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Original Article

Optimizing Workstation Design for Standing Work System in an Electronics Assembly Work

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Abstract

Background: Standing workstation can be a strategic approach for many electronics manufacturers to achieve work optimization. However, the well-being of the workers has become a great issue for both workers and employers. The main objective of this research was to study the effects of standing working posture on the workers and their impact to workers' health and productivity and then to re-design and optimize their workstations to a better the working posture.

Methods: The methods used in this study included ergonomics risk assessment using Standing Risk Assessment (SRA), Body Parts Symptoms Analysis (BPSA) and anthropometric data measurements. The subjects in this study were 146 female workers. This case study was carried out in 2011 in a multinational electronics company situated in Beranang Industrial Area, Selangor, Malaysia.

Results: After the re-design, a 26% floor space savings, as well as 30% improvement in productivity, quality and reduction in Work In Progress (WIP) was seen. The risk level was at level 2, which was considerably low. Nevertheless, the calculated numbers of industrial accidents and total lost hours were reduced sharply by implementing correct standing cell operation.

Conclusion: Standing while working might be the most productive posture in manufacturing and assembly work. However, it can be the opposite if the workers are exposed to musculoskeletal disorders and fatigue because of working standing for too long.

Keywords: Standing work, Workstation design, Ergonomic, Standing risk assessment

Introduction

Ergonomics studies have been dealing a lot with re-designing workstation aimed to optimize human-machine interface. In the past, as a result of poor workstation design and poor static standing postures usually for longer hours, workers in electronics industries often suffer from lower limbs musculoskeletal disorders. Large proportions of the semiconductor work force were exposed to prolonged standing and experienced pain in the lower limbs (1). Statistical data from the UK indicate more than 11 million UK workers, half the UK workforce, could be facing health risks caused by prolonged standing (2).

Standing with different task can be categorized based according to leg movements and whether it is dynamic (continuous movement), static (less or no leg movement) or combination of both actions (3). Standing work has some advantages compared to sitting where it has a greater reach, less leg rooms (4) and also has maximum reach envelope (5). However, diurnal working for prolonged periods by adopting a stationary standing posture can aggravate muscle fatigue, lower back pain, stiffness in the neck or shoulders, and other health problems (6). From the medical point of view, prolonged standing causes inflammation on feet or varicose vein, back pain, arthritis and potential loss of bone alignment (7). Therefore, suitable and effective ergonomic workstation is needed to help workers do their tasks while standing. DOSH (8) recorded a certain guidelines for standing work-station in Malaysia especially to avoid strain and damage to any part of the body.

This case study was carried out in a multinational electronics company situated in Beranang Industrial Area, Selangor, Malaysia. The setting up of the electronics production line is based on a conveyor system and normally installed in fixed workstation. This required large amount of space used to install machineries and other production equipments. As the company started to fully implement lean manufacturing system, the management started to realize the importance of having ergonomics based workstation as a better alternative.

The main objective of this study was to propose a suitable workstation with specific features to enhance the capacity of the assembly processes after the effects of standing working posture on the workers and their impact to workers' health and productivity have been investigated.

Methods

First standing work optimization model was developed (9). The optimization model was established so that the management could be convinced that the workers would have a wider work envelope and get maximum output with minimum human risk when carrying out the task. Four main control factors including working environment, machines (technology), man-power (human) and working methods (system) were considered into this model. The model concentrates on repetitive work task were done in a sequential flow throughout all assembly processes. Fig. 1 depicts the standing work optimization model.

