A Study on Common Risks and Body Parts Complaints by Standing Workstation Female Operators in an Electronics Product Manufacturing Company

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Abstract

Ergonomics have improved the scope on safety and minimize risk at workplace by looking into possible factors effecting product quality, work performance and machine efficiency. The main objectives of this study are to assess, identify risks and body parts that received high number of complaints with respect to standing workstation. The methodology use in this study includes anthropometric data measurements of 146 female Malaysian operators, standing risk assessment and body parts symptoms survey form. Anthropometric data measurement results in company X showed the current standing workstation match with the female operators working height and workspace. The common risks identified for standing work are awkward posture, contact stress, wrist, static posture, fatigue, twisting of the spine, bending, too far and not reachable. Three body parts (i.e. shoulder, ankle/feet and neck) received 53% of total complaints in terms of pain and un-comfortableness. Therefore, the authors strongly recommended company X top management to find the solution to this pain and un-comfortableness complaints.

Keywords*: ergonomics, complaint, standing workstation, workers, risk*

1 Introduction

Ergonomics plays a vital role in determining the workers' safety and health at the workplace. Very often, poor workstation design caused workers to suffer from low back pain, muscles and joints injury. Today this phenomenon is considered a serious health related issues in electronics industries. Heng et al. [1] found 55% assembly work force in the semiconductor industry were exposed to prolonged static standing, 52% are experiencing pain in the lower limbs and need to take frequent breaks to relief the pain. Rory [2] showed more than 50% (i.e. 11 million) of workforce in the United Kingdom were facing health risks as a result of prolonged standing. In addition, about 200,000 workers in the United Kingdom had reported lower limb disorders due to the job they performed, which cause over 2 million days sick leave a year [2].

Several ergonomics concept was applied to ensure comfort, efficient and safe ways of working in standing operation. This is an exploratory study on standing operation from manufacturing point the view and its impact to worker's safety, health and productivity. Ergonomically designed and installed workstation can result in higher quality product, increase productivity, better space consumption as well as increasing the production capacity in meeting the customer demand.

To developed an approriate standing workstation, the designer needs to incorporate ergonomic features to fit the workers who are actually performing the task. This study could capture ways to reduce and possibly eliminate hazards related to design, process, equipments usage, and work tasks while standing. The main objectives of this study are are to assess, identify risks and body parts that received high number of complaints with respect to standing workstation.

2 Standing Operation

Standing at work has become an apparent issue being discussed today. This is due to the fact standing operation had been implemented in workplace by many manufacturers. However, there is a negative perception that standing operation working posture can cause discomfort to body muscles compared to other working postures. Inappropriate workstation design causes static working posture and restricts normal work.

Standing while performing different tasks can be categorised based on leg movements such as dynamic (continuous movement), static (less or no leg movement) or combination of both actions. In prolonged standing condition; a stationary position means doing work without much leg movements due to the nature of work. In this type of work, most of worker's body weight is supported by the lower limb and large muscle trunk. Some common tasks that used standing work features includes: frequent handling of heavy items; frequent reachable and continuous movement using heavy force; frequent mobility to and from the workstation; and frequent force exertion, which required more energy [3].

2.1 *Needs of a Standing Workstation*

A good ergonomic workstation is needed for standing operation to smooth up the workers' daily work task. Therefore, it is highly recommended to perform a study prior to designing a suitable workstation to match their work task according to the given job or task. Normally, movement in standing position is minimal and it depends very much on upper body movements while performing assembly task. It can be easily noticeable that standing work does not obviously have frequent changeable movement from one place to another. Figure 1 showed that standing operations be categorized as performing assembly work for light, medium or heavy task. In general, postural movement may involved the whole body trunk such as when bending, twisting, turning, and arm over reaching, where only the supporting legs remains in the stationary state [4]. The type of work done for standing operation can be categories as light, medium or heavy work depending on whether the employee is required to exert downward forces and manipulate heavy objects [5].

