Journal of Asian Vocational Education and Training
Vol. 8, pp. 25-35, 2015
ISSN 2005-0550

Determination of Ergonomic Hazards at a Semiconductor Manufacturing Company: An Initial Study

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ABSTRACT

This study examined the ergonomic hazards faced by the production line employees of a semiconductor company in Malaysia. Prolonged standing could cause circulatory problem among factory workers. The objectives of this study were to determine the effect of prolonged standing during work, to assess the work method and to evaluate employees' awareness of ergonomic hazards. The risk identification process was conducted using observation and interview involving 50 employees to collect the empirical data regarding ergonomic hazards. The interview results revealed that a total of 17 workers were suffering from sore feet and 19 workers complained about their back pain. Nonetheless, based on the Industrial Accident Prevention Association (IAPA) Ergonomic Risk Assessment indicators, the ergonomic hazards faced by the production line workers in the company were at an acceptable level. However, the interview data showed that the level of employees' awareness about ergonomic hazards is still low and proper strategies should be adopted by the company management to enhance the workers' ergonomic awareness.

Keywords: Ergonomic hazards, musculoskeletal disorders, manufacturing sector, risk assessment, Malaysia

INTRODUCTION

Human factors and ergonomics have a huge impact in the industry, organization, management, employees and well-being of the entire system (O'Neill, 2005). Most of the work processes in the semiconductor industry are performed in standing position. Among the significant rationale to perform job in standing is that workers can freely move and perform faster the work processes especially when picking up and moving material from one place to another. In manufacturing system, it is an important decision to assign employees according to their competencies (Krijnen et al., 1998). Working in a standing position can be considered as versatile as the movement of the position of the legs and the workers have a large degree of freedom. The standing position allows a worker to carry out the work process in a way that it is easy and effective. Thus, it is assumed that this position will allow the workers to be more productive, hence contributing to the higher productivity to the industry.

The purpose of this case study was to determine the ergonomic hazards at a semiconductor manufacturing company. This initial study would identify the challenges faced by the production-line employees at the company. Based on ergonomics literature, prolonged standing would have side effect to the body such as circulatory problem and standing symptoms. This situation may lead to discomfort and muscle fatigue to the workers. In addition, in the long-run, employers may lose income in the forms of lower productivity, workers compensation, and health treatment costs (Dolhy, 2006; Zander et al., 2004).

Determination of ergonomic hazards due to prolonged standing often involves the search for symptoms. Physiological stress, muscular strain, and discomfort are often the symptoms of ergonomic problem. Lafond et al. (2009) asserted that prolonged standing has been associated with the onset of back pain symptoms among factory workers. A qualitative study was conducted to determine the impact of prolonged standing operators in a production line. Specifically, the production line operators were observed to determine the potential ergonomics hazards or risks (Kleiner, 2008). Figures 1 and 2 showed the workstation and a common way a worker takes a break due to fatigue.

Figure 1: Wire bonder workstation

Figure 2: Symptom of fatigue

LITERATURE REVIEW

Manual material handling (MMH) is the most common cause of musculoskeletal disorders (MSDs) and low back pain (LBP). Examples of MMH are manual lifting, lowering, carrying, pushing and pulling loads. From ergonomics perspective, manual material handling is a high risk activity that could cause spinal injuries. From physiological aspect, manual material handling requires high amount of energy and strength (Baba et al., 2015). Ergonomics (or its synonym human factors) is the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system. In addition, ergonomics applies theory, principles, data and methods in designing work-related environment in order to optimize human well-being and overall system performance (IEA, 2010) and it considers both a social goal (human well-being) and an economic goal (overall system performance) (Dul & Neumann, 2009). The ergonomic rating scales to justify the risk levels are also obtained from literature. The scales should be applicable to non-health practitioners such as a trained safety officer to avoid a possible lack of training that may lead to the non-recognition of the hazards (Graves, 1993).

