is found that position number 4 and 8 are the comfortable positions.

CONCLUSION AND SUGGESTIONS

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. They are at higher risk for the muscular disease. To avoid this new workstation was made according to recommendations made on which the operator was relax comfortable and having back support. This will surely help to reduce the musculoskeletal disorder and the pain in lumbar region, neck, trunk and the lower extremities.

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. The ergonomic recommendations are presented for a typical sewing workstation is use for a better working and stress and strain free environment for operator.

The result and discussion, in the previous chapter the conclusion drawn are under:

(1) There is direct relationship between operator and his working posture and stress on various parts of the body.
(2) Proper adjustments in the workstation influence the working condition of the operator.
(3) Having proper sitting posture minimizes the risk of musculoskeletal disorder.
(4) Relaxation plays vital role in working efficiency of the operator.

SUGGESTIONS

(1) Proper adjustment of the workstation should be done according to the anthropometry of the operator.
(2) Awkward posture should be avoided by the operator on sewing machine.
(3) Change the sitting position frequently throughout the day.
(4) Take breaks after every 45 minutes for one or two minutes before resuming. Find opportunities to get of yours chair and move around.
(5) The working condition of the operator should be clean.
(6) Periodic checkups should be done by the sewing machine operator.
(7) Awareness about the disease/disorder caused due to faulty practices should be spread.

REFERENCES

[1] Roebuck J.A., Kroemer K.H.E., Thomson W.G. *Engineering Anthropometry Method*. 2nd Edn., 1975.

[2] Bolstad G., Benum B., Rokne A. *Anthropometry of Norwegian Light Industry and Office Workers*. 2001.

[3] Industrial and Textile Employees. *Ergonomic Handbook for the Clothing Industry Published by the Union of Needletrades*. Industrial and Textile Employees, the Institute for Work & Health, and the Occupational Health Clinics for Ontario Workers, Inc.

[4] Punnett L., Robins J.M., Wegman D.H., et al. Soft tissue disorders in the upper limbs of female garment workers, *Scand J Work Environ Health.* 1985; 11: 417–25p.

[5] Westgaard R.H., Jansen T. Individual and work related factors associated with symptoms of musculoskeletal complaints, Different risk factors among sewing machine operators, *Br J Ind Med*. 1992; 49: 154–62p.

[6] Armstrong T.J., Punnett L., P. Ketner, Subjective worker assessments of hand tools used in automobile assembly, *Am Ind Hygiene Assoc J.* 1989; 50(12): 639–45p.

[7] Brochure: Ergonomie an Näharbeitsplätzen – Ratgeber für die Praxis. (BGI 804-2). With extensive explanations, tables, pictures and images (Only in German available).
[8] Ariens G.A., van Mechelen W., Bongers P.M., et al. Physical risk factors for neck pain, *Scand J Work Environ Health.* 2000; 26(1): 7–19p.
[9] Delleman N.J., Dul, J. Sewing machine operation: workstation adjustment, working posture, and workers' perceptions, *Int J Ind Ergon*. 2002; 30: 341–53p.
[10] Vihma T., Nurminen M., Mutanen P. Sewing-machine operators' work and musculoskeletal complaints, *Ergonomics*. 1982; 25(4): 295–8p.
[11] http://en.wikipedia.org/wiki/Sewing_machine.
[12] http://www.sciencedirect.com.

