A SOLUTION FOR REDUCING THE ERGONOMIC PROBLEM AMONG SEMICONDUCTORS WORKES BY USING SAFE WORK PROCEDURES

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A SOLUTION FOR REDUCING THE ERGONOMIC PROBLEM AMONG SEMICONDUCTORS WORKERS BY USING SAFE WORK PROCEDURES

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ABSTRACT

Ergonomics in the workplace involves the design and arrangement of tools to ensure workers can use easily and safely. Practicing ergonomics reduce risk of injury and increase comfort and productivity at workplaces. Use resources to ensure work environment and work practices. The purpose of the study is to develop a conceptual model of ergonomic workplace design through an observation survey to enhance the workplace safety in manufacturing. The study emphasizes the need to redesign the work environment in lab with the ergonomic approach. Safety is a basic physical and psychological need of human beings in daily life and work. The study clarifies the measures taken to ensure workers' safety and health, also establishes the relation between ergonomic workplace design and productivity. Promoting occupational safety and health, and ergonomic workplace design is the need of the hour. Most of company values is to "ensure a safe, clean and injury-free workplace. All injuries are preventable. Understanding the risks and ergonomic behavior are the main paths to prevention. To avoid injuries and after successful internal trials in some area, by implement ergonomic program across the workplace. It seen the positive impact of short break advice. Just takes a few seconds break, but across a day, a week, a year all the little breaks will help keep your injury free. Our actions have effects on others. Similarly, when something is unsafe, it impacts you and consciously take micro-breaks so that can minimize ergonomic risks and stay productive. Safety begins with us and when we see something unsafe, we should do something about it.

Keywords: #Safer Place for You and Me, # Stay Safe, # Be Safe

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Abstract

Ergonomik di tempat kerja melibatkan reka bentuk dan pengaturan alatan untuk memastikan pekerja dapat menggunakan dengan mudah dan selamat. Mengamalkan ergonomik mengurangkan risiko kecederaan dan meningkatkan keselesaan dan produktiviti di tempat kerja. Gunakan sumber untuk memastikan persekitaran kerja dan amalan kerja. Tujuan kajian adalah untuk membangunkan model konsep reka bentuk tempat kerja ergonomik melalui kaji selidik pemerhatian untuk meningkatkan keselamatan tempat kerja dalam pembuatan. Kajian ini menekankan keperluan untuk mereka bentuk semula persekitaran kerja di makmal dengan pendekatan ergonomik. Keselamatan adalah keperluan asas fizikal dan psikologi manusia dalam kehidupan harian dan kerja. Kajian ini menjelaskan langkah-langkah yang diambil untuk memastikan keselamatan dan kesihatan pekerja, juga mewujudkan hubungan antara reka bentuk dan produktiviti tempat kerja ergonomik. Menggalakkan keselamatan dan kesihatan pekerjaan, dan reka bentuk tempat kerja ergonomik adalah keperluan masa. Kebanyakan nilai syarikat adalah untuk "memastikan tempat kerja yang selamat, bersih dan bebas kecederaan. Semua kecederaan boleh dicegah. Memahami risiko dan tingkah laku ergonomik adalah laluan utama untuk pencegahan. Untuk mengelakkan kecederaan dan selepas percubaan dalaman yang berjaya di beberapa kawasan, dengan melaksanakan program ergonomik di seluruh tempat kerja. Ia melihat kesan positif nasihat rehat pendek. Hanya mengambil masa beberapa saat rehat, tetapi merentasi sehari, seminggu, setahun semua rehat kecil akan membantu menjaga kecederaan anda free. Tindakan kami mempunyai kesan ke atas orang lain. Begitu juga, apabila sesuatu yang tidak selamat, ia memberi kesan kepada anda dan secara sedar mengambil micro-breaks supaya dapat meminimumkan risiko ergonomik dan kekal produktif. Keselamatan bermula dengan kita dan apabila kita melihat sesuatu yang tidak selamat, kita harus melakukan sesuatu mengenainya.

Kata kunci: #safer tempat untuk anda dan saya, #stay selamat, #be selamat

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Ong Su Hoon

25 Dec 2020

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LIST ABBREVIATIONS

BCPE	Board of Certification for Professional Ergonomists
DOSH	Department of Occupational Safety & Health
OSHA	Occupational Safety and Health Administration
MSD	Musculoskeletal Disorders
PPE	Personal Protective Equipment
OSH	Occupational safety & Health
OD	Occupational Diseases
SOCSO	Social Security Organization
HoC	Hierarchy of Control

CHAPTER 1

INTRODUCTION

1.1 Research Background

The term ‘ergonomics’ is derived from the Greek word which ‘ergo’ defined as work and ‘nomos’ defines as laws. Board of Certification for Professional Ergonomists (BCPE) asserted that “Ergonomics is the discipline that applies scientific data and principles about people to the design of equipment, products, tasks, devices, facilities, environments, and systems to meet the needs for human productivity, comfort, safety and health”. (BCPE, 1993). In short, ergonomics is the interaction of system design with human abilities, human limitations and human characteristics. Ergonomics addresses (Öztürk & Arici, 2017):

i) Human physical characteristics (sense, physical, rational) and abilities
ii) Working style (posture and movements, fatigue, tension, monotony, work safety, accidents, motivation, work shifts, working hours, authority, power, responsibility, group behavior and wage structure)
iii) Human-machine design (Indicator-control mechanism, Size problems, Mechanical problems).
iv) Environmental conditions (lighting, noise, vibration, temperature, humidity, airflow, toxic substances, vapors, gases, radiation, order and hygiene, color and landscape)

The principles of ergonomics are concerned with prevent discomfort in people. Provide comfortable working environment in industry such as keep minimum noise level, optimized lighting, and ambient temperature play an important role to make sure employees to work healthy, safely and efficiently. With these comfortable workplace environments, it helps to improve productivity of industry which respect to both quantity and quality of production. If ergonomic principles are not properly implementation, occupational safety will less aware and the risk of occupational hazards will increase.

In 2017, Department of Occupational Safety and Health (DOSH) has introduced Guidelines of Ergonomics Risk Assessment at Workplace. The aim of these guidelines is to identify, determine and regulate ergonomics risk that related to work in workplace. These

guidelines help employer to have better planning in preventative action, thus minimize the rate the ergonomics-related incident and reduce the medical expenses.

Besides that, OSHA is planned to protect people in the workplace other than those who are currently working on safety or health risks arising from the activities of the people who are working. In additional, OSHA is also aimed to promoting a working environment for those who are working custom-made to their physiological and psychological needs. The statement presented above shows the importance of occupational safety and health against the public. However, various ways and actions have been taken to be ineffective to reduce and avoid accidental industrial accidents. Therefore, many constraints and obstacles in creating an accident-free industrial site.

A study of Shaliza et al. (2009) on ergonomics awareness in Malaysian manufacturing industries discovered that only 35.6% of Malaysian manufacturing industries have a high level of ergonomics awareness. Besides that, there is only a few manufacturing industries having ergonomic implementation. Low ergonomics awareness is mostly attributed to the lack of ergonomic education, training to industry and no initiative from the top management to focus on ergonomics issue.

1.2 Problem Statement

As of now, ergonomics cases are in an increasing trend. In Malaysia, the electronics industry is one of the largest employers and becoming the leading industry in the manufacturing sector. (Malaysia Industrial Development Authority,1998). Semiconductors is the largest sector within electronics because it is accounting for more than a third of total electronics exports. The semiconductor industry is a labor-oriented industry and involves many employees to support the productivity. From the statistics until December 2019, total 7984 occupational accidents had been reported by DOSH in which 259 cases lead to death. (DOSH, 2019) shown in Figure 1.1.

The workers in front of line of semiconductor need to walk around in clean room to operate machines, had the lowest prevalence of back pain. Meanwhile, the workers who work in assembly line, especially for those who works in encapsulation process need to have frequent lifting action, tends to experience high pain prevalence in the neck/shoulders and upper back. Others than that, testing workers had a high prevalence of lower limb pain due to frequent

climb steps to load units. (Chee et al., 2004). The workers in semiconductor laboratory are exposed to chemicals and different sample preparation for analysis had the possibility to experience neck/shoulders and back pain.

The occupational health and safety of semiconductor employee is therefore becoming popular research topic. Ergonomics is one of the studies in the aspects of occupational health and safety which carried out by government in the semiconductor industry in 1998–2002. The study found out work process is the major factor that contributed to body pain. (Chee & Rampal 2004). This might be due to a lack of awareness about ergonomic issues as well as the existence of limited resources for implementing ergonomics within allocated budgets.

In this study, the problem of accidental safety and health that related to ergonomics issue at semiconductor site are reviewed. There is no denying that an incident occurred could not be expected when it would occur. It will happen without a law and sudden. But it is not a reason to ignore and not to interpret all aspects related to safety and health at the workplace. The issues of accidents on the semiconductor site happen to be unexpected. Musculoskeletal disorder (MSD) is the most common disease that occur in most employee who work in semiconductor environment. Increasing trend of reported MSD case based on Social Security Organization (SOCSO) (2015) due to the increase in awareness among Malaysia employers & employee as shown in Figure 1.2

The symptoms of an MSD are lower back pain and limb pain. It is due to from long period of improper posture of working. For example, worker is not lifting goods with good form, standing too long, sitting position is not correct will lead to ergonomic issue. Besides that, worker who work in chemical environment will be risky if bad quality PPE (Personal Protect Equipment) was provided. It may cause injuries such as skin corrosive from acidic element, skin burn from high heated equipment and frostbite from nitrogen gas. Furthermore, sound pollution from the machine equipment, high working temperature and the improper lightning, workbench to limited space and ventilation level will result in ergonomic issue. In these cases, ergonomic solutions are important, but most companies do not take it seriously because this is consuming semiconductor profit and revenue.

The factors for such ergonomics issue are various and mainly involving safety and health. Study have shown that the effects of MSDs will lead to decrease in work productivity loss,

illnesses, absence, and disability (Bruce & Bernard, 1997; Aptel et al., 2002; Punnett & Wegman, 2004).

OCCUPATIONAL ACCIDENT STATISTICS BY STATE UNTIL DECEMBER 2019 (REPORTED TO DOSH ONLY)

STATE	NPD	PD	DEATH	TOTAL
JOHOR	1273	25	38	1336
KEDAH	299	19	8	326
KELANTAN	92	4	8	104
LABUAN	26	2	0	28
MELAKA	361	9	8	378
N SEMBILAN	464	11	8	483
PAHANG	446	19	21	486
PERAK	903	39	32	974
PERLIS	43	0	1	44
PULAU PINANG	805	22	21	848
SABAH	319	26	26	371
SARAWAK	410	28	32	470
SELANGOR	1595	69	33	1697
TERENGGANU	129	3	7	139
WPKL	279	5	16	300
TOTAL	**7444**	**281**	**259**	**7984**

Figure 1.1: Occupational Accident by state until December 2019 (DOSH 2019)

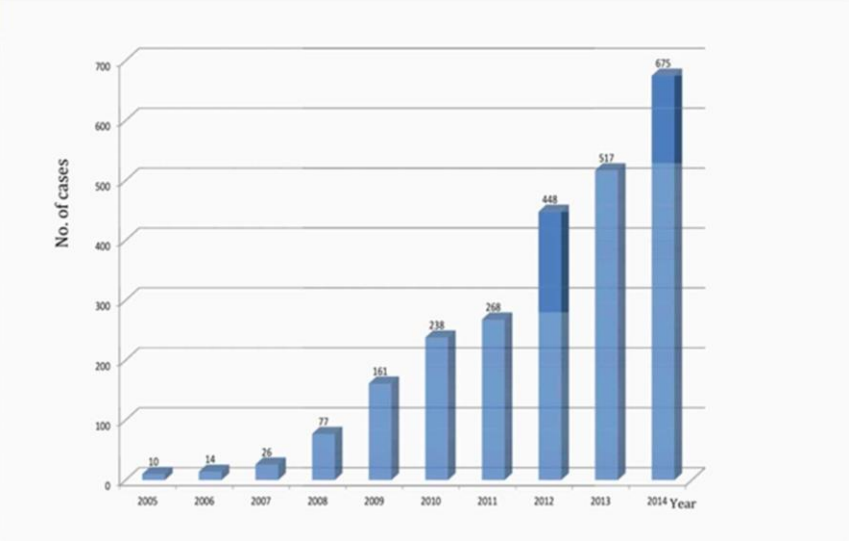

Figure 1.2: Trend of reported musculoskeletal disorders (MSDs) case from 2005-2014.
(Musri, 2017)

1.3 Research Objective

Based on accomplish study, some objectives have been drawn to control the goal of the study.

i) To prioritize personal safety semiconductor workers while working at semiconductor site.

ii) To identify the factors that can lead to bad ergonomic problems among workers that work in semiconductor company and the solutions to reduce the problems.

iii) To emphasis worker on ergonomic safety and to improve & implement ergonomic program to address safety ergonomic problem working on semiconductor site.

1.4 Research Questions / Hypotheses

This research is to obtain answers to the following research questionnaire.

i) Do semiconductor workers prioritize personal safety while working at semiconductor site? Does worker emphasis on ergonomic safety at semiconductor site?

ii) How the factors that can lead to bad ergonomic problems among workers that work in semiconductor companies and the solutions to reduce the problems.

iii) What is the ergonomic program that can improve & implemented to address safety ergonomic problem working on semiconductor site?