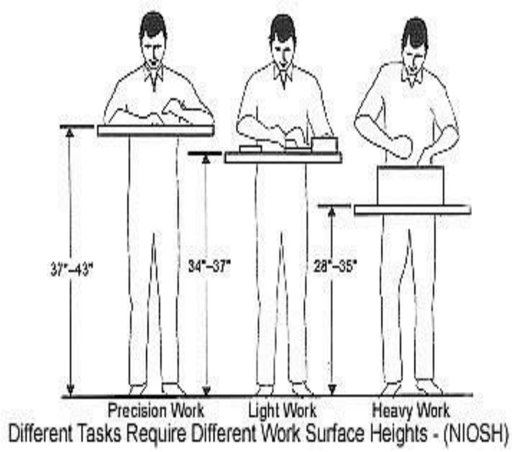

Figure 1: Different Tasks Require Different Work Surface Height [6]

Referring to Figure 1 standing height for selected task for workstation measurements are as follows:-

Precision work: 37 - 43" (939.8 - 1092.2 mm)
e.g. Inserting tiny/ micron/small parts

Light work: 34 - 37" (863.6 - 939.8 mm)
e.g. General assembly task, read, write

Heavy work: 28 - 35" (711.2 - 889 mm)
e.g. Loading bulky parts / typing

A standing workstation may involve tasks where the employee's upper limbs are used to move loads within the standing workstation and the lower leg and trunk movement are used to provide the momentum to move the loads. DOSH [4] guidelines also stated that employee may also adopt a certain amount of postural movements on the whole body to perform his/her task such as trunk bending, twisting, turning and with the arms reaching upwards and outwards within the workstation but the legs are in a relatively stationary position. Standing work can utilizes workbenches with a proper height for selected job task either in a precision, light or heavy work task. DOSH [4] recommended standing work also provide a limited access to shelf height, which is up to a maximum height of free-standing operation a standing person can reach. Working workbenches height for precision work should be above the elbow height level (Figure 1). Examples of standing workstations are: assembly tasks such as medium or heavy work; packing tasks such as grocery, warehouse work; moulding tasks such as feeding or receiving materials; photocopying work; kitchen tasks such as washing utensils, meal preparation and cooking.

2.2 *Importance of correct working posture*

The standing guidelines published by DOSH [4] indicates working posture and task should be designed to avoid strain and damage to any part of the body such as the tendons, muscles, ligaments and also the back. During work, employees sub-consciously tend to accept and adapt to unsatisfactory standing working conditions.They may not realise that their body is under strain until they feel the actual pain and even then they may not understand the causes.

Furthermore, these guidelines suggested that all work activity should permit employees to adopt several different, equally healthy and safe postures without reducing the capability to perform the work. The employees should be able to maintain an upright and forward facing posture. The work should be arranged so that it may be done either in the seated or standing position. However, if standing posture was chosen for a task and if there is insufficient rest to the legs, or if they have to maintain an awkward posture for long duration, then it can lead to fatigue, pain and discomfort. Prolong daily standing in the awkward posture of the upper body is known to be associated with low back pain. Frequent break and rest should be given to all workers. According to Kroemer and Grandjean [7] the workstation design should facilitate body movement instead of promoting or maintaining static postures. The importance of adjustable work surface is to accommodate postural changes. In standing operation most of the body weight is supported by the lower limb. It is almost impossible to make immediate changes to ergonomically design standing workstation. However, friendly ergonomics measures can be applied to resolve stress due consistent standing. To make it workable, adjustable work surface can fit the task requirements for employees with different height and trying to match each process. Adjustable work surface can resolve fixed static work surface for shorter or taller employees. This can minimize the awkward postures, which will cause back pressure like twisting, bending and forwarding towards position that is not easily reachable. Such awkward postural position can cause injuries, which can be minimized by installing adjustable work surface. Installing workstation with adjustable work surface; would result in less postural injuries for workers.

In this study, generating the ideal workstation concept was derived through observations, data collections and the workstation assessment. As the requirements become more stringent, the concept was developed to minimize risks on health related issues that are associated to standing operation. Some of the risk factors considered in standing operation includes positioning, reach or clearance, maximum grip or handling of each task, durations, mechanical aids provided and most importantly how closely we can fit the human worker to the work task.