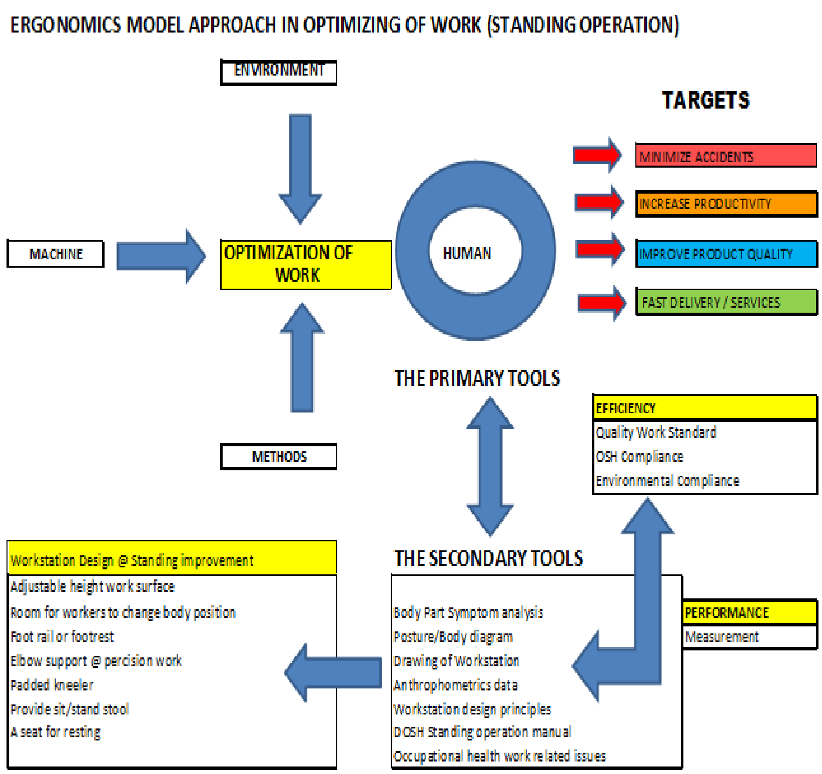

Fig. 1: Ergonomic model approach for work optimization

The primary concern in this model is that the human potentials, which include using minimal force for human movement, arrange task to match human flexibility in work and fit the machine or installed equipment to the workers based on their anthropometry. Hence, in order to evaluate human potentials and performance of the workers, ergonomic assessments were carried out among the assembly line operators. This case study was carried out in 2011 in a multinational electronics company situated in Beranang Industrial Area, Selangor, Malaysia. The subjects for this study were 146 female workers. Other than the evaluation, anthropometry measurement was also done manually using measurement tape and anthropometer for height. At the end of the study, the new workstation developed was tested in the assembly line. The workers' performance before and after using the new workstation were also calculated in this study.

Ergonomic Assessments

Standing Risk Assessment (SRA) and Body Parts Symptom Analysis (BPSA) which are elements adopted from Nordic Musculoskeletal Questionnaire (NMQ) were used to assess health or Musculoskeletal Disorder (MSD) related problems associated to the standing work performed by the workers. These tools are basic tools being used when risk of musculoskeletal disorders being investigated (10). NMQ was an acceptable screening tool and was almost 80% reliable and valid (11). The ten principles of ergonomics risk factors considered for this study to overcome stressful conditions in workplace are: operators should work in neutral posture, reduce excessive force and human energy, keep everything within easily reach position, work at proper height, minimize and reduce excessive motions, minimize fatigue and static load, minimize pressure points or contact stress, provide enough clearance, release pressure of stress by exercising or stretching, and finally an environmentally comfortable working condition.

SRA was applied to analyze what were some ergonomics risk associated to standing operations. Most common risks identified include awkward posture, contact stress, back pain, twisting, bending and far reachable. From the observation, many workers do experienced distress or postural distress while performing standing work in assembly processes. Uneasiness of workers was caused by faulty design of workstation such as wrongly allocated of machine and equipment. BPSA is considered as one of proactive approaches recommended by the Department of Occupational Safety and Health of Malaysia (9) in identifying risk assessment for standing work. Each standing operators are given BPS survey forms according to their particular work task done in line processes (9).

Results

Standing Risk Assessment (SRA) result

The workers feel discomfort as a result of working in the standing position. The assembly tasks that the workers do includes use of automation equipment, manual soldering task of automotive parts and components assembly. Wrong design of the workstations and wrongly allocated machines and equipment could be one of the reasons. The discomfort while doing the standing tasks can be seen when the workers have to work with their hands in awkward reaching positions, constrained foot position due to lack of clearance, working at the corner of the bench and standing with a twisted spine. Some postures were captured as shown in Fig. 2.

Body Parts Symptoms Analysis (BPSA) result

Assessment of the body part symptom survey shows the findings fall under classification of Level 2 Risk. Table 1 shows the details of the BPSA results. A total of 124 total pains and discomfort were recorded ranging from upper body parts until lower body parts. Based on data from the BPS survey, shoulder pain recorded the highest rating as 21.8%; followed by ankle and feet pain (17.7%) and pain at the neck (13.7%). All the three body parts made an accumulation of 53.2% from the total BPS survey done for standing operators. The pain at upper body side got highest rating due to the nature of work, while ankle and feet pain was due to the nature of standing for long periods at the workplace.

Fig. 2: Common postures captured from the assembly line

Table 1: Results of the body parts symptoms analysis

Body parts	Frontal body side	Back body side	Accumulation (Ratio) n (%)	
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	100

Ergonomically designed workstation

The anthropometric measurements for the 146 Malaysian females were recorded as shown in Table 2. The measurements were taken to help design new workstation for the workers to help them work more ergonomically.