1.5 Significant of the Research

Through this research, it will figure out what is the factors that affect ergonomic solution to the workers work in semiconductor companies and provide good solutions in resolving the issues that occur in the workplaces. So, it can increase the satisfactory level of the workers work in the semiconductor companies.

1.6 Definition of Terms

The limitations of the study are as follows:

i) This study involves only companies engaged in semiconductors works at Penang Island.

ii) This study also only reviews on several elements that provide information about the problems that occurred during semiconductor operation.

iii) This study has a limitation, which is implemented in a semiconductor company and this resulted in a limited result. This decision cannot be used to obtain a global semiconductor workers Occupational safety awareness level.

1.7 Expected results from study

Based on the study conducted, we can evaluate the extent of awareness of semiconductors workers to occupational health safety. In addition, we can aware of workers ' perception of occupational safety practices ergonomic in semiconductor workplace. As a result of this study, studies also contributed towards the Quality enhancement of occupational safety management during operation especially related to ergonomic activity and follow the ergonomic awareness program, as well as safe work procedures. The roles that related with ergonomics and human factors knowledge such as ergonomists, occupational health and safety (OHS) agents, medical/ health service staff, consultants must have same mandate, expectation or training to suggest design changes, purchases and work task modifications. (Cecilia B & Caroline A, 2017).

Besides that, proper use of bio-break in sectors can reduce different types of risk and hazards which not only will cause injury but could lead to a permanent disable. The Management and health committees shall work closely to ensure that adherence to the safe work procedures and the proper use of PPE continuously followed by workers. Keep employees safe and healthy by implement an ergonomic assessment in workplace so that employee work without injury, pain and hurt.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This study discusses about the ergonomics risks among semiconductor industry. The most significant factors that caused ergonomics risks are surveyed and the working procedures for better ergonomics are optimized.

2.2 Semiconductors Industry

Semiconductor industry is one of the major contributors in terms of economy growth. According to Rajah & Shan (2016), in 1971, semiconductor firms became the first large wave of electronics firms to relocate in Malaysia before commencing export-oriented production in 1972.

Table 2. 1 shows that the industry's contribution to manufacturing employment reached its peak in 2000 of 30.5% before falling to 20% in 2010. Its contribution to manufacturing value added rose to 24.6% in 2000 before falling to 20.0% in 2010. In other words, the electronics industry accounted for 20% of Malaysia's manufacturing employment and value added in 2010.

Table 2.1: Contribution of electronics in manufacturing, Malaysia, 1990–2010H

Source: Malaysia Department of Statistics (2010, 2012)

Year	Employment	Value added (US$ millions)	Manufacturing Employment (%)	Manufacturing value Added (%)
1990	217,600	1952.1	25.8	21.5
2000	480,800	6854.0	30.0	24.6
2010	375,800	34,062.9	20.0	20.0

Figure 2. 1 shows the share of semiconductor exports in overall national exports of Malaysia gradually fell from 24.9% in 1990 to 22.4% in 2000 and 21.3% in 2011. Malaysia accounted for 7.7% of global semiconductor exports in 1990. This share fell gently to 6.1% in 2000 before rising again to 7.1% in 2011.

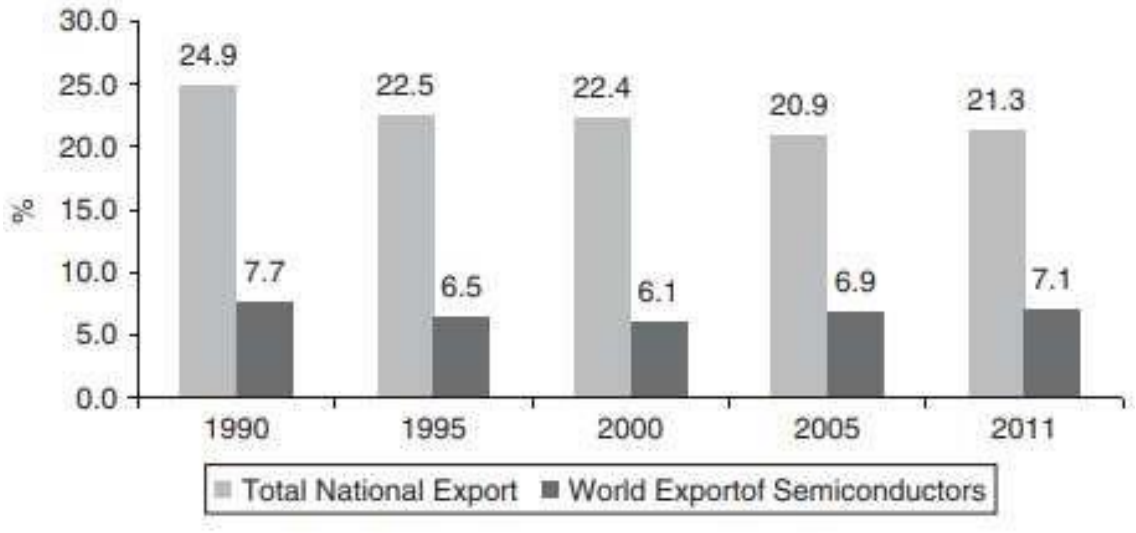

Figure 2.1: Share in exports, semiconductors, Malaysia, 1990– 2011.
Source: Computed from WTO (2001, 2006, 2012),
Bank Negara Malaysia (2000, 2006, 2012)

Hence, this shows that the importance of semiconductor industry in terms of national economic growth. As summary, continuous of development in sector of semiconductor industry is needed for increasing of national income.

2.3 Ergonomics

According to Öztürk & Arici (2017), ergonomics is the interaction of system design with human abilities, human limitations and human characteristics. Based on Weerdmeester (2008), ergonomics has been developed during World War II for purpose of operating military equipment. Then, this interdisciplinary has been applied in industrial activities. This is because ergonomics system can help to avoid the unsafe, unhealthy and uncomfortable situations which caused by human abilities and human limitations. Table 2.2 shows the factors play a role in terms of ergonomics:

Table2.2: Factors Play a Role in Terms of Ergonomics

Factors	Examples
Body Movement and Posture	Sitting Standing Lifting Pulling Pushing
Environment	Noise Vibration Climate Chemical Substances
Information and Operation	Information Gained Visually or Through other Sense Relation between Display and Control

According to Internal Ergonomics Association, ergonomics has been divided into three domains of specialization, which are physical, cognitive and organizational.

2.3.1 Physical Ergonomics

Physical ergonomics deals with the human body's responses to physical and physiological stress. It considers characteristics of the human such as anatomy, physiology, and biomechanics as they relate to physical activity. Physical ergonomics issues, primarily in the workplace, typically dominate the public view and understanding of ergonomics. It is certain that when ergonomic principles are ignored in the workplace, musculoskeletal disorders (MSD) are a potential outcome (White & Gamma 2008). According to Jeffress (2000), 1.8 million of American faced MSD and approximately 600,000 of the injuries caused loose of job, due to the characteristics of job such as frequent of repetitive, award posture, heavy, duration and environment (noise, vibration, light, climate).

2.3.2 Cognitive Ergonomics

According to White & Gamma (2008), cognitive ergonomics is an emerging branch of ergonomics. It is a subset of the larger field of human factors. It focuses on the fit between human cognitive abilities and limitations and the machine, task, and environment. Cognitive

ergonomics is concerned with mental processes, such as perception, memory, reasoning, and motor response, as they affect interactions among humans and other elements of a system.

Relevant topics in cognitive ergonomics include mental workload, decision making, human-computer interaction, and work stress. Typical domains of application include process control rooms and command and control center. Cognitive ergonomics is especially important for operators in modern industries. Human performance must be sustained in work environments where performance may be time constrained, multiple simultaneous goals may be in conflict, and events may be difficult to predict.

2.3.3 Organizational Ergonomics

According to White & Gamma (2008), organizational ergonomics (also called as macro-ergonomics) is focused on the optimization of sociotechnical systems, including their organizational structures, processes, and policies. The area of organizational ergonomics proves that ergonomics is not just about how an individual interacts with an object. Even organizations need to be ergonomically designed.

Organizational ergonomics is concerned with topics such as communication, work design, teamwork, crew resource management, teleworking, shift work, safety culture, job satisfaction, and motivation. How groups of people interact with each other in a work environment is the core of macro-ergonomics.

2.3.4 Application of Ergonomics

Ergonomics draws knowledge from various field such as anthropometric, biomechanics, mechanical engineering, industrial design, information technology and management. According to Harari et al. (2017), a good ergonomics system can help to improve workers productivity; at the same time, can help to reduce the injuries or accidents in workplace. Thus, ergonomics system plays a main role in industrial activities, including semiconductor.

2.4 Musculoskeletal Disorders

However, ergonomics problem is one of the major challenges faced by semiconductor industry and musculoskeletal disorders are the major problems which caused by ergonomics issue. According to Chee et al. (2004), in wafer preparation and polishing (manufacturing process in semiconductor industry), a combination of lifting weights and prolonged standing

might have led to high pain prevalence in the low back (35.0% wafer preparation, 41.7% wafer polishing) and lower limbs (90.0% wafer preparation, 66.7% wafer polishing). Semiconductor front of line workers, who mostly walked around to operate machines in clean rooms, had the lowest prevalence of body pain. Semiconductor assembly middle of line workers, especially the molding workers, who did frequent lifting, had high pain prevalence in the neck/shoulders (54.8%) and upper back (43.5%). In the semiconductor assembly end of line work section, chip inspection workers who were exposed to prolonged sitting without back support had high prevalence of neck/shoulder (62.2%) and upper back pain (50.0%), while chip testing workers who had to climb steps to load units had a high prevalence of lower limb pain (68.0%). Workers in the assembly of electronic components, carrying out repetitive tasks with hands and fingers, and standing in awkward postures had high pain prevalence in the neck/shoulders (61.5%), arms (38.5%), and hands/wrists (30.8%).

There are several previous studies show that musculoskeletal disorders are major ergonomics issue faced by semiconductor industry. According to Chandrasakaran et al. (2003), more than 80% of semiconductor workers had symptoms of musculoskeletal disorders. The surveys showed that back pain, lower leg and shoulder pain are three major musculoskeletal disorder in semiconductor manufacturing process.

2.5 Accident Theories

Accidents always been happened unpredictable in unsafe conditions. Since the hazards and accidents are not to be identified easily; thus, data investigation for accidents investigation may in terms of root cause analysis and minimization of accidents (Hosseinian & Thorghabeh, 2012). There are several accident theories as shown at below:

2.5.1 Domino Theory

According to Sulaiman (2013), most safety-conscious people have talked the Domino theory numerous times. Several of us have use dominoes to demonstrate this theory. As the first domino tips, it knocks down the other dominoes unless a domino has been removed at some point to stop the sequence. Obviously, the easiest and most effective domino to remove is the one at the center, the one which is labelled as an “unsafe act or condition”. This theory is quite clear, and it is also a practical approach to loss control. Simply stated, if you are to prevent loss, remove the unsafe act or the unsafe condition. During this era that H. W. Heinrich published his text, Industrial Accident Prevention. This text impact on industrial safety even

more than most of us in safety realize to this day

. Heinrich suggested more accidents are caused by people rather than conditions. He suggested that unsafe acts are the cause of a high percentage of accidents (88 percent), while the remaining percentage is due to unsafe conditions. This led the safety professionals of the 1930s and 1940s to start a two-sided approach in dealing with safety at work by:

i) Cleaning up the conditions; and

ii) Trying to teach and train the workers in the safe ways of working. Thus, 1931 ended the inspection period and marked the beginning of an era of concentration split between removing the unsafe conditions and stopping the unsafe acts in the workplace.

We use this theory in two fundamental areas today, which are:

a) Accident Investigation

In an accident investigation, nearly always, in the forms that we use or that we give to our supervisors to use, there is a section asking for the unsafe act and/or unsafe condition to be identified and removed. This, of course, seems very logical, considering the statements and principles expressed by the domino theory.

b) Inspection Possibly, though, our interpretation of this Domino theory has been too narrow. For instance, when we identify a single act and/or a single condition that causes an accident in the investigation procedures today, how many other causes are we leaving unmentioned? When we remove the unsafe condition that we identify in our inspection, have we really dealt with the cause of potential accident? Today, we know that behind every accident, there are many contributing factors, causes and sub causes.