2.3 *Significance of standing workstation data*

Very often standardization of workstation is by matching human physical characteristics with the task carried out. Normally, the main objectives of designing a flexible standing workstation are greater space savings, comfortable and improve efficiency. Workstation flexibility creates better layout and able to improve the overall production engineering and design processes. Interchangeable workstation layout can suit various manufacturing needs in assembling electronics product. By applying correct ergonomics principles, better workstation can be installed; the work tasks can be controlled and managed easier. The actual working surrounding becomes more organized, with better visual management and reflects a safer working environment.

According to Pheasant and Haslegrave [8] standing height is defined as the vertical distance from the floor to the vertex (i.e. crown of head). As for standing eye height, they defined it as the vertical distance from the floor to the inner corner of the eye. This is an important measurement because standing work demands proper eye view to focus on the work task and read the manual visually at acceptable level. Thirdly, standing elbow height is defined as vertical distance from the floor to the bony landmark formed by the upper end of the radius bone which is palpable on the outer surface of the elbow [8]. Figure 2 shows three critical measurements for the purpose of evaluating the standing workstation.

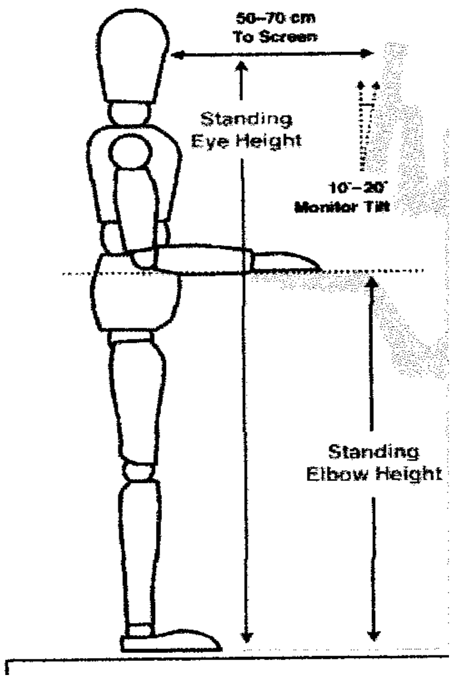

Figure 2: Critical measurements on standing (Source: Pheasant and Haslegrave [8])

3 Methodology

This study covers all production processes involving standing operation in company X. It includes all main assembly processes starting from beginning until the end in producing remote commanders. The study also looked into area of plant safety layout, efficiency as well as productivity point of views. Company X used a systematic line process layout and established manufacturing cell system concept that mobilized its workers into standing operation workstations. The methodology use in this study includes anthropometric data measurements of 146 Malaysian female operators performing the assembly work, ergonomics risk assessment and body parts symptoms survey. The anthropometric data measurements of the 146 Malaysian female operators were done manually using measuring tape and mechanical callipers. The same procedure for measuring anthropometric data was repeated twice for each operator on two different days at about the same time so that the data collected can be averaged for repeatability and reliability purposes.

For the survey, each standing operators were given a Body Part Symptoms survey form to be filled out. They were categorized according to their particular work task done in line processes. In this study, segregation includes of auto insert, parts assembly, injection, printing, spraying or final assembly parts/products. According to DOSH [4] requirements, body parts symptoms survey must be carried out at least once a year for all employees who work at standing workstation.

4 Results and analysis

a. Anthropometric data

Anthropometric data of 146 Malaysian female operators doing assembly work were measured and recorded. Later, the data average (mean), 5th percentile (minimum) and 95% percentile (maximum) values were calculated for female operators and shown in Table 1.

Some examples of calculations for determining the 5th percentile (minimum) and 95% percentile (maximum) values of anthropometric data measured and recorded in the study.