For an example, the calculation of standing height (1) stature @ Height of workstation using K as values from z-score:

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

Therefore p = m + k (S) = 1550 + (1.64) (90) = 1550+147.6 = 1631mm (95%) Max (-1.64) (90) = 1550 - 147.6 = 1403mm (5%) Min

Therefore current design workstation can accommodate about 95% of female operators doing standing operation within these ranges.

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.

Therefore p = m + k (S) = 1440 + (1.64) (60) = 1440.50 + 98.4 = 1539mm (95%) Max (-1.64) (60) = 1440.50 - 98. = 1342.1mm (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.

Table 2: Anthropometric measurements for standing work

No	Body parts	Mean (mm)	SD (mm)	5th percentile (mm)	95th percentile (mm)	Remarks
1	Standing height (Stature)	1550.50	90	1403.00	1631.00	W/Station max reach (by hand) height-1900mm
2	Standing eye height	1440.50	60	1342.00	1539.00	W/Inst. Display Height-1473mm
3	Standing shoulder height	1250.25	60	1151.90	1348.70	
4	Standing elbow height	980.25	72	862.20	1098.00	Work surface-914mm
5	Hip height	450.00	70	352.10	565.30	
6	Knuckle height	690.50	65	592.10	797.10	
7	Fingertip height	520.00	52	421.90	605.60	
8	Knee height	468.66	32	370.30	521.20	
9	Forearm/Arm span	1535.00	85	1437.00	1674.80	
10	Chest height	980.25	72	881.80	1098.30	
11	Waist height	950.00	58	851.60	1045.20	
12	Shoulder width	400.00	85	301.60	539.40	

Therefore p= m + k(S) = 980.2 + (1.64) (72) = 980.25+118.1= 1098.3mm (95%) Max
(-1.64)(72) = 980.25-118.1= 862.15mm (5%) Min
Therefore, the new workstation should have a maximum dimension height for the workstation, which is 1900 mm (ideally 1650 mm) for the highest reachable distance for upper working reach. While for working surface, the height is at 950mm (862~1098) which is suitable for light, middle or heavy task and then 1473mm (1345~1539) height for displaying instruction manual. The workstation comes with a standard dimension but flexible which can be arranged to suit manufacturing process requirement.

The workstation is made of detachable tubes, made of conduct metal frame and easily assembled such as wooden cabinet installation concept. The features in standing workstation include footrest, stand bar, reject bin, parts or materials bin, work surface, visual control and working instruction. It consists of five different shelf layers, which are meant for different storage. Firstly, the lowest 1st tier stage is to place No-Go boxes to identify reject parts from line process. The 2nd tier is for placing materials or parts for assembly within reachable distance. Then, the 3rd tier is the main work space area of the standing workstation. This level is suitable for light work to assemble electronics parts and components at elbow height level. Meanwhile, the 4th tier is meant for parts and special process items. Finally, the 5th tier is for displaying instruction manual.

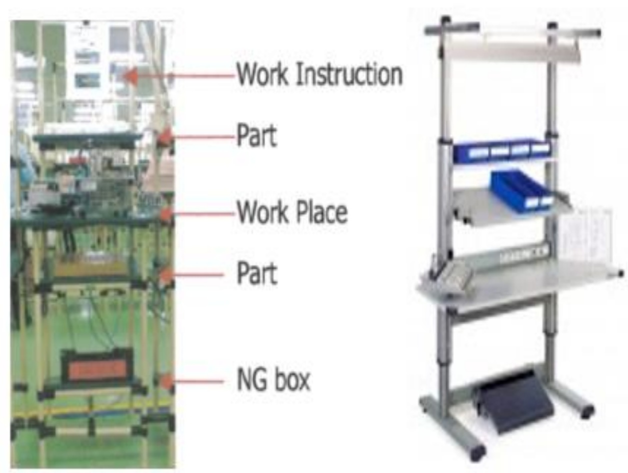

Fig. 3: Standing workstation at the factory

There has been an outstanding achievement resulting from implementing this new workstation where it was capable of improving productivity by 30%. The new workstation also improved space consumption, as well as reduced number of defects and WIP items. There was also significant increase in terms of production output capacity by 30% (P<0.05). Fig. 4 shows a conveyor cell being converted into straight-line concept. The space was reduced from 1.2 m x 7.8 m = 9.36 m^2 to 1.2 m x 5.4 m =6.48 m^2 with total saving of 2.88 m^2, but capable of producing similar output capacity. This saves space consumption by almost 26%. After converting from half rounded cell to U-Shape configuration (Fig. 4), consumption of the floor space reduces from 4.5 m x 3.5 m =15.75 m^2 to 3.0 m x 3.9 m=11.7 m^2.