Ergonomic and Prolonged Standing

Ergonomic is a study related to work. The main aim of ergonomics is to ensure employees can work comfortably in their workplace. The goal is to decrease the risk of injury illness and the most common types of ergonomic injuries and illness are musculoskeletal disorders (MSDs). MSDs are injuries or illness that affect nerves, tendons, muscles, ligaments, spinal or joint discs. Many industrial workplaces require workers to perform their jobs in a standing position. One of the advantages of standing is that it can provide a large degree of freedom to workers when manipulating materials and tools at their workstation. A standing working position also encourages workers to be more productive and consequently contributes to higher productivity, however, when workers spend long periods of time standing, they may experience discomfort and muscle fatigue at the end of the working day (Isa Halim et al., 2011).

Awkward Postures

Awkward postures are work positions with various body parts to bent, flex or extend positions that are not in the natural position which may pose as risk factors (see Figure 3). Figure 4 shows the proper postures to control the risks of ergonomic hazards. Awkward postures may increase a human's muscle exertion and may compress the tendons, nerves and blood vessels. In normal circumstances, the more extreme postures, the more power is required for the movement. Genaiday et al. (1999) stated that prolonged standing has been associated with the onset of low back pain symptoms in working population. Table 1 shows the human anatomy system and function.

Figure 3: Risk Factor

Figure 4: Controlling Risk Factor

Table 1: Human anatomy system and functions

Anatomy System	Functions
Muscles	Exert forces to create movement and to hold body in various positions
Bones	Provide the framework to which muscles ligaments and tendons attach
Ligaments	Connect the bones
Tendons	Attach muscles to bones
Nerves	Transmit signals from and to the brain
Veins/Arteries (Vascular)	Circulate bloods

Musculoskeletal Disorder (MSD)

Muscles disorders related to work (MSD) refers to a situation where workers have experienced discomfort in one or several parts of the body (back, elbow, neck, shoulder, hand, knee or hip), joint pain, tingling and swelling. It is well known that prolonged standing has been associated with the incidence of muscle disorders associated with work related lower back pain among industrial workers (Lafond et al., 2009).

Tendon Disorders

Tendons are strong bands of fibers that attach muscle to bone. Tendon transfers power from the muscle to the bone to produce movement of the joints and tendon disorders are medical conditions that cause the tendon not functioning normally. Tendon disorders occur at or near the joints where the tendons rub nearby ligament and bones. Some of the fibers which are connected to the tendons can actually tear apart or fray with further exertion.

Nerve Disorders

Nerve disorder caused by repeated or sustained work activity that involves pressure on the nerve from the hard, sharp from the work surface, tool or nearby bone ligaments or tendons. Tables 2 and 3 illustrated the list of nerve disorders and the list of neuro-vascular disorders adopted from the US Department of Labor Occupational Safety and Health (2002).

Table 2: List of nerve disorders

Disorder	Body part	Symptoms	Factors	Descriptions
Carpal Tunnel Syndrome	Hand, wrist	Pain, numbness, tingling loss of dexterity, weakness	Repetition, wrist flexion, motion through poor postures	Compression of median nerve through the tunnel, contributed by tenosyvitis or finger tendons
Pronator Syndrome	Forearm	Tingling, pain	Wrist and elbow flexion	Compression of the median nerve in forearm
Cubital Tunnel Syndrome	Elbow	Pain, numbness, tingling	Resting elbow on sharp edge, reaching over and onstruction	Compression of the ulnar nerve below notch of elbow
Guyon Tunnel Syndrome	Hand, wrist		Prolonged flexion and extension of wrist, repetitive forces on palm	Entrapment of ulnar nerve below notch of elbow
Radial Canal Syndrome	Forearm	Decreased sensation, pain	Passive stretching, resisted extension of middle finger	Radial nerve compression at the lateral epicondyle
Anterior Interosseous Syndrome	Forearm	Pain on forearm, weakness in thumb/ index finger pinch	Repetitive forceful activities	Compression of medical nerve by forearm muscles
Posterior Interosseous Syndrome	Forearm	Pain in forearm	Repetitive, forceful activities	Compression of radial nerve by the supinator muscles in forearm
Reflex Sympathetic Dystrohpy	Non-spesific	Burning, pain, swelling, sensitive to cold	Overusage of sympathetic nervous system	Progression from CTDs