For standing height (1) stature @ Height of workstation

K = -1.64 for 5% percentile below mean and k = 1.64 for 95% upper mean.

p = m + k (S) = 1550 + (1.64) (90) = 1550+147.6 = 1631 mm (95%) Max

p = m + k (S) = 1550 – (1.64) (90) = 1550-147.6 = 1403 mm (5%) Min

For standing eye height (2) @ Visual display for instruction manual

K = -1.64 for 5% percentile below mean and k=1.64 for 95% upper mean.

p = m + k (S) = 1440 + (1.64) (60) = 1440.50 + 98.4 = 1539 mm (95%) Max

p = m + k (S) = 1440 – (1.64) (60) = 1440.50 - 98.4 = 1342 mm (5%) Min

For standing elbow height (4) @ Work surface height

K = -1.64 for 5% percentile below mean and k=1.64 for 95% upper mean.

p = m + k(S) = 980.2 + (1.64) (72) = 980.25+118.1= 1098 mm (95%) Max

p = m + k(S) = 980.2 - (1.64) (72) = 980.25 - 118.1= 862 mm (5%) Min

Table 1: Anthropometric data measurements and calculations for standing work

Body parts	Mean mm	SD mm	Min mm	Max mm	Remarks
Standing height (Stature)	1551	90	1403	1631	workstation max reach height - 1900 mm
Standing eye height	1441	60	1342	1539	workstation display height - 1473 mm
Standing shoulder height	1250	60	1152	1349	
Standing elbow height	980	72	862	1098	work surface height – 914 mm
Hip height	450	70	352	565	
Knuckle height	691	65	592	797	
Fingertip height	520	52	422	606	
Knee height	469	32	370	521	
Forearm/ Arm span	1535	85	1437	1675	
Chest height	980	72	882	1098	
Waist height	950	58	852	1045	
Shoulder width	400	85	302	539	

The rest of the values were calculated using the same principle for 5% and 95% percentile for female operators range coverage. In other words, the proposed workstation design standing height, standing eye height, standing shoulder height, standing elbow height, hip height, knuckle height, fingertip height, knee height, forearm/arm span, chest height, waist height, shoulder width can accommodate about 90% of female operators in company X who are performing standing operation tasks within these ranges.

Comparing to the measurement of the workstation all the three critical readings (i.e. standing height (stature), standing eye height and standing elbow height) have met the requirement to accommodate the female operators working height and proper workspace matching their standing at work height. Based on the anthropometric data of female operators in company X, the proposed standing workstation, a maximum dimension height for the workstation is 1900mm, while working surface height is at 980mm (862-1098) and 1440mm (1342-1539) height for displaying instruction manual.

b. Standing risk assessment (SRA)

In addition, standing risk assessment was done to analyse the ergonomics risks associated to standing operations. Most common risk identified includes awkward posture, twisting, bending, far reachable. Table 2 summarise the findings for standing workstation evaluation and their respective ergonomics risk involved.

Table 2: Standing risk assessment (SRA)

Work Checklist	Evaluation	Ergonomics Risk
Work space tolerance	Allow full range of space movement	Awkward postures
Vision/Display aids	Assist on easy assemble guide	Awkward, not easily reach
Work surface	Flexible, adjustability, tilted, or angle	Contact stress, wrist, twist
Human interface	Suitability to user	Bend, twist, reach, static
Equip Interchange	Flexibility to user	Posture
Sharp/hard edges	Disturbance during assemble	Contact stress
Handling parts	Overload	Back pain, poor shoulder
Working height	Suitable height, anthropometric	Awkward too high or low
Standing hours	Cushioning/ Footrest/ Rest arms	Fatigue, twisting
Material placement	Closely located for frequent user	Not easily reach, twist
Static gesture	Required frequent movement/breaks	Fatigue, body
Standing posture	Correct body posture required	Overuse, pain. discomfort
Floor/Steps	Required soft/anti-fatigue mat	Fatigue
Room clearance	Anthropometric, enough space	Contact stress / Blockage
Working envelope	Ensure parts are reachable	Awkward, Twist
Reachable distance	Extended beyond reach	Awkward