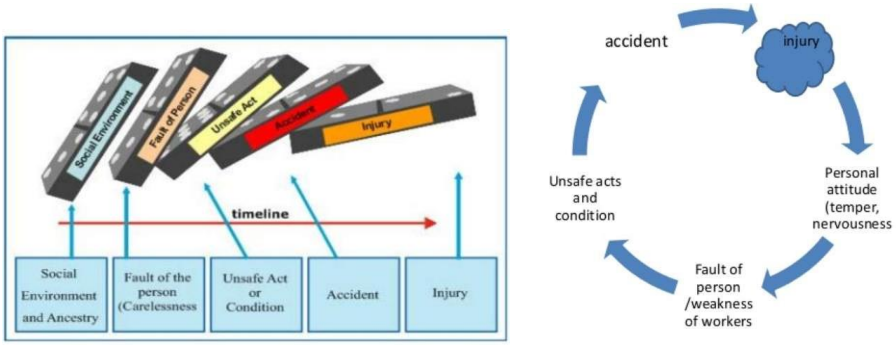

Figure 2. 2: Illusion of Domino Theory

Source: Sulaiman (2013)

2.5.2 Multiple causation theory

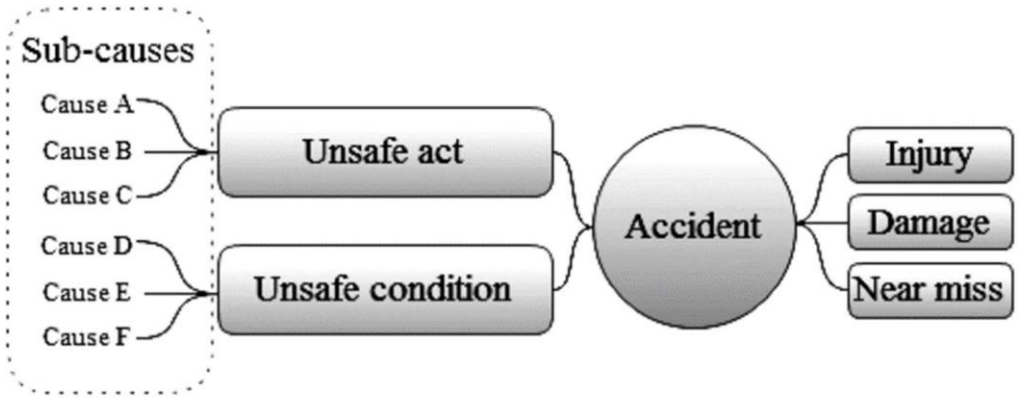

Figure 2. 3: Multiple Causation Theory

Source: Sulaiman (2013)

2.5.3 Goals Freedom Alertness theory

According to Sulaiman (2013), multiple causation theory is an outgrowth of the domino theory, but it postulates that for a single accident there may be many contributory factors, causes and sub-causes, and that certain combinations of these give rise to accidents. Is an event having not just one cause, but several different causes. For example, a person doing well on a test is likely with this accident, as with any accident, we must find some fundamental root causes and remove them if we hope to prevent a recurrence. When we look at the act and the condition, we are looking only at the symptoms, not at the causes. Too often, our narrow interpretation of the Domino theory has led us to the symptoms alone. If we deal only at the symptomatic level, we end up removing the symptoms but allowing the root causes to remain to cause another accident or possibly some other type of operational error. Root causes often relate to the management system. They may be due to the management policies and procedures, supervision and its effectiveness, or training. Root causes are those which would affect permanent results when corrected. They are weaknesses which not only affect the single accident being investigated, but also might affect many other future accidents and operational.

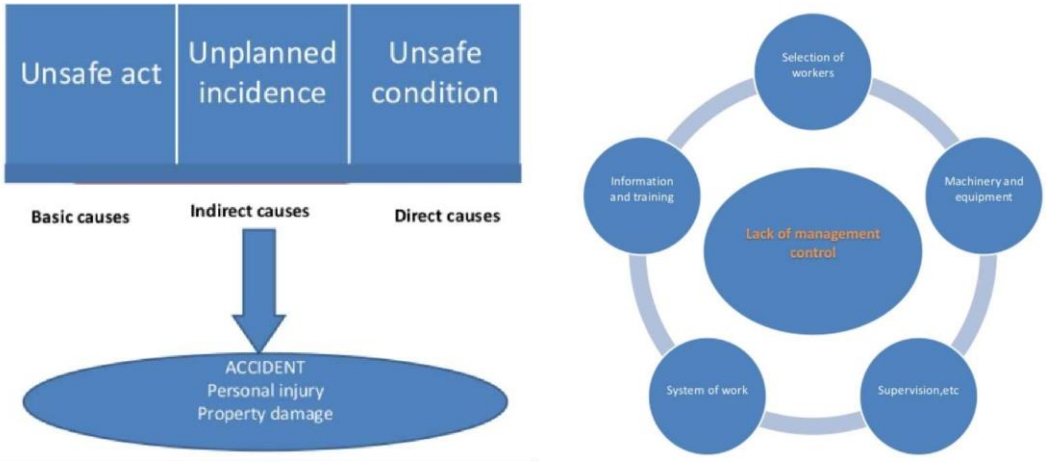

Figure 2. 4: Goals Freedom Alertness Theory (Kerr 1957)

According to Hosseinian & Thorghabeh. (2012), goals Freedom Alertness theory of accident reflects the idea that the psychologically satisfying and desirable work environment lead to the safe performance of tasks and activities. The theory expresses the idea that accidents are low-quality activities due to unpleasant psychological work environment. Alertness will be lowered as a result; the higher and the richer the climate is in terms of economic and non-economic opportunities; the more chance of alertness is created. The result of alertness is a higher quality performance and finally an accident-free work environment.

A psychologically satisfying work environment is a place where the workers are encouraged for performing their best, taking part, arranging achievable goals and innovating methods of achieving those goals. Workers are free for participating in identifying and solving work problems; the management system permit their workers to define goals for themselves and let them innovate methods of achieving their goals. Management can improve the environment of work for workers by managerial techniques, participative methods, setting defined goals for workers etc.

Human factors model is based on the idea that the human errors are the major cause of accidents; however human unsafe behaviors as well as poor design of workplace and environment which do not consider the human limitation, are considered as contributory factors. Ferrel theory (Ferrel 1977), the Human-error causation model (Petersen 1982), the McClay model (McClay 1989) and the Dejoy model (Dejoy 1990) are samples of human factor model.

2.5.4 Ferrel Theory

According to Hosseinian & Thorghabeh (2012), Doctor Russel Ferrel (1997) developed his theory of accidents based on a chain of human factors causes (See Figure 4). He believed that the human errors are the main causes of accidents occurrence and they are caused by the following factors:

i) Overload; the overload factor reflects the incompatibility between the load and the capability of the human. The result of this mismatch is anxiety, pressure, fatigue and emotions that can be intensified by physical environment such as dust, light, noise, fumes etc. where the person is working.

ii) Incorrect response; the incorrect response by the person is caused by the incompatible situation where he/she is working in.

iii) Improper activity; the person performs the activity improperly either due to lack of knowledge of appropriate way of performing the activity, or intentionally take the risk.

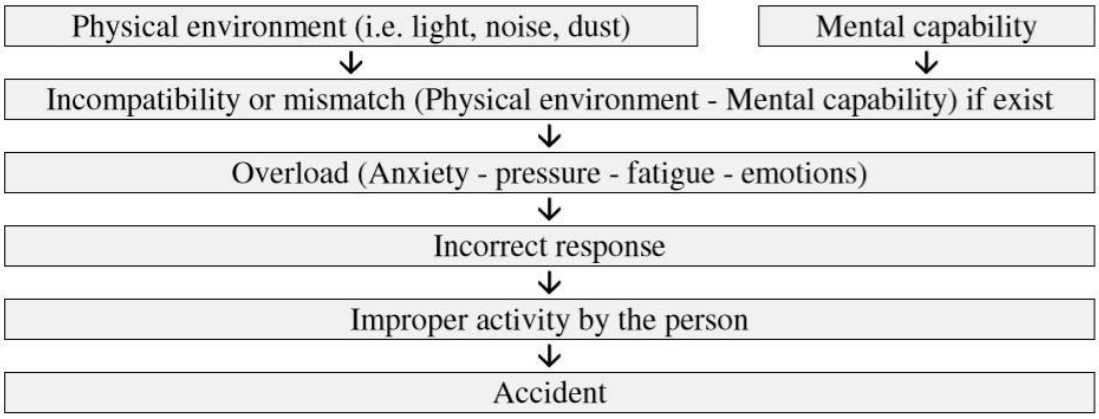

Figure 2. 5: Ferrel's theory of accidents causation

2.5.5 'Swiss Cheese' Model

According to Hosseinian & Thorghabeh (2012), The 'Swiss Cheese' accident causation model was first developed by James Reason (1970-1977) as a linear accident causation model. The theory is currently widely used since it simply suggests that the organizations try to prevent accidents by defenses in order not to allow the risks and hazards become loss (See Figure 5). These organizational defenses are divided into two groups:

i) Hard defense which are automatic alarming systems, physical obstacles, engineered safety appliances and weak points included into the main system for protection such as fuses.

ii) Soft defense which are dependent upon the personnel and procedures; regulations of required performance, investigation, checking, regular procedures of performance, education and training, supervision and working permission. Soft defenses also involve supervisors and operators as the pioneers. Losses to people, equipment, assets are the potential consequences of hazards in an organization.

Reason claims that a trade-off exists between the level of protection provided for the product and the production; the risks included in any product should be defended by the organization for the well-being of customers but the level of safety and protection should be equivalent to the risks associated with the work. If the level of protection is higher than required, then the company will not be commercially profitable and if the protection level is less than the associated risks the occurrence of accident is susceptible, and the organization will lose the business opportunities. The equilibrium between the protection and the production is essential for the durable commercial survival of the business; since the production process is visible the product can be managed and inspected for the desired output but the level of protection can be measured only after the inadequacy is determined.

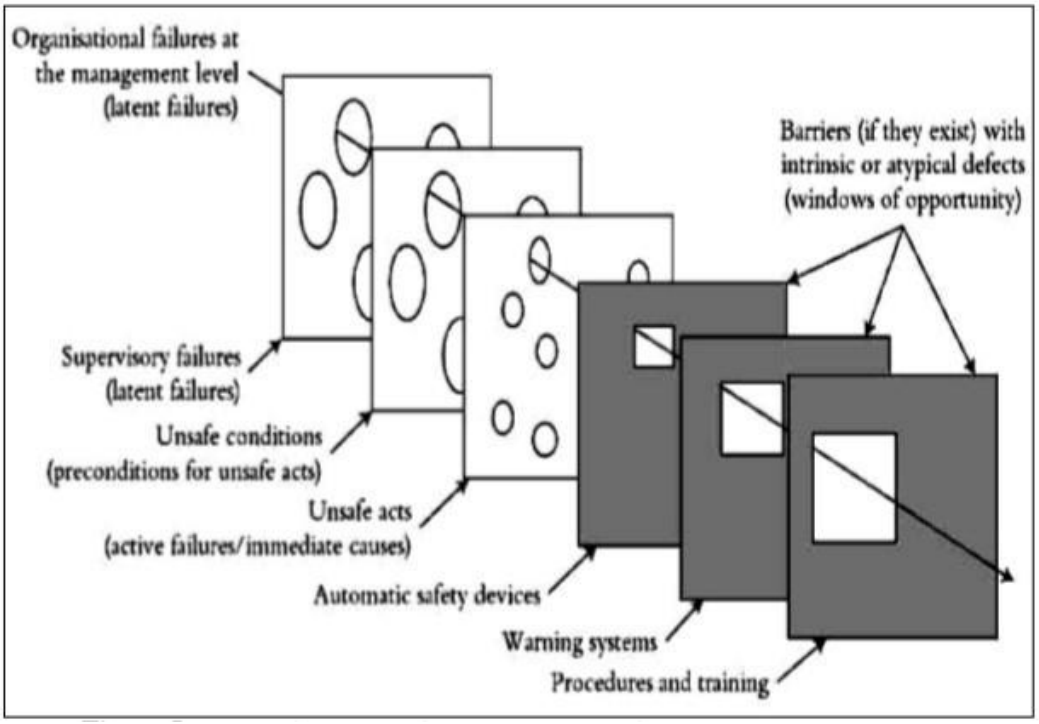

Figure 2. 6: Swiss Cheese Accident Causation Model

Although organizational accident defenses are obstacles which prevent the hazards from converting into losses, the obstacle and barriers have holes in them as slices of Swiss cheese; Reason called his model Swiss cheese because of theses defects in the organizational defenses. The foremen of an organization oversee the sharp-end procedures which represent the "unsafe acts" slice of cheese in the model. The holes in the unsafe act slice are the human errors or unsafe acts. Reason believed that accidents are caused by active failures and immediate causes which are the results of mistakes, slips and violations of standards. Accidents can be either caused by singular human error or a combination of them as immediate causes of accidents; the combination of violation and mistake is a very usual cause of accidents. There have been a lot of improvements in technology and engineering which means the technical failures are tried to be eliminated; therefore, most of the time human errors are blamed to be the major cause of accidents.

On the contrast the more improvements have been achieved in technology and engineering, the greater number of accidents caused by human errors are reported. Unsafe condition is represented by holes in the next slice of Reason Swiss cheese model; the unsafe condition and the psychological risk factors are the contributory factors to unsafe act of workers. Unlike active failures and immediate causes in previous slice, the holes in this slice are the hidden contributory factors of accident. The relationship between unsafe condition and unsafe act is a one-to-many interaction; unsafe condition can lead to many hazards and unsafe acts.

2.6 Benefits of Prioritize Ergonomics Safety in Workplace

According to survey of Santos et al. (2013); Thiede & Thiede (2015), the main benefit from implementing ergonomic safety at the workplace is to improve working conditions. 94.1% of interviewees response that implementation of ergonomic safety improves working conditions to minimize work injuries. The survey of Santos et al. (2013) shows that compliance with legislation results in better internal communication for workers which surely, decreases the number of work-related accidents (58.3%), reduces the cost of accidents and occupational diseases (58.3%) and decreases accident risk through the prevention of occupational risks (50%). The survey of Thiede & Thiede (2015) shows that implementation of ergonomic safety reduces the injury rates from more than 500 cases per month to nearly zero.