Source: US Department of Labor for Occupational Safety and Health (2002)

Neuro-Vascular Disorders

Table 3: List of neuro-vascular disorders

Disorder	Body part	Symptoms	Factors	Descriptions
Thoraric Outlet Syndrome	Shoulder, upper arm	Numbness, pain, tingling, loss of strength,loss of dexterity, may involve entire upper extremity	Shoulder abduction, repetitive reaching overhead	General term for compression of the nerves and blood vessles between the neck and shoulder
Vibration Syndrome	Hand	Cold, pale, numbness, tingling fingersm loss of sensation and feeling	Cold temperatures exposure, segmental vibration	Tiny blood vessels and nerves of the hand constrict; common exposures come from large power tools

Source: US Department of Labor on Occupational Safety and Health (2002)

Standing Work Postures

Human body is affected by the arrangement of the work area and tasks while standing. The layout of workstation, tools and placement of keys, controls and displays that employees need to handle or observe this is in accordance with standard operating procedures that have been set, this restrict the workers body to move more freely while standing. As a result, employees do not have choice to determine the movement of the body more freely. This gives employees the freedom to move less and to relax the muscle from working. This lack of flexibility in selecting the position of the body could contribute to health problems. A workstation can either be designed for tasks to be conducted in standing, sit-stand or sitting position. Workers have to work standing when working in either of this situations: limited knee or foot clearance, extended reaches are beyond an arm length, and frequent distance movement, force exerted by hand or weight of the subject is more than 4.0 kg. There are four types of tasks: precision, light, medium and heavy (Department of Occupational Safety and Health Malaysia, 2002). As a good ergonomics approach to a production line, the workplace or workstation design should emphasize an adequate balance between the workers capabilities including workstation requirements (Black & Hunter, 2003). Table 4 showed the suitable position according to types of task.

Table 4: Suitable position according to types of task

Types of task	Preferred position	Criteria
Medium and heavy	Standing	Requires significant amount of force exertion by the body which involves the bigger muscle of the body located on the shoulder, back and thighs. Standing position will allow greater flexibility to exert such force
Precision	Sitting	Requires small amount of force exertion by the body which involves the forearm and hand. Standing is acceptable but for short duration, preferably less than 10 minutes. Task should be done in sitting position for longer duration to avoid fatigue
Light duty	Seated or standing	Preferably conducted in sitting position but with occasional standing requirements

RESEARCH METHODOLOGY

This research was designed to determine the risk levels of the ergonomic hazards which the company operators' exposed to during their working hours at the production area. This required a risk assessment for each production area. The risk assessment results were compared to other data (medical claim record, discomfort survey and questionnaire). In order to determine the causes of the ergonomic discomfort, complains and incidents in the company were recorded. Then suitable solution would be recommended for each production area. In this research, an exploratory survey was used which involved 50 wire bond operators at the production areas. Simple interviews have been conducted where initially all of them assumed the discomforts they experience were attributed to the workplace and the given tasks. The survey only involved wire bond operators whom were healthy to ensure the data obtained were valid. The checklist that being used was adopted from guidelines on occupational safety and health for standing work developed by the Malaysian Department of Occupational Safety and Health Malaysia (2002). The checklist was designed to measure body part symptoms.

RESULTS AND DATA ANALYSIS

Step 1: Direct Observation

Basically a direct observation was performed by walking through inspection at the standing workstation areas. Observation should focus and emphasize on the problematic areas.

Step 2: Body Symptoms Survey

Body symptoms survey has been carried out for all employees who work in standing position at their workstations. The purpose of the symptoms survey was to document whether there were trends in pain, discomfort and injuries among workstation employees who were standing long-hours to do their work. Obviously, if worsening condition in the lower limbs were detected, this would indicate a risk. In order to ensure that the data collected were valid and free from factors which were non-related to workplace, employees whom have these problem were exempted from the survey:

1. Overweight or obesity.
2. Pregnancy.
3. Back injury from previous job.
4. Past accident that may have impaired certain body parts.
5. Reduced ability to work due to activities such as golfing, gardening and fatigue because of other jobs.
6. Joint disease such as rheumatism and arthritis or degenerative bone disease (lumbar, trunk and lower back spondylitis) or peripheral circulatory disorder.
7. Physical disability.
8. Psychosocial problem.