From the observation of workers, it's note that many company X operators do show some clear sign of distress while performing standing work. Postural stress amongst workers is seen as one the drawbacks perceived. This phenomenon is seen in many assembly tasks from handling of automation equipment, performing manual soldering task, up till components and parts assembly in the final assembly process. Wrongly allocated of machine and equipment might be one of the reasons. This mismatch could affect the task to be performance in much more difficult in nature. Wrongly design of workstation can cause uneasiness to operators who relying on regular day to day work task. In standing operation few shortcomings areas were identified:

i. Working with the hands too high or too far away i.e. compensatory lumbar lordosis
ii. Work surface too low i.e. trunk flexion and back muscle strain
iii. Constrained foot position due to lack of clearance i.e. worker standing too far away
iv. Working at the corner of the bench (i.e. constrained foot position, toes turned out too much
v. Standing with a twisted spine i.e. having to work at either side rather than directly ahead
vi. It is strongly recommended objects which are used for standing operation should be place in position between worker's hip and shoulder height. This could minimize postural stress caused by stooping or working with hands and arms elevated. All the principles of ergonomics on design consideration must also be considered. A well structured designed workstation is crucial to prevent occupational hazards and risk associated to poor working posture as well assist workers to increase efficiency, safe working environment and enhanced productivity. This can boost workers morale to work in much desirable workplace by maintaining correct and comfortable body posture and a healthy lifestyle.

c. Body parts symptoms (BPS) survey analysis

Body Part Symptoms survey is a proactive approach recommended by DOSH [4] for identifying risk assessment of standing work. Parts are clearly put into different body regions as illustrated in Figure 3. In this study, body part symptoms survey form was modified from Corlett and Bishop [9]. The form was used to gather data with regards to operator's particular line process and assessing postural discomfort as illustrated in Figure 3 body regions.

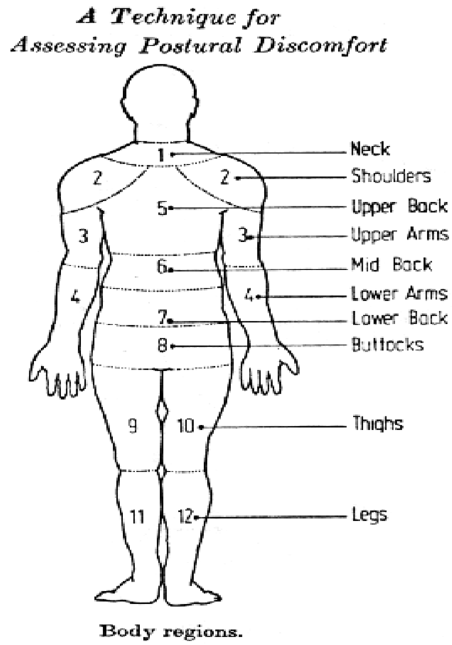

Figure 3: Body regions.
(Source: Corlett and Bishop, [9])

A cross sectional study reveals the result of Body Parts Symptom (BPS) survey in company X. Results of the discomfort at the respective body parts are reported in Table 3 for standing at work operations. From the survey a total of 124 total pains and discomfort were recorded ranging from upper body parts until lower body parts.

From the data in Table 3, it's clear to see shoulder pain recorded the highest rating of 21.8% compared to others. It is followed by ankle and feet pain with 17.7 % and the neck pain at 13.7%. All the three body parts (i.e. shoulder, ankle/feet, neck pain) make up of 53.2% from total body parts symptoms survey done for standing operators. Results from the BPS survey showed that the upper body side, neck and shoulder pains received the highest number of complaints due to the nature of work done such as continuously inserting component, soldering and assembling of parts. On lower body parts, it is noted that ankle and feet pains have the highest rating due to the nature of standing for long periods at the workstation.

According to standing at work guideline published by DOSH [4] assessment on body part symptom survey shows the findings fall under Classification of Level 2 Risk. Some of the findings include body part symptoms showing persistent pains, high rate of absenteeism and medical certificates sick leave (MCs) that are effecting quality and productivity (i.e. inconsistent production rate, increase scrap and rework) on the workers interviewed.