Besides, according to Thiede & Thiede (2015), implementation of ergonomics safety can help to improve cost benefits. This is because work accidents not only cause injuries. At the same

time, it may lead to damage of equipment, tools and properties. On the other way, implementation of ergonomics safety such as purchasing of PPE may help to reduce the injuries; as a result, the medical treatment cost for injured workers can be saved. Besides of reducing 500+ injury rates to nearly zero, according to cost-benefit analysis which carried out by Thiede & Thiede (2015), implementation of ergonomics reduces cost of injury treatments as much as USD7.82 per worker. In terms of annually, the injury treatment cost has been saved as much as USD 16,536.00.

Other than that, implementation of ergonomics can lead to reduce absenteeism. According to Santos et al. (2013) and Bergstrom G. et al. (2017), absenteeism may be caused by either injuries or common mental disorders (CMD). According to survey of Santos et al. (2013), absenteeism is related to the working environment. High absenteeism rate may be led by unsafe working environment due to high risk of industrial accidents. According to Bergstrom et al. (2017), common metal disorders (CMD) are major reason of sick leave. However, implementation of ergonomics safety can benefit both employees and condition of working environment. By application of ergonomics safety, besides of injuries; at the same time, CMD issues may be reduced due to reduction of fearfulness through work accident. These show that no matter injuries or CMD issues can be deducted by implementation of OSHMS. As a result, this may lead to reduction of sick leave.

Then, implementation of ergonomics safety may lead to improve productivity. According to Thiede & Thiede (2015), although cost and time consumption are needed by implementing ergonomics safety such as purchasing of PPE training and time consumption for rest; however, it may lead to reduction of work accidents. As per discuss, implementation of ergonomics safety may help to reduce absenteeism either caused by injuries or CMD issues [Santos. et al. (2013); Bergstrom et al. (2017)]; as a result, the manpower of workplace can be always maintained. As a result, higher manpower leads to higher productivity Jewalikar & Shelkeand (2013). On the other hand, productivity will not be delayed by damage of equipment or tools which caused by work accidents Thiede & Thiede (2015).

Lastly, implementation of ergonomics safety may lead to improvement of profit. According to survey of Jewalikar & Shelkeand (2013), 60% of interviewees agreed that implementation of ergonomics may lead to image fortification of organizations or companies due to lack of work accidents. As per discuss, implementation of ergonomics safety may lead

to improvement of productivity; at the same time, it may lead to scarification of customers which help to results in enhancement of business volume.

2.7 Effectiveness of Training for Improvement of Ergonomics

According to Tsang S.M.H et al. (2019), work-related neck and shoulder pain (WRNSP) is highly prevalent among patients who seek physiotherapy treatment. Thus, 101 participants have been involved in the study within 12 weeks intervention and training program, with separated into two groups, Ergo Motor Group (51 participants) and Control Group (50 participants). The results showed that more than 80 percent of participants have scenario of reduction in terms of pain and functional disability (Ergo Motor Group: 40 participants; Control Group: 42 participants). Besides, according to study of Robertson M.M. et al. (2008) which focused on computer-based office working environment, there were involvement of 165 participants divided into three groups [flexible workspace workers: 89 participants; flexible workspace with trained workers: 31; non-ergonomics intervention control workers: 45]. As a result, the group of flexible workspaces with trained workers showed higher positive results than others in terms of work-related musculoskeletal discomfort, job control and business efficiency; followed by group of flexible workspace workers and non-ergonomics intervention control workers. Both studies showed that intervention of ergonomics training comes with positive effects in terms of improvement of musculoskeletal disability and productivity.

2.8 Conclusion

Since ergonomics risks lead to negative impacts among semiconductor industry; on the other way, prioritize ergonomics may help to gain benefits for semiconductor industry. Thus, in this study, ergonomics safety among semiconductor workers has been prioritized and emphasized. The ergonomics risk factors has been identified with solution of minimizing ergonomics risks among semiconductor workers.

CHAPTER 3

METHODOLOGY

3.1 Methodology Plan of Study

Implementation of the project & time management for every element in completing the Methodology plan is carried out by using a Gantt Chart of Study as in Table 3.1.

Table 3.1 Gantt chart of **Methodology Plan**

No.	Activity	Month					
		1	2	3	4	5	6
1	Choosing Research Instrument						
2	Research Instrument Implementation						
3	Data Collection						
4	Data Analysis						
5	Occupational Safety and Health Campaign implementation						
6	Subsequent Audit						
7	Conclusion and Report Writing						

Indicator:

	Proposed progress
	Actual progress

3.2 Problem Identification

AA company is a company which manufacture semiconductor chip for computer manufacturers such as Apple, Huawei, Samsung, HP, Dell. Some defect may occur during the production assembly or by external customer. The defects found will be further analyze for improvement studies in order to avoid repetitive defect or to find the root cause of the defect.

The analysis is carried out by a technical team that is working inside technical lab. The team is responsible to analyze the failing defect and identify possible root cause by using analytical and technical method. Both methods have effect on ergonomics aspect that will affect personnel well-being. Analytical method is usually taking long hours to be carried out as it requires a high-end data collection of every details of the defects. For technical method, lab personnel will be facing constant physical stress by the usage of tools/equipment if workers not used properly.

3.3 Research Method

This research is a quantitative study which involves data collection with the Occupational Safety and Health Administration (OSHA) Checklist. Unsafe Act observation Checklist form is the source of data collection technique used in this study. The data is obtained through an internal audit in AA Lab.

According to Boddy CR (2016), sample size with minimum of 15 interviewees are required for qualitative research. In this research, there are involved of 20 workers in different stations, including sample preparation lab, inspection station (scope, X-Ray, CSAM), testing, equipment maintenance and computer-based workbench. Different ergonomics issues have been inspected in different workstations.

The survey question from Unsafe Act observation Checklist is an investigation instrument for this study. In addition, the perfect questionnaire form clearly states its objectives and the statement of each question are clear and easy to understand by respondents. Data is collected on individual worker in different station during normal working hours. Workers from each station workers are working with different instruments and tools. Every element in completing this Research proposal is supervised using a flow chart as Figure 3.1 below.

This chapter will present and show the research methodologies used to address the research aim, objectives and questions. This chapter will begin with explanation of research perspective, followed by data collection method, data analysis method, reliability and validity issue. Then, implementation of ergonomics in terms of training and facilities upgrades will be applied and followed by data re-collection for purpose of comparison before and after ergonomics implementation. Finally, limitation of the study will be discussed for future research purpose.

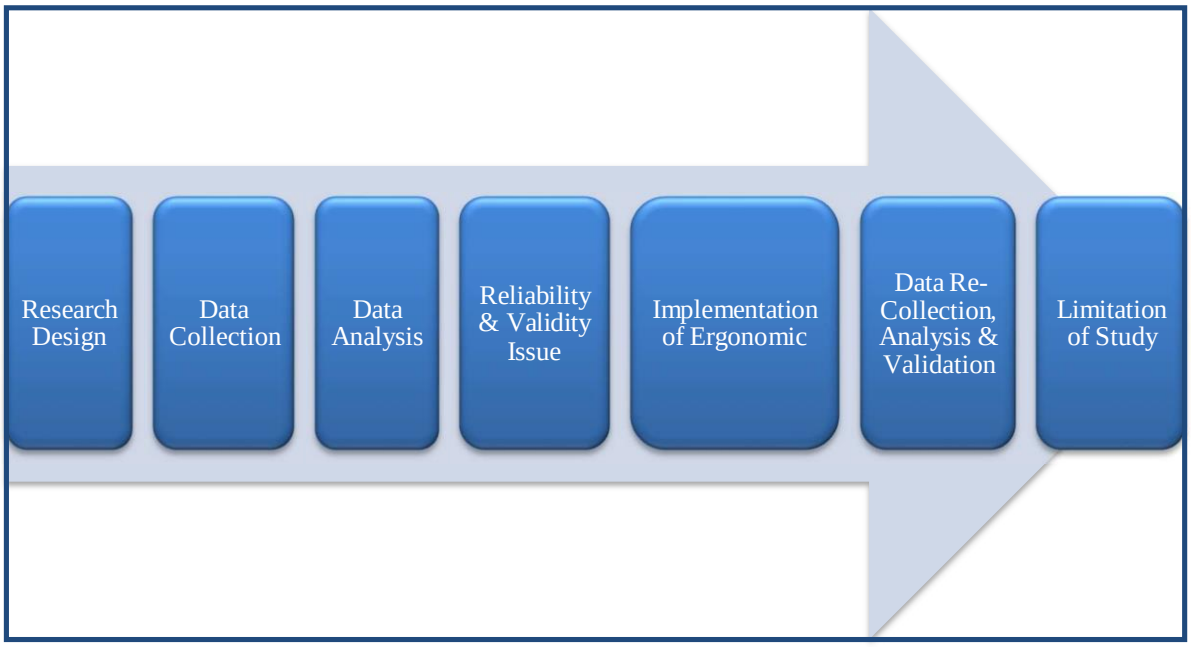

Figure 3.1: Research Flow Chart

3.4 Research Design

3.4.1 Classification of Research Purpose

i) Exploratory research
   a. Exploratory research is done through the observation in current workplace.
   b. Problem statement is made through the observation.

ii) Descriptive research
   a. Descriptive research is done to answer the problem in the current workplace.
   b. Descriptive research is used to study the characteristics and behavior of a population being studied

iii) Explanatory research
   a. Explanatory research is done to interpret the causal relationship between two variables and explain differences between two or more responses.

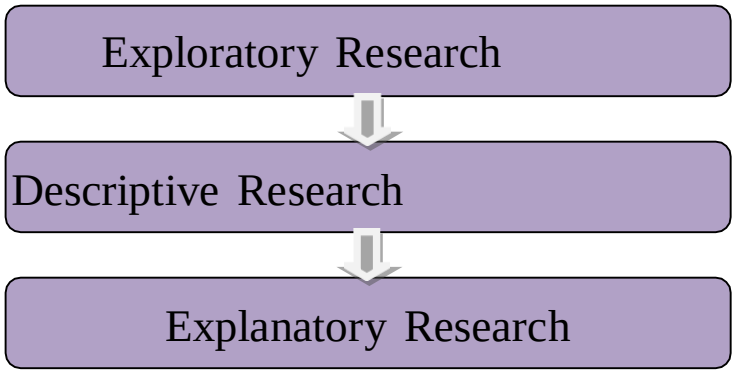

Figure 3.2: Classification of Research Purpose

Exploratory research, descriptive research and explanatory research will help to generate the data quantitatively and qualitatively. Therefore, a mixed method research is used to collect and analyses the data.

i) Exploratory Research

Exploratory Research is applied to discover the new insights or things that is happening and to ask questions for acquiring the experiences in new way. It is very helpful when it is needed to find out and understand the issue. Normally when it's at qualitative analysis. There are 3 ways to conduct this research. The ways are literature search, interviewing the expert and create a focus group interviews.

ii) Descriptive Research

Descriptive research focus on the imitation an event, status and a person detail accurately. This can be an expansion, or a pioneer of an explanatory studies or an exploratory study. The relation between descriptive studies and quantitative and qualitative research methodology does not fit based on the definition of both methodologies. But it can handle properly for the elements of both methodologies in a study. Besides that, it can useful for gaining the popularity status in a population sample.

iii) Explanatory research

Explanatory research is focus on create an inventive relationship between variables. It strongly points out on a status and issues currently studying so it can clarify the relationship between them. Normally it involves with quantitative analysis.

3.4.2 Ergonomics Risks Factors & Musculoskeletal Disorders

Ergonomics risk factors and musculoskeletal disorders are the main themes of this research. According to survey of Chandrasakaran et al. (2003), there are 83.4% of semiconductor workers had problems of musculoskeletal disorders, with three majority problems of back (57.8%), lower leg (48.4%) and shoulders (44.8%). The survey showed that the musculoskeletal disorders are majority caused by prolong hours spent in certain postures or movements such as standing, sitting and bending.

Based on survey of Chee et al. (2004), wafer fabrication workers are particularly high risk in terms of high pain prevalence in the lower limbs (90.0% during wafer preparation) and low back (41.7% in wafer polishing process). In terms of molding process, 54.8% and 43.5% of workers had high pain prevalence in neck/shoulder and upper back respectively, which majority caused by frequent lifting. In terms of end-of line section workers had high pain prevalence in all parts of body, especially 62.2% of neck pain and 52.2% of upper back pain which caused by prolong sitting without back support.

In simple way, the main factors of musculoskeletal disorders which faced by semiconductor workers are prolonged of posture, motion (material handling and lifting) and environment (working place, noise, vibration). Thus, in this study, factors of award posture, motion (material handling and lifting), environment are been selected as causes of musculoskeletal disorders.