The survey was carried out to the workers responsible to handle wire bonder machines which required standing position during setup and material handling. Based on the survey results, the operators believed the discomfort that they felt was related to their work at the present company. The interview results revealed that a total of 17 workers were suffering from sore feet and 19 workers complained about their back pain. Nonetheless, based on the Industrial Accident Prevention Association (IAPA) Ergonomic Risk Assessment indicators, the ergonomic hazards faced by the production line workers in the company were at an acceptable level. However, the interview data showed that the level of employees' awareness about ergonomic hazards is still low and proper strategies should be adopted by the company management to enhance the workers' ergonomic awareness.

IAPA Ergonomic Risk Assessment

Ergonomic survey should be conducted by certified practitioner. Also, it was critical to ensure reputable and dependable risk assessment method was used. In this research, an Ergonomic Risk Assessment published by Industrial Accident Prevention Association (IAPA) in Canada was used as it was suitable to be conducted by non-professional ergonomic practitioner. When manual repetitive tasks are unavoidable then a risk-assessment approach should be adopted. This approach should follow four steps:

1. Hazard identification
2. Risk estimation by simple method
3. Risk evaluation by detailed method (if necessary)
4. Risk reduction

Data from Industrial Accident Prevention Association (IAPA) were derived from the production of wire bonds. The assessment involved 50 operators of wire bonds. Risk assessment involved only wire bond operators to ensure that the data collected were accurate and valid. However, the design of different work-stations required different assessment methods. In the IAPA Ergonomic Risk Assessment, it was found that the potential risk for wire bond operators was at an acceptable risk level. In terms of contact stress exposure, it appeared that no one was exposed to movements such as that required in daily work. The results were displayed in Table 5.

Table 5: Wire bond operators contact stress risk assessment results

Body part contact stress	**Physical risk factor**	**Duration**	**Risk level**
Hands	Using the hand (base of palm) as a hammer more than once per minute	None	None. This movement is not required in daily task
Knees	Using the knee as a hammer more than once per minute	None	None. This movement is not required in daily task

All tasks conducted by the operators involving the repetition of body movement showed a low risk of exposure to hazardous level. The level of risk was low due to duration exposure was lower than the critical limits. The results were tabulated in Table 6.

Table 6: Wire bond operators repetition stress risk assessments

Body part repetition	**Physical risk factor**	**Combined with**	**Duration**	**Risk level**
Neck Shoulders Elbows Wrists Hands	Using the same motion with little or no variation every few seconds (exclude keying activities)	No other risk factors	More than six hours per day	Low. Actual duration exposure was less than one hour daily. Operators have time and space to avoid localised fatigue occurance
Wrists Hands	Using the same motion with little or no variation every few seconds (exclude keying activities)	Wrists bent in 30^0 flexion, or 40^0 extension or 30^0 ulnar deviation	More than two hours total per day and high forceful hands exertions	Low. Actual duration exposure was less than 1 hour daily. Operators have time and space to avoid localized fatigue occurance

The entire task involving attraction body parts showed low risk of exposure to operators of wire bond. The level risk was low because the duration of exposure and weights handled objects was lower than the critical limits. The results showed in Table 7.