As for suggestion of control measures to be taken under Level 2 categories, DOSH [4] recommended the following 3 basics steps:

1. Create ergonomic management team to-initiate task analysis, formulate of safe standing work procedures, improve workstation/work redesign and looking into other feasible ways to minimize risk exposure.
2. Educate the designer of standing workstation on ergonomics such as looking into anthropometric, strength and movement, workplace design and work physiology
3. Finally, training personnel as recommended for Level 1 according to DOSH [4] requirement:

   i. Importance of proper standing work procedures and how it effects productivity, quality and long-term OSH of the employee,
   ii. Competency to understand the risk
   iii. Practical measures to reduce risk such as stretching, adjusting workbench height, rearranging workstation and others
   iv. How to report body symptoms

Implementing good and sound ergonomics program shall reflect the organization's commitment in putting safety, comfort and efficiency of plant as the first priority compared to other matters. As for cumulative trauma disorders, one of the best ways to avoid back, neck, and shoulder injuries is to minimize sustained over exertions. Based on company X findings more than 50% of body parts that received the highest number of complaints are neck, shoulder and feet pain. The following tips could help to ease these problems:

- Alternate tasks. If possible, get up from your workstation periodically to use the phone, make copies and file paperwork.
- Take several rest breaks. For many people, "micro breaks" that allow you to pause frequently are more effective than the traditional 15-minute break after every two hours of work.
- Consider installing software that reminds you to take periodic breaks throughout the workday.
- Take short breaks that involve active exercise (walking, stretching), very often they are the most effective for relieving stress on the back, neck, and shoulders.

Table 3: Body parts symptoms analysis result

Body parts	Frontal body side	Back body side	Cumulative freq. &%	
Eye	Eye	Nil	1	0.81%
Head	Head	Head	1	0.81%
Neck	Neck	Neck	17	13.7%
Shoulders	Shoulders	Shoulders	27	21.8%
Elbows	Elbows	Elbows	8	6.45%
Wrists/ Hands	Wrists/ Hands	Wrists/ Hands	11	8.87%
Stomach/ Buttock	Stomach	Buttock	10	8.06%
Upper back	Upper back	Upper back	14	11.3%
Low back	Low back	Low back	0	0.00%
Hips/ Thighs	Hips/ Thighs	Hips/ Thighs	12	9.68%
Knees	Knees	Knees	1	0.81%
Ankles/ Feet	Ankles/ Feet	Ankle/ Feet	22	17.7%
		Total	124	

6 Conclusions

The measurement of standing workstation in company X, which includes standing height (stature), standing eye height and standing elbow height shows they have met the requirement to accommodate the female operators working height and proper workspace. In addition, standing risk assessment was done to analyse the ergonomics risks associated to standing operations. Common risk identified includes awkward posture, contact stress, wrist, static posutre, fatigue, twisting of the spine, bending, too far and not reachable.

The body part symptoms survey results showed that shoulder pain recorded the highest rank with 21.8%, followed by ankle and feet pain with 17.7%, neck pain at 13.7%, upper back with 11.3%, hip/thigh with 9.68%, wrist/hand with 8.87%, buttock 8.06% and elbow with 6.45%. The eight body parts mentioned above made up of 97.56% of the total complaints by standing operators. This may be due to the nature of work done in company X such as continuously inserting component, soldering, assembling of parts and standing for long periods at the workstation.

Many musculoskeletal disorders can be reduced and thus enhancing workers confident in carryout their routine work. In this study, risk factors identified can be eliminated by suggestions and recommendation set by DOSH [4]. Further development in improving work task and eliminate possible risk is part of an ongoing process in company X. Standing work, if it is done in the appropriate manners actually will result better productivity, efficiency and safety. Proper postural techniques should be applied to avoid any risk associated to musculoskeletal disorders (MSDs) at the workplace.

The authors believe, findings from this study would be able of convince company X senior management on the cost benefit of ergonomics approach in the long run. Therefore, the authors strongly recommended company X top management to conduct more in-depth study to identify the source and find a solution to this pain and un-comfortableness complaints among standing workstation female operators.

This could also give benefit to the workers in term of minimizing their health risks and maintaining safe workplace, which in-turn could improve their work efficiency and productivity. Most organizations considered workers as their most valuable assets and it is their management's responsibility to take up the challenge and make sure that workers are safe and their welfare are taken care.

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