There was an improvement of product quality as number of defects is reduced by 30%. Fig. 5 shows the combination of a PWB cell and straight cells where both were integrated between the first two cell systems.

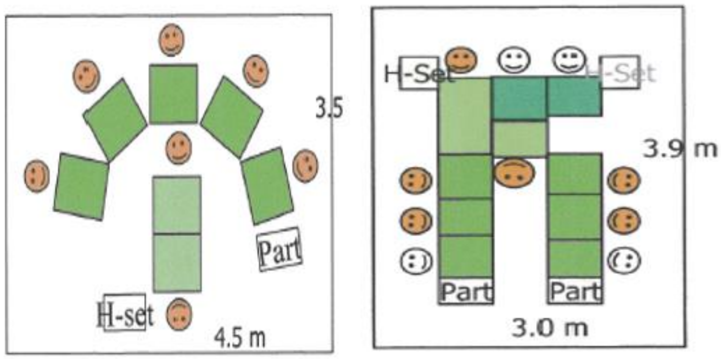

Fig. 4: Conveyor system converted to straight line

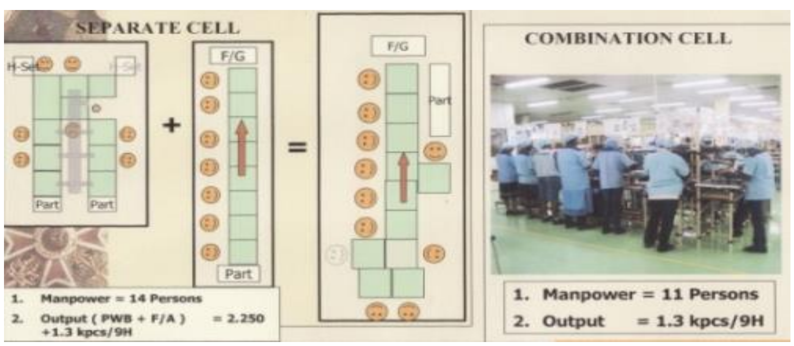

Fig. 5: Combination Cell

There was about 20% reduction of direct labor from 14 to 11 workers. Significantly, working in standing cell had 30% of capacity output and 30% of reduced number of defects in line. In total, the reduction in the number of work in progress (WIP) was by 30%. The stockpile up has reduced as well as reducing of WIP parts on line. Furthermore, with significant result in reduction of risk, the number of accidents and lost days was reduced (Table 3); hence, workers tended to spend more time on productive works.

Table 3: Occupational accident data trends from 2004-2008

Fiscal Year				Remarks
2005	2006	2007	2008	
8	6	8	3	Accident
70	33	6	2	Lost days

Discussion

Although the results show improvement in many areas, there are other recommendations on how to prevent health issues arising in the workplace (9). A standalone workstation installed in adjustable form could reduce some stress on legs and lower back impact from prolonged standing.

There are many supporting accessories suggested such as footrest, floor mats and shoes with insole. Besides, workers can also stand on rubberized platform to adjust working height to suitable elbow level. Sufficient foot clearance is also recommended (7). Besides, tools like hand jack and roller conveyor can be used to prevent awkward or improper postures. It is also important to do alternate tasks, arrange for task variation, take several rest breaks, consider installing software that reminds worker to take periodic breaks throughout the workday, and take short breaks that involve active exercise such as walking. Ultimately, equipment and tools are there to assist but knowledge and awareness of doing it ergonomically and the right way is the most important step to ensure good practice.

Conclusion

In standing operation, a few shortcoming areas were identified such as working with the hands too high or too far away, work surface is too low, constrained foot position due to lack of clearance, working at the corner of the bench and standing with a twisted spine. SRA result shows that many workers show some signs of distress while performing standing work. Initial standing work assessment shows the percentages for scrap, quality, complaint, turn over and reject rate were high. While the percentage for rework and output was low. The pain at shoulder, ankle, feet and neck make an accumulation of 53.2% from the total BPS survey done for standing operators because of the nature of work and standing for long periods at workplace. Based on the anthropometric standing measurement result of the female workers, the new flexible workstations with standard dimension was designed and tested. There were significant increase in production by 30%, saving space consumption by almost 26%, improvement of product quality as number of defects reduced by 30% and the number of work in progress (WIP) was reduced by 30%.

Ethical considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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