3.5 Data Collection Method

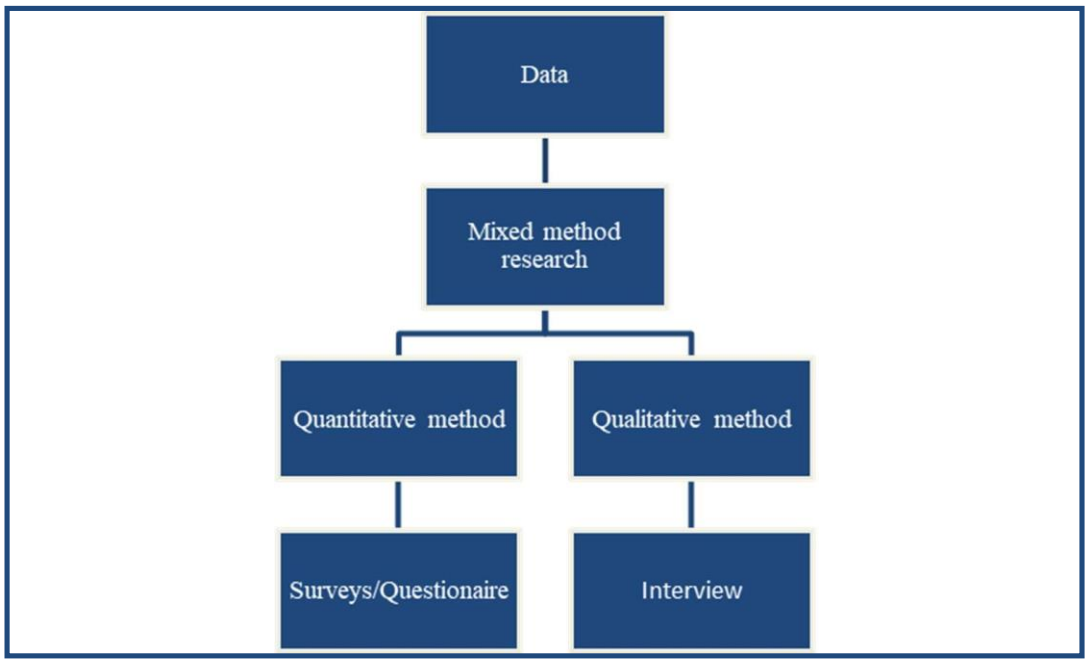

Figure 3.3: Data collection Method

Regarding this research study, both primary data and secondary were used to answer the research aim, objectives and questions. Primary data will provide the author with specific and up-to-date information on current state of ergonomic problems among workers in semiconductor industry. As most of the secondary data from literatures is readily available and inexpensive to obtain, it will help the author to identify the knowledge gaps in semiconductor industry. According to Gomez-Bull K.G. et al. (2015), questionnaire is one of the methods which can be applied by ergonomists and engineer for ergonomics evaluations. Thus, questionnaire has been chosen as a method for this research.

3.6 Data Analysis Method

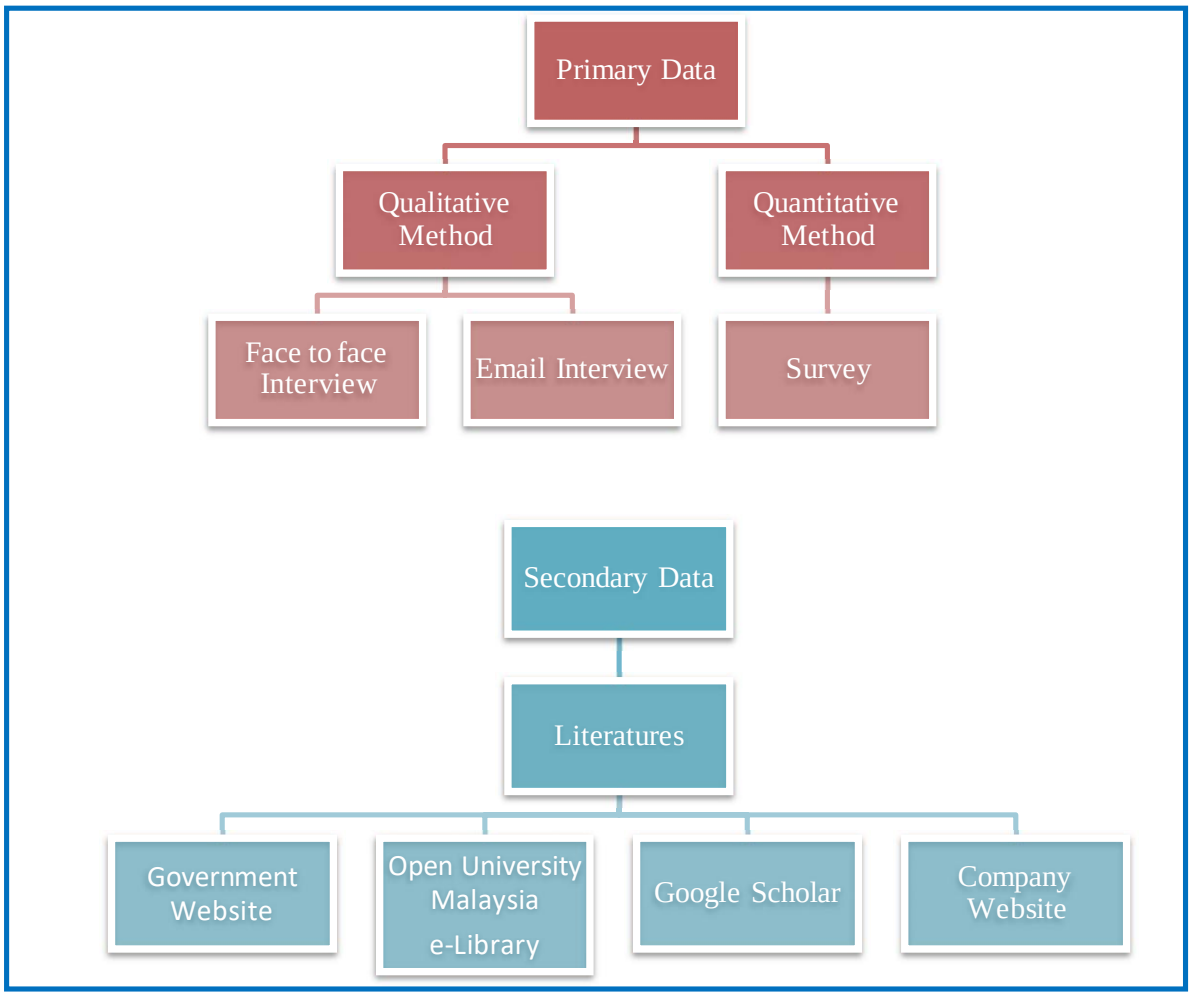

Figure 3.4: Data Analysis Method

a. Analyzing Quantitative Data

Descriptive analysis is used to identify the absolute number and summarize the individual variables.

i) Percentage: used to express how a value or group of respondents within the data relates to a larger group of respondents.

ii) Range: the highest and lowest value in a set of values.

b. Analyzing Qualitative Data

Narrative analysis is used to analyze content from various sources, such as interviewsof respondents, observations from the field and surveys.

Qualitative research and Quantitative research are chosen for this research. Qualitative research is the main exploratory research. It can use for acquiring compassionate of elemental

ideas, facts and motivations. It can also give understanding of the issues or helps to create an idea and hypothesis for probable quantitative research. Besides that, Qualitative research also applied for discover a direction in a though and views. The sample sizes are mostly small, and the respondents are selected to answer the provided survey.

Quantitative research is applied for evaluate the issues through the way such as create a numerical data, or a useable statistic convert from a data. It used to evaluate behavioral, views, attitudes and other specific variable, and then create results from large size sample of population. Quantitative research used measurable data to codify the facts and discover figure in a research. The methods that use for quantitative research is through different type of surveys such as in online, papers, phone and interview through face to face.

3.7 Reliability and Validity Issue

3.7.1 Primary Data

Primary data is mostly considered as a field research due to it is focused on the years and collection of raw data from a field of research or observation such as the data collected from the employees of an organization. So, it means the collected data are used for specific purpose. After the data has been obtained, it will be processed and pass on to make it available to another person as second information. The ways that use to obtain primary data can be interview, survey, meetings and in-depth research.

3.7.2 Secondary Data

Secondary Data is a data always knows as desk research that can be external or internal. The information is already existed around in the environment. It is only obtained for others purpose. The sources can be obtained from peer review, publicity or official websites, data from government agencies, radio, TV, internet.

Data Source	Data Credibility
Primary data - Survey	·Professional on floor who are currently working in semiconductor industry.
Primary data - Interview	·Professional on floor who have a minimum of 2 years working experience.
Secondary data - Literatures	·Peer reviewed, published or official websites

Figure 3.5: Reliability and Validity Issue

3.8 Implementation of Ergonomics

After data analysis and validation for identifying the factors which lead to bad ergonomics issue, implementation of ergonomics will be applied in terms of providing training and facilities upgrade. This is because according to previous studies, lack of training and facility issues are the factors which lead to bad ergonomics results Cecilia & Caroline (2017).

3.9 Data Re-Collection, Analysis and Validation

Data re-collection, analysis and validation is the repeated procedures as per discussed from "Data Collection Method" until "Reliability and Validity Issue" after implementation of ergonomics, for purpose of data comparison with pre-implementation. At the same time, the data comparison may lead to validate the effectiveness of implementation in terms of improvement of ergonomics issue.

3.10 Case Study

Observation method has been applied for data collection in this study. It uses the unsafe and risky action checklist form (Sulaiman 2013) on the semiconductor site. Observation technique is a method used to obtain information on safety and hazards that can bring ergonomics in semiconductors areas.

As discussed previously, different type of ergonomics risk factors (postures, motions, environment, equipment or tool) which applied in semiconductor industry activities and impacted body parts have been questionnaire of survey in this case study, as shown in Table 3.2.

For the purpose of assessing safety compliance aspects by workers at workplace, the non-secure and risky action checklist form is developed by researchers based on five types of hazard and items derived from the literature review are used for observation purposes. Below formula shows the calculation of percentage of safe observation.

$$\% \text{ Safe Observation } (\%) = \frac{\text{Total Safe Observation} \times 100\%}{\text{Total Safe Observation} + \text{Total Unsafe Observation}}$$

After completion of data analysis, implementation of ergonomics safety will be applied in terms of training provided and facility upgrades, by using period of 2 months. Then, one more survey will be provided for purpose of data comparison between prior andpost implementation of ergonomics.

Table 3.2: Unsafe Act Observation Check List (Sulaiman 2013)

No	Unsafe Act Observation Checklist for lab use	Safe	Unsafe
1	**Workplace**	**Yes**	**No**
	Is the leg/knee have clearance under worktable?		
	Is neck and shoulders relaxed when performing tasks?		
	Is worker comfortable without any pressure on body (wrists, forearms, back of thighs)?		
	Is furniture adjusted, positioned, and arranged to minimize strain		
	Is less than < 1 hour working in chemical room?		
2	**Material Handling & Lifting**		
	Does worker get someone's help when lifting heavy materials?		
	Is the work be performed without twisting or overly bending the lower back?		
	Is the weight of units carrying or lifting light?		
	Do you shorten levels arms to lift the things?		
3	**Tools and equipment**		
	Is tools light weight and well balanced?		
	Is anti-fatigue matting to be used when required to stand all day?		
	Is use adjustable stools to allow workers to rest?		
	Is your work have no highly repetitive motions and high hand forces?		
	Is workers have no high force, awkward postures, and repetitive motions in working?		
4	**Minimum Safety Requirements**		
	Is worker trained on safe lifting techniques, uses and carry devices working postures?		
	Is worker knowledgeable about ergonomics policies and procedures		
	Is worker feel free to report ergonomic symptoms or injured		
	Is rotation or bio breaks used to reduce time in awkward postures?		
	Is Wellnomics Workplace is installed on your computer?		
	TOTAL		

3.11 Limitation of the study

In this project, we have several limitations.

In the delivery of this study there are several constraints that can cause this study failed.The following are the constraints faced by the reviewer:

a) Lack of skill to conduct studies

b) Time constraint to review the study because the reviewer conducted the research at the same time

c) The inability to carry out a company study on the cause will affect the reputation of the company at the time of project carry out.

d) Researchers are unable to cooperate with responder accordingly during their studies, this attributed from workers who do not want to give feedback

e) Due to Malaysian Movement Control Order MCO, a lot of worker work from home, therefore the appointment cannot be carried out and social distancing as a precautionary measure against the prevention of coronavirus pandemic 2019 (COVID-19).

CHAPTER 4

DATA ANALYSIS AND RESULTS

4.1 Introduction

Findings from data analysis and study results will obtain test results as well as responses resulting from observations conducted at AA Lab. In addition, the analysis of the study is a detailed method performed with a combination of data that has been taken throughout the study. From the analysis of the collected data will be the result of the study from the study conducted. The aim of the study was to obtain any possible occurrences and identify the necessary safety aspects as well as employee problems that contributed to the accident.

This study was analyzed using a full observation process. The information is obtained through self-conducted observation methods according to formula Unsafe Act Observation Check List. The results of the observations and all the results obtained will be recorded and will be compared on the initial analysis and the results of the analysis.

After the security program is run. All recorded data will be stored and analyzed to obtain the results of a five-day study conducted at AA Lab. Employee safety awareness programs and activities are conducted to obtain the results of the study whether the program is successful or not. The results of these observations will be presented in the contents of this chapter.

4.2 Data Collection and Analysis (Pre-Implementation of Ergonomics)

4.2.1 Observation of Musculoskeletal Disorders

The final number of respondents in the survey within 5 days was 95. Overall, there were more than 50 % of respondents had issues of musculoskeletal disorders at any body parts. According to Table 4.1, neck pain was the highest (76.84%); followed by leg (65.26%), back [upper/lower] (61.05%) and hands (51.58%).

Table 4.1: Unsafe Act Observation Check List (musculoskeletal disorders)

Days	Day 1	Day 2	Day 3	Day 4	Day 5	Total	Percentage (%)
Number of Respondents	20	18	23	17	17	95	100%
Neck	15	13	18	14	13	73	76.84%
Hands	10	8	13	9	9	49	51.58%
Back (Upper/Lower)	12	11	14	10	11	58	61.05%
Leg	13	11	15	11	12	62	65.26%

4.2.2 Observation of Ergonomics Risk Factors

From Table 4.2 until Table 4.7 show the observation of ergonomics risk factors within 5 days. Overall, it can be observed that most of the respondents have low safety awareness since the percentage of safe act observation are less than 40% among 5 days.

Table 4.2: Unsafe Act Observation Check List from day 1 to day 5

No	Unsafe Act Observation Checklist for lab	Safe		Unsafe
1	**Workplace**			
	Is the leg/knee have clearance under worktable?	33		62
	Is neck and shoulders relaxed when performing tasks?	22		73
	Is worker comfortable without any pressure on body (wrists, forearms, back of thighs)?	38		57
	Is furniture adjusted, positioned, and arranged to minimize strain on body	48		47
	Is less than < 1 hour working in chemical room?	57		38
2	**Material Handling & Lifting**			
	Does worker get someone's help when lifting heavy materials?			
	Is the work be performed without twisting or overly bending the lower back?	31		64
	Is the weight of units carrying or lifting light?	31		64
	Do you shorten levels arms to lift the things?	42		53
3	**Tools and equipment**			
	Is tools light weight and well balanced?	31		64
	Is anti-fatigue matting to be used when required to stand all day?	32		63
	Is use adjustable stools to allow workers to rest?	37		58
	Is your work have no highly repetitive motions and high hand forces?	31		64
	Is workers have no high force, awkward postures, and repetitive motions in working?	41		54
4	**Minimum Safety Requirements**			
	Is worker trained on safe lifting techniques, uses and carry devices working postures?	27		68
	Is worker knowledgeable about ergonomics policies and procedures	31		64
	Is worker feel free to report ergonomic symptoms or injured	27		68
	Is rotation or bio breaks used to reduce time in awkward postures?	22		73
	Is Wellnomics Workplace is installed on your computer?	13		82
	Total	637		1168

$$\text{Percentage of Safe Observation (\%)} = \frac{\text{Total Safe Observation} \times 100\%}{\text{Total Safe Observation} + \text{Total Unsafe Observation}}$$

$$= \frac{637 \times 100\%}{637 + 1168} = 35.29\%$$

Table 4.3: Unsafe Act Observation Check List for day 1

No	Unsafe Act Observation Checklist for lab	Safe	Unsafe
1	**Workplace**		
	Is the leg/knee have clearance under worktable?	7	13
	Is neck and shoulders relaxed when performing tasks?	5	15
	Is worker comfortable without any pressure on body (wrists, forearms, back of thighs)?	8	12
	Is furniture adjusted, positioned, and arranged to minimize strain on body	10	10
	Is less than < 1 hour working in chemical room?	12	8
2	**Material Handling & Lifting**		
	Does worker get someone's help when lifting heavy materials?	7	13
	Is the work be performed without twisting or overly bending the lower back?	7	13
	Is the weight of units carrying or lifting light?	10	10
	Do you shorten levels arms to lift the things?	10	10
3	**Tools and equipment**		
	Is tools light weight and well balanced?	7	13
	Is anti-fatigue matting to be used when required to stand all day?	7	13
	Is use adjustable stools to allow workers to rest?	8	12
	Is your work have no highly repetitive motions and high hand forces?	7	13
	Is workers have no high force, awkward postures, and repetitive motions in working?	9	11
4	**Minimum Safety Requirements**		
	Is worker trained on safe lifting techniques, uses and carry devices working postures?	6	14
	Is worker knowledgeable about ergonomics policies and procedures	7	13
	Is worker feel free to report ergonomic symptoms or injured	6	14
	Is rotation or bio breaks used to reduce time in awkward postures?	5	15
	Is Wellnomics Workplace is installed on your computer?	3	17
	Total	141	239

$$\text{Percentage of Safe Observation (\%)} = \frac{\text{Total Safe Observation } \times 100\%}{\text{Total Safe Observation} + \text{Total Unsafe Observation}}$$

$$= \frac{141 \times 100\%}{141 + 239} = 37.11\%$$

Table 4.4: Unsafe Act Observation Check List for day 2

No	Unsafe Act Observation Checklist for lab use	Safe	Unsafe
1	**Workplace**		
	Is the leg/knee have clearance under worktable?	7	11
	Is neck and shoulders relaxed when performing tasks?	5	13
	Is worker comfortable without any pressure on body (wrists, forearms, back of thighs)?	8	10
	Is furniture adjusted, positioned, and arranged to minimize strain on body	10	8
	Is less than < 1 hour working in chemical room?	10	8
2	**Material Handling & Lifting**		
	Does worker get someone's help when lifting heavy materials?	7	11
	Is the work be performed without twisting or overly bending the lower back?	7	11
	Is the weight of units carrying or lifting light?	9	9
	Do you shorten levels arms to lift the things?	9	9
3	**Tools and equipment**		
	Is tools light weight and well balanced?	7	11
	Is anti-fatigue matting to be used when required to stand all day?	7	11
	Is use adjustable stools to allow workers to rest?	7	11
	Is your work have no highly repetitive motions and high hand forces?	7	11
	Is workers have no high force, awkward postures, and repetitive motions in working?	9	9
4	**Minimum Safety Requirements**		
	Is worker trained on safe lifting techniques, uses and carry devices working postures?	6	12
	Is worker knowledgeable about ergonomics policies and procedures	7	11
	Is worker feel free to report ergonomic symptoms or injured	6	12
	Is rotation or bio breaks used to reduce time in awkward postures?	5	13
	Is Wellnomics Workplace is installed on your computer?	3	15
	Total	136	206

$$\text{Percentage of Safe Observation (\%)} = \frac{\text{Total Safe Observation } \times 100\%}{\text{Total Safe Observation} + \text{Total Unsafe Observation}}$$

$$= \frac{136 \times 100\%}{136 + 206} = 33.75\%$$

Table 4.5: Unsafe Act Observation Check List for day 3

No	Unsafe Act Observation Checklist for lab use	Safe	Unsafe
1	**Workplace**		
	Is the leg/knee have clearance under worktable?	8	15
	Is neck and shoulders relaxed when performing tasks?	5	18
	Is worker comfortable without any pressure on body (wrists, forearms, back of thighs)?	9	14
	Is furniture adjusted, positioned, and arranged to minimize strain on body	11	12
	Is less than < 1 hour working in chemical room?	14	9
2	**Material Handling & Lifting**		
	Does worker get someone's help when lifting heavy materials?	7	16
	Is the work be performed without twisting or overly bending the lower back?	7	16
	Is the weight of units carrying or lifting light?	10	13
	Do you shorten levels arms to lift the things?	9	14
3	**Tools and equipment**		
	Is tools light weight and well balanced?	7	16
	Is anti-fatigue matting to be used when required to stand all day?	7	16
	Is use adjustable stools to allow workers to rest?	9	14
	Is your work have no highly repetitive motions and high hand forces?	7	16
	Is workers have no high force, awkward postures, and repetitive motions in working?	9	14
4	**Minimum Safety Requirements**		
	Is worker trained on safe lifting techniques, uses and carry devices working postures?	6	17
	Is worker knowledgeable about ergonomics policies and procedures	7	16
	Is worker feel free to report ergonomic symptoms or injured	6	17
	Is rotation or bio breaks used to reduce time in awkward postures?	5	18
	Is Wellnomics Workplace is installed on your computer?	3	20
	Total	146	291

$$\text{Percentage of Safe Observation (\%)} = \frac{\text{Total Safe Observation } \times 100\%}{\text{Total Safe Observation} + \text{Total Unsafe Observation}}$$

$$= \frac{146 \times 100\%}{146 + 291} = 33.41\%$$

Table 4.6: Unsafe Act Observation Check List for day 4

No	Unsafe Act Observation Checklist for lab use	Safe	Unsafe
1	**Workplace**	**Yes**	**No**
	Is the leg/knee have clearance under worktable?	6	11
	Is neck and shoulders relaxed when performing tasks?	3	14
	Is worker comfortable without any pressure on body (wrists, forearms, back of thighs)?	7	10
	Is furniture adjusted, positioned, and arranged to minimize strain on body	9	8
	Is less than < 1 hour working in chemical room?	10	7
2	**Material Handling & Lifting**		
	Does worker get someone's help when lifting heavy materials?	5	12
	Is the work be performed without twisting or overly bending the lower back?	5	12
	Is the weight of units carrying or lifting light?	7	10
	Do you shorten levels arms to lift the things?	7	10
3	**Tools and equipment**		
	Is tools light weight and well balanced?	5	12
	Is anti-fatigue matting to be used when required to stand all day?	6	11
	Is use adjustable stools to allow workers to rest?	7	10
	Is your work have no highly repetitive motions and high hand forces?	5	12
	Is workers have no high force, awkward postures, and repetitive motions in working?	7	10
4	**Minimum Safety Requirements**		
	Is worker trained on safe lifting techniques, uses and carry devices working postures?	5	12
	Is worker knowledgeable about ergonomics policies and procedures	5	12
	Is worker feel free to report ergonomic symptoms or injured	4	13
	Is rotation or bio breaks used to reduce time in awkward postures?	4	13
	Is Wellnomics Workplace is installed on your computer?	2	15
	Total	109	214

$$\text{Percentage of Safe Observation (\%)} = \frac{\text{Total Safe Observation} \times 100\%}{\text{Total Safe Observation} + \text{Total Unsafe Observation}}$$

$$= \frac{109 \times 100\%}{109 + 214} = 33.75\%$$

Table 4.7: Unsafe Act Observation Check List for day 5

No	Unsafe Act Observation Checklist for lab use	Safe	Unsafe
1	**Workplace**		
	Is the leg/knee have clearance under worktable?	5	12
	Is neck and shoulders relaxed when performing tasks?	4	13
	Is worker comfortable without any pressure on body (wrists, forearms, back of thighs)?	6	11
	Is furniture adjusted, positioned, and arranged to minimize strain on body	8	9
	Is less than < 1 hour working in chemical room?	11	6
2	**Material Handling & Lifting**		
	Does worker get someone's help when lifting heavy materials?	5	12
	Is the work be performed without twisting or overly bending the lower back?	5	12
	Is the weight of units carrying or lifting light?	7	10
	Do you shorten levels arms to lift the things?	7	10
3	**Tools and equipment**		
	Is tools light weight and well balanced?	5	12
	Is anti-fatigue matting to be used when required to stand all day?	5	12
	Is use adjustable stools to allow workers to rest?	6	11
	Is your work have no highly repetitive motions and high hand forces?	5	12
	Is workers have no high force, awkward postures, and repetitive motions in working?	7	10
4	**Minimum Safety Requirements**		
	Is worker trained on safe lifting techniques, uses and carry devices working postures?	4	13
	Is worker knowledgeable about ergonomics policies and procedures	5	12
	Is worker feel free to report ergonomic symptoms or injured	5	12
	Is rotation or bio breaks used to reduce time in awkward postures?	3	14
	Is Wellnomics Workplace is installed on your computer?	2	15
	Total	105	218

$$\text{Percentage of Safe Observation (\%)} = \frac{\text{Total Safe Observation} \times 100\%}{\text{Total Safe Observation} + \text{Total Unsafe Observation}}$$

$$= \frac{105 \times 100\%}{105 + 218} = 32.51\%$$

4.3 Reliability and Validity Issue (Pre-Implementation of Ergonomics)

The questionnaire survey results show that only less than 40% of respondents have a good awareness in terms of ergonomics safety. According to questionnaire which carried out by Shaliza et al. (2009), the evaluation showed that only 35.6% of respondents from manufacturing industry have adequate awareness in terms of ergonomics safety. On the other hand, according to Chee H.L. et al. (2004), neck pain has the highest prevalence (61.0%); while the lowest prevalence was arm pain. As per comparison between this research with previous studies, it can be concluded that the prevalence of musculoskeletal disorders is high while the awareness of ergonomics safety is low.

4.4 Implementation of Ergonomics

To overcome the situation of musculoskeletal disorders, there are several risk controls have been taken with conducting awareness campaigns and upgrading facilities based on concept of Hierarchy of Control (HoC) which developed by National Institute for Occupational Safety and Health (Liberati, 2018), as shown in Figure 4.1.

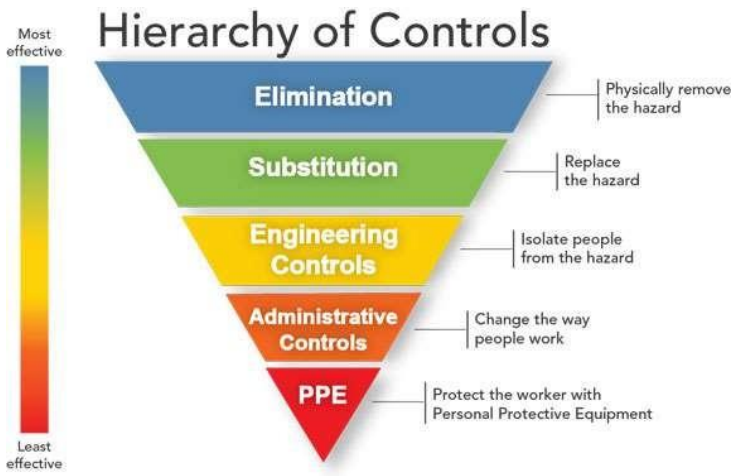

Figure 4.1: Hierarchy of Control (HoC)
(Sourced by: National Institute for Occupational Safety and Health)

This risk control means the process of identifying and implementing measures to reducing the risk of potential hazards in the form of injury or poor health to humans, property damage, environmental damage around or a combination of any such harm. Hazard identification is necessary performed in advance through risk assessment made for each work

that performed. Propose control measures should follow the control hierarchy so that it orderly and appropriate to the hazard for the type of measures to be taken to control the risk. According to Figure 4.1, elimination control is the most effective while Personal Protective Equipment is the least effective method in terms of risk control. However, according to Card et al (2012), only 3.3% of risk controls are classified as elimination control even it is the most effective and administrative control is the most common method applied in nature (78.0%). On the other way, based on the study of Liberati (2018), there are 42 action of risk controls for purpose of delivering safety of healthcare, there are only 3 type of actions have been taken based on HoC, which are substitution control, engineering control and administrative control, as shown in Figure 4.2.

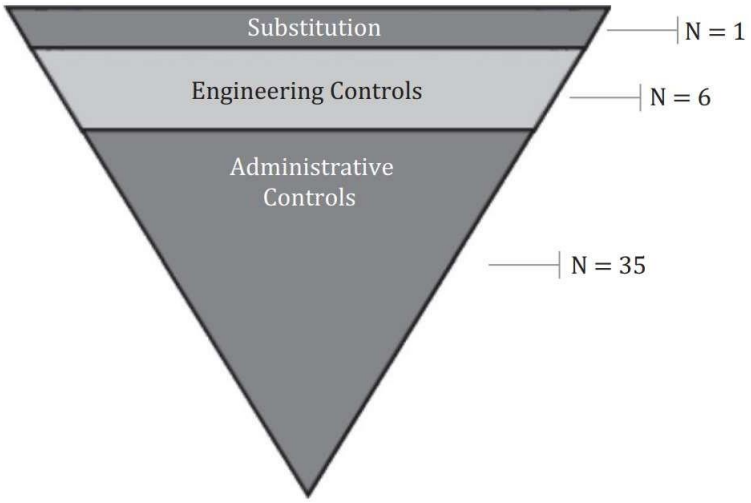

Figure 4.2: Distribution of Interventions Classified According to the NIOSH Hierarchy of Risk Controls (Sources by: Liberati; 2018)

Thus, as long as the safety of working culture or working place can be improved, it is available that only certain controls from HoC have been selected instead of fully applied all which as shown in Figure 4.4 even the risk control chosen in Figure 4.1 may not be the most effective. Since there has no hazardous equipment of materials in this research; at the same time, there has no any related to Personal Protective Equipment (PPE), thus, there are only 3 type of controls from HoC have been chosen, which are substitution, engineering control and administrative control, as shown in Figure 4.3.

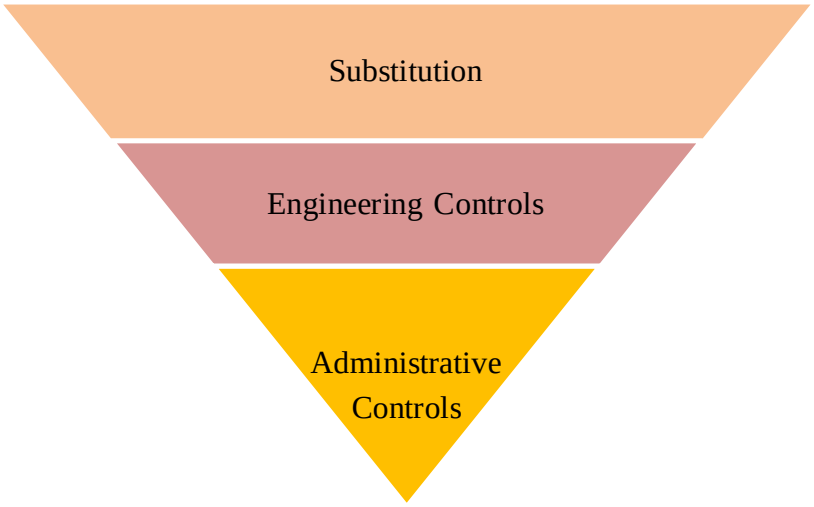

Figure 4.3: Distribution of Risk Control Applied Based on Hierarchy of Control

Overall, there are 7 actions have been implemented in this research which are usage of anti-fatigue mat, height adjustment chair, tool upgrade, working time control, provide training, buddy system and supervision, which have been classified in Table 4.8.

Table 4.8: Implementation of Actions Taken Based on Concept of HoC

Action Taken	Classification Based on HoC
Anti-Fatigue Mat	Substitution
Height Adjustment Chair	Engineering Control
Tools Upgrade	Engineering Control
Working Time Control	Administrative Control
Training	Administrative Control
Buddy System	Administrative Control
Supervision	Administrative Control

There are 4 actions are classified as “administrative control” (policies, regulations, standard operating procedure) (Card et al., 2012), which are working time control, training, buddy system and supervision. Working time controlled by management team because according to Bedi et al. (2015), long working hours may cause different part of body pains, especially in fixed postures. Thus, besides of limitation of working hours, small breaks are allowed for rest and recovery purpose. Then, According to Thiede & Thiede (2015), although

cost and time consumption is needed for training; however, it may lead to minimize the body impact and accident. At the same time, may help to reduce absenteeism either caused by injuries or body pain (Santos et al., 2013) and it may lead to a positive cost-benefit ratio (Taylor & Green, 2008). Moreover, according to Albrigtsen et al. (2015), instead of individual, buddy system is beneficial due to workload reduction between each other; at the same time, immediate safety attention and faster rescue can be carried out during emergency. Besides, a fair and transparency supervision is important because according to study of Masi et al. (2014), some interviewees underlined how often managers perceive safety "as a waste of time" if compared to production needs, thus hindering the improvement process. Another negative attitude is the reluctance to follow safety directives. Some of the senior managers were reluctant to follow the safety directives coming from younger managers, because these directives were perceived as disrespectful and as a way of denying the experience of senior managers. As a result, it may be a barrier for company or organization in terms of safety management and increasing ergonomic risks. Thus, besides of working time and workload control; at the same time, application of software such as Wellnomics can provide a better supervision. According to Taylor & Green (2008), a small rest break may help to reduce musculoskeletal disorders and improve productivity. Thus, a small paused by Wellnomics may stimulate workers to have a small rest and apply body stretching.

Figure 4.4 Safety Training

Figure 4.5 Safety Planning and discussion

There are 2 actions are classified as “engineering controls” (controlling human factors, tools) (Card et al., 2012), which are height adjustment chair and tool upgrade. According to Vledder & Louw (2015), vertical height adjustment chair may help to improve comfortable; at the same time, it may help to reduce upper quadrant musculoskeletal disorder such as neck pain. Besides of height adjustment chair, according to Gupta (2015), a combination of musculoskeletal disorders including neck, shoulders, wrists and back may be occurred during visual inspection by using microscope as figure 4.6. Thus, upgrade of microscope with connection of digital screen can help to minimize the usage of eyepieces which lead to minimize of head bent as showed figure 4.7. As a result, visual inspection can be done by using a proper sitting posture.

Figure 4.6: Visual Inspection using scope

Figure 4.7: Scope upgrade digital screen

There has only 1 action which classified as “substitution” (minimizing hazards once hazards cannot be eliminated) (Card et al., 2012), which is application of anti-fatigue mat showed Figure 4.9. According to research of Aghazadeh et al. (2015), musculoskeletal pain in terms of leg and lower back are common prevalence and significantly caused by prolonged standing position, especially in the region of industry workers and service workers. Based on the research by carrying out 2 hours standing, majority of participants are positive to application of anti-fatigue mat, due to stress reduction among body parts. The lower back and

leg pain have been significantly reduced; at the same time, most of the participants are able to stand with more than 2 hours without musculoskeletal pain on the surface of anti-fatigue mat.

Figure 4.8 Unsafety standing place

Figure 4.9 Anti-fatigue Mat

4.5 Data Re-Collection, Analysis and Validation (Post-Implementation of Ergonomics)

After the implementation of ergonomics within 2 months, the questionnaire has been carried out once again for comparison purpose between pre-implementation. Table 4.9 shows the total of respondents which impacted by musculoskeletal disorders while Table 4.10 until Table 4.15 show the data of safe act observation among 5 days.

Table 4.9: Unsafe Act Observation Check List for post implementation

Days	Day 1	Day 2	Day 3	Day 4	Day 5	Total	Percentage (%)
Number of Respondents	15	17	24	20	19	95	100%
Neck	9	11	16	12	11	59	62.11%
Hands	3	4	7	5	4	23	24.21%
Back (Upper/Lower)	5	6	4	6	5	26	27.37%
Leg	4	4	3	4	5	20	21.05%

Table 4.10: Unsafe Act Observation Check List from day 1 to day 5

No	Unsafe Act Observation Checklist for lab use	Safe	Unsafe
1	**Workplace**		
	Is the leg/knee have clearance under worktable?	73	22
	Is neck and shoulders relaxed when performing tasks?	36	59
	Is worker comfortable without any pressure on body (wrists, forearms, back of thighs)?	71	24
	Is furniture adjusted, positioned, and arranged to minimize strain on body	68	27
	Is less than < 1 hour working in chemical room?	59	36
2	**Material Handling & Lifting**		
	Does worker get someone's help when lifting heavy materials?	58	37
	Is the work be performed without twisting or overly bending the lower back?	71	24
	Is the weight of units carrying or lifting light?	49	46
	Do you shorten levels arms to lift the things?	49	46
3	**Tools and equipment**		
	Is tools light weight and well balanced?	47	48
	Is anti-fatigue matting to be used when required to stand all day?	73	22
	Is use adjustable stools to allow workers to rest?	32	63
	Is your work have no highly repetitive motions and high hand forces?	69	26
	Is workers have no high force, awkward postures, and repetitive motions in working?	55	40
4	**Minimum Safety Requirements**		
	Is worker trained on safe lifting techniques, uses and carry devices working postures?	74	21
	Is worker knowledgeable about ergonomics policies and procedures	69	26
	Is worker feel free to report ergonomic symptoms or injured	86	9
	Is rotation or bio breaks used to reduce time in awkward postures?	81	14
	Is Wellnomics Workplace is installed on your computer?	82	13
	Total	1202	603

$$\text{Percentage of Safe Observation (\%)} = \frac{\text{Total Safe Observation} \times 100\%}{\text{Total Safe Observation} + \text{Total Unsafe Observation}}$$

$$= \frac{1202 \times 100\%}{1202 + 603} = 66.59\%$$

Table 4.11: Unsafe Act Observation Check List for day 1

No	Unsafe Act Observation Checklist for lab use	Safe	Unsafe
1	**Workplace**		
	Is the leg/knee have clearance under worktable?	11	4
	Is neck and shoulders relaxed when performing tasks?	6	9
	Is worker comfortable without any pressure on body (wrists, forearms, back of thighs)?	11	4
	Is furniture adjusted, positioned, and arranged to minimize strain on body	11	4
	Is less than < 1 hour working in chemical room?	10	5
2	**Material Handling & Lifting**		
	Does worker get someone's help when lifting heavy materials?	9	6
	Is the work be performed without twisting or overly bending the lower back?	11	4
	Is the weight of units carrying or lifting light?	8	7
	Do you shorten levels arms to lift the things?	8	7
3	**Tools and equipment**		
	Is tools light weight and well balanced?	8	7
	Is anti-fatigue matting to be used when required to stand all day?	11	4
	Is use adjustable stools to allow workers to rest?	6	9
	Is your work have no highly repetitive motions and high hand forces?	12	3
	Is workers have no high force, awkward postures, and repetitive motions in working?	9	6
4	**Minimum Safety Requirements**		
	Is worker trained on safe lifting techniques, uses and carry devices working postures?	13	2
	Is worker knowledgeable about ergonomics policies and procedures	12	3
	Is worker feel free to report ergonomic symptoms or injured	14	1
	Is rotation or bio breaks used to reduce time in awkward postures?	13	2
	Is Wellnomics Workplace is installed on your computer?	13	2
	Total	196	89

$$\text{Percentage of Safe Observation (\%)} = \frac{\text{Total Safe Observation} \times 100\%}{\text{Total Safe Observation} + \text{Total Unsafe Observation}}$$

$$= \frac{196 \times 100\%}{196 + 89} = 68.77\%$$

Table 4.12 Unsafe Act Observation Check List for day 2

No	Unsafe Act Observation Checklist for lab	Safe	Unsafe
1	**Workplace**		
	Is the leg/knee have clearance under worktable?	13	4
	Is neck and shoulders relaxed when performing tasks?	6	11
	Is worker comfortable without any pressure on body (wrists, forearms, back of thighs)?	12	5
	Is furniture adjusted, positioned, and arranged to minimize strain on body	12	5
	Is less than < 1 hour working in chemical room?	10	7
2	**Material Handling & Lifting**		
	Does worker get someone's help when lifting heavy materials?	10	7
	Is the work be performed without twisting or overly bending the lower back?	12	5
	Is the weight of units carrying or lifting light?	8	9
	Do you shorten levels arms to lift the things?	8	9
3	**Tools and equipment**		
	Is tools light weight and well balanced?	8	9
	Is anti-fatigue matting to be used when required to stand all day?	13	4
	Is use adjustable stools to allow workers to rest?	6	11
	Is your work have no highly repetitive motions and high hand forces?	13	4
	Is workers have no high force, awkward postures, and repetitive motions in working?	10	7
4	**Minimum Safety Requirements**		
	Is worker trained on safe lifting techniques, uses and carry devices working postures?	14	3
	Is worker knowledgeable about ergonomics policies and procedures	13	4
	Is worker feel free to report ergonomic symptoms or injured	16	1
	Is rotation or bio breaks used to reduce time in awkward postures?	15	2
	Is Wellnomics Workplace is installed on your computer?	15	2
	Total	214	109

$$\text{Percentage of Safe Observation (\%)} = \frac{\text{Total Safe Observation} \times 100\%}{\text{Total Safe Observation} + \text{Total Unsafe Observation}}$$

$$= \frac{214 \times 100\%}{214 + 109} = 66.25\%$$

Table 4.13: Unsafe Act Observation Check List for day 3

No	Unsafe Act Observation Checklist for lab use	Safe	Unsafe
1	**Workplace**		
	Is the leg/knee have clearance under worktable?	19	5
	Is neck and shoulders relaxed when performing tasks?	8	16
	Is worker comfortable without any pressure on body (wrists, forearms, back of thighs)?	18	6
	Is furniture adjusted, positioned, and arranged to minimize strain on body	16	8
	Is less than < 1 hour working in chemical room?	14	10
2	**Material Handling & Lifting**		
	Does worker get someone's help when lifting heavy materials?	14	10
	Is the work be performed without twisting or overly bending the lower back?	18	6
	Is the weight of units carrying or lifting light?	12	12
	Do you shorten levels arms to lift the things?	12	12
3	**Tools and equipment**		
	Is tools light weight and well balanced?	11	13
	Is anti-fatigue matting to be used when required to stand all day?	19	5
	Is use adjustable stools to allow workers to rest?	8	16
	Is your work have no highly repetitive motions and high hand forces?	17	7
	Is workers have no high force, awkward postures, and repetitive motions in working?	15	9
4	**Minimum Safety Requirements**		
	Is worker trained on safe lifting techniques, uses and carry devices working postures?	18	6
	Is worker knowledgeable about ergonomics policies and procedures	17	7
	Is worker feel free to report ergonomic symptoms or injured	22	2
	Is rotation or bio breaks used to reduce time in awkward postures?	21	3
	Is Wellnomics Workplace is installed on your computer?	21	3
	Total	300	156

$$\text{Percentage of Safe Observation (\%)} = \frac{\text{Total Safe Observation} \times 100\%}{\text{Total Safe Observation} + \text{Total Unsafe Observation}}$$

$$= \frac{300 \times 100\%}{300 + 156} = 65.79\%$$

Table 4.14: Unsafe Act Observation Check List for day 4

No	Unsafe Act Observation Checklist for lab	Safe	Unsafe
1	**Workplace**		
	Is the leg/knee have clearance under worktable?	16	4
	Is neck and shoulders relaxed when performing tasks?	8	12
	Is worker comfortable without any pressure on body (wrists, forearms, back of thighs)?	15	5
	Is furniture adjusted, positioned, and arranged to minimize strain on body	15	5
	Is less than < 1 hour working in chemical room?	13	7
2	**Material Handling & Lifting**		
	Does worker get someone's help when lifting heavy materials?	13	7
	Is the work be performed without twisting or overly bending the lower back?	15	5
	Is the weight of units carrying or lifting light?	11	9
	Do you shorten levels arms to lift the things?	11	9
3	**Tools and equipment**		
	Is tools light weight and well balanced?	10	10
	Is anti-fatigue matting to be used when required to stand all day?	16	4
	Is use adjustable stools to allow workers to rest?	5	15
	Is your work have no highly repetitive motions and high hand forces?	12	8
	Is workers have no high force, awkward postures, and repetitive motions in working?	9	11
4	**Minimum Safety Requirements**		
	Is worker trained on safe lifting techniques, uses and carry devices working postures?	13	7
	Is worker knowledgeable about ergonomics policies and procedures	12	8
	Is worker feel free to report ergonomic symptoms or injured	15	5
	Is rotation or bio breaks used to reduce time in awkward postures?	15	5
	Is Wellnomics Workplace is installed on your computer?	17	3
	Total	241	139

$$\text{Percentage of Safe Observation (\%)} = \frac{\text{Total Safe Observation} \times 100\%}{\text{Total Safe Observation} + \text{Total Unsafe Observation}}$$

$$= \frac{241 \times 100\%}{241 + 139} = 63.42\%$$

Table 4.15: Unsafe Act Observation Check List for day 5

No	Unsafe Act Observation Checklist for lab use	Safe	Unsafe
1	**Workplace**		
	Is the leg/knee have clearance under worktable?	14	5
	Is neck and shoulders relaxed when performing tasks?	8	11
	Is worker comfortable without any pressure on body (wrists, forearms, back of thighs)?	15	4
	Is furniture adjusted, positioned, and arranged to minimize strain on body	14	5
	Is less than < 1 hour working in chemical room?	12	7
2	**Material Handling & Lifting**		
	Does worker get someone's help when lifting heavy materials?	12	7
	Is the work be performed without twisting or overly bending the lower back?	15	4
	Is the weight of units carrying or lifting light?	10	9
	Do you shorten levels arms to lift the things?	10	9
3	**Tools and equipment**		
	Is tools light weight and well balanced?	10	9
	Is anti-fatigue matting to be used when required to stand all day?	14	5
	Is use adjustable stools to allow workers to rest?	7	12
	Is your work have no highly repetitive motions and high hand forces?	15	4
	Is workers have no high force, awkward postures, and repetitive motions in working?	12	7
4	**Minimum Safety Requirements**		
	Is worker trained on safe lifting techniques, uses and carry devices working postures?	16	3
	Is worker knowledgeable about ergonomics policies and procedures	15	4
	Is worker feel free to report ergonomic symptoms or injured	19	0
	Is rotation or bio breaks used to reduce time in awkward postures?	17	2
	Is Wellnomics Workplace is installed on your computer?	16	3
	Total	251	110

$$\text{Percentage of Safe Observation (\%)} = \frac{\text{Total Safe Observation} \times 100\%}{\text{Total Safe Observation} + \text{Total Unsafe Observation}}$$

$$= \frac{251 \times 100\%}{251 + 110} = 69.53\%$$

According to Table 4.9, the highest prevalence was neck pain (62.11%); followed by back [upper/lower] (27.37%); hand (24.21%) and leg (21.05%). As summarized at table 4.16, besides of neck pain, it can be significantly showed that the prevalence of body pain has been reduced compare to pre-implementation (percentage of reduction more than 50%) (refer to Figure 4.10).

Table 4.16 Summary of implementation for Unsafe Act Observation Check List

Body Parts	Pre-Implementation	Post-Implementation	Percentage of Reduction (%)
Neck	73	59	19.18%
Hands	49	23	53.06%
Back (Upper/Lower)	58	26	55.17%
Leg	62	20	67.74%

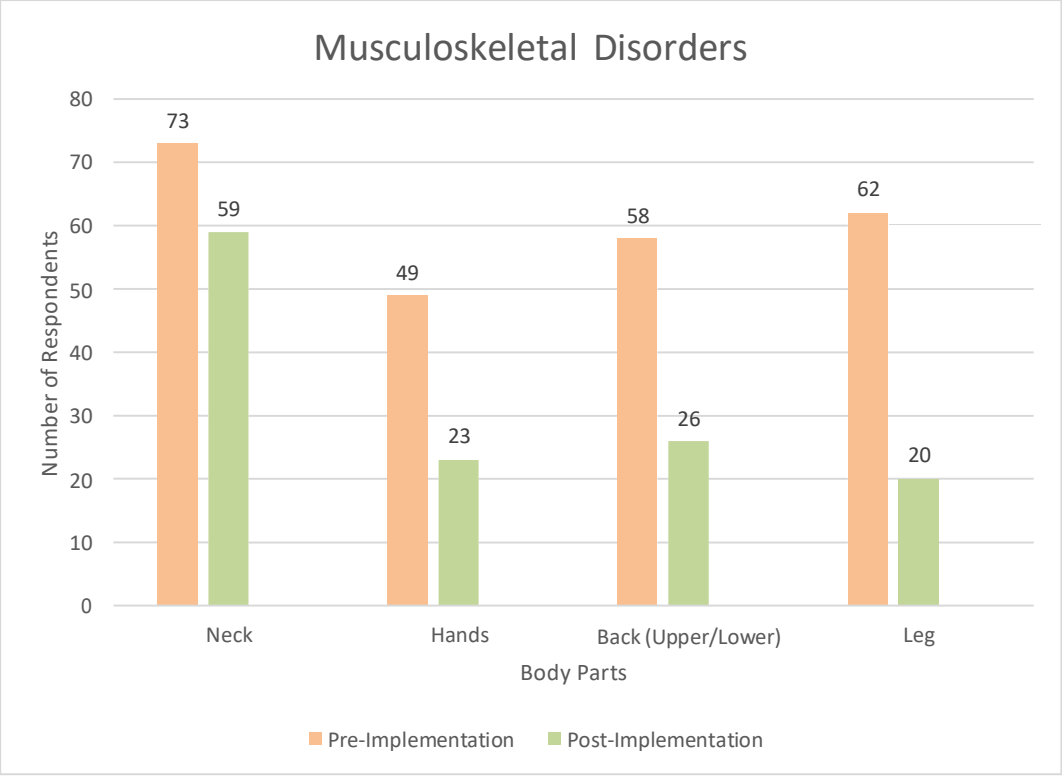

Figure 4.10: Percentage of Musculoskeletal Disorders between Pre- and Post-Implementation

Then, overall, the safe act observation among 5 days were more than 60% (refer to Table 4.10 until Table 4.15). As summarized at table 4.17, it can be observed that the safe act observation has been significantly increased among 5 days (refer to Figure 4.11). Thus, it can be concluded that the implementation of ergonomics safety has been improved the ergonomics issues significantly.

Table 4.17 Record safe act observation after conducted ergonomic campaign

	Day	1	2	3	4	5
Safe Act Observation	Pre-Implementation (%)	37.11	33.75	33.41	33.75	32.51
	Post- Implementation (%)	68.77	66.25	65.79	63.42	69.53

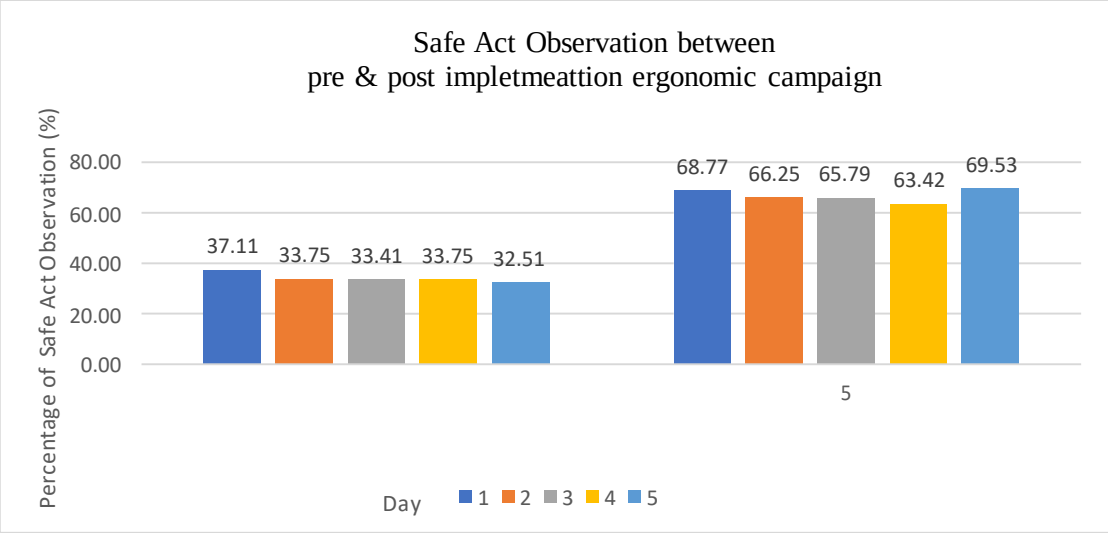

Figure 4.11: Percentage of Safe Act Observation between Pre- and Post-Implementation

CHAPTER 5

CONCLUSIONS

5.1. Introduction

This chapter is the last part of this study. The conclusions made will be covers the entire research that has been conducted and the findings of analysis of studies that have been made. Further study proposals are also submitted along with problems faced by researchers throughout this research period.

5.2 Summary of Findings

In this study, the ergonomics problems among semiconductor workers have been identified. Overall, the prevalence of musculoskeletal disorders is high at all parts of body, which impacts more than 50% of respondents in this research. Since prevalence of body pains may lead to negative effects such as physical health, low productivity and high absenteeism; thus, ergonomics of workers must be prioritized. According to survey carried out in this study, the main factor which lead to high prevalence of ergonomics problems is low