Table 7: Wire bond operators' grip force risk assessment result

Body part grip force	**Physical risk factor**	**Combined with**	**Duration**	**Risk level**
Arms Wrists Hand	Pinch gripping an unsupported objects weighing 1kg or more per hand or Pinch gripping with a force of 2kg or more per hand comparable to pinch gripping half a stack of photocopy paper.	Highly repetitive motion Wrists bent ini 30^0 flexion or 45^0 extension or 30^0 ulnar deviation circle the appropriate movements. No other risk factor	> 3 hours total per day More than 3 hours total More than 4 hours total per day	Low. No highly repetitive motion involved Weight or magazine less than 500grams Duration of exposure less than 1 hour/day
Arms Wrists Hand	Power gripping an unsupported object weighing 5kg or more per hand	Highly repetitive motion Wrists bent ini 30^0 flexion or 45^0 extension or 30^0 ulnar deviation circle the appropriate movements.	More than 3 hours total per day	Low. No highly repetitive motion involved Weight or magazine less than 500grams Weight of pizza box is 3kg Duration of exposure less than 1 hour/day

Overall, the awkward postures of the body showed a low risk of exposure to operators of wire bond. The level of risk was acceptable because the low risk of the awkward position due to ergonomic workstations and tasks designed to be stopped or paused. The results can be seen in Table 8.

Table 8: Wire bond operators' awkward posture risk assessment

Body part awkward posture	Physical risk factor	Duration	Risk level
Knees	Squatting	> 4 hours/day	Low < 30 minutes of daily exposure
	Kneeling	> 4 hours/day	Low < 30 minutes of daily exposure
Shoulder	Working with the hands above the head or the elbows above the shoulders	> 4 hours/day	None No such movement needed in daily task
	Repetitively raising the hands above the head or the elbows above the shoulders more than once per minute	> 4 hours/day	Low < 30 minutes of daily exposure with possible stop and pauses Not a repetitive movement
Neck	Working with the neck bent more than 45^0 (without support or the ability to vary posture)	> 4 hours/day	Low This awkward posture is avoidable due to the suitable workstation design
	Working with the neck bent more than 30^0 (without support or the ability to vary posture)	> 4 hours/day	Low This awkward posture is avoidable due to the suitable workstation design
Back	Working with the neck bent more than 30^0 (without support or the ability to vary posture)	> 2 hours/day	Low This awkward posture is avoidable due to the suitable workstation design

Demographic Information

This section described the respondents' demographic information in terms of gender, race, age, highest education level and years of service. Table 9 illustrated the respondents' demographic data. Majority (92%) of the respondents were females. In terms of the age group, most (56%) of the respondents were in the 18-25 age group. Production line workers with less than 5 years working experience in the company constituted the largest (62%) segment of the respondents with Malays were also the dominant group of respondents (65%). Finally, in terms of academic qualification, the high majority (96%) possessed secondary school qualification (Malaysia Education Certification – *Sijil Pelajaran Malaysia*) or equivalent (for foreign workers).

Table 9: Summary of Respondents Demographic Data

Variabel	Category	Percentage (%)
Gender	Male	8% (4)
	Female	92% (46)
Age	18-25 years old	56% (28)
	26-35 years old	26% (13)
	36-45 years old	10% (5)
	46-55 years old	8% (4)
Years of Service	Less than 5 years	62% (31)
	6-10 years	22% (11)
	11-15 years	6% (3)
	16-20 years	6% (3)
	More than 20 years	4% (2)
Ethnic group	Malay	65% (65)
	Chinese	2% (2)
	Indian	13% (3)
	Indonesian	25% (25)
Education/Qualification	Sijil Pelajaran Malaysia or equivalent (foreign worker)	96% (48)
	Diploma or higher	4% (2)

CONCLUSION

The results of the assessment risk by using IAPA Ergonomic Assessment to determine whether the respondents were exposed to high risk forceful exertion for lifting or lowering loads. The findings indicated that the operators were exposed to the risk of moderate injury. Based on the observation of the work area as proposed by the Department of Occupational Safety and Health (DOSH), it was found that the production of wire bonds meet the criteria for the design of safe work-station in standing postures. It was also found that operators were not in awkward posture during work and they were wearing light weight working clothes. In addition, the study found that the operators were required to stand on a hard surface with suitable floor mat when performed standing work. Thus, it was also possible for them to do leg movement during standing at work which exceeded 10 minutes time. The usage of proper shoes to support body weight provided by the employer was also an added advantage. Furthermore, items arranged in the standing workstation were within reach and were not exceeded maximum reach limit. Finally, operators could release the physical stress of the body during break times where they could have bodily movements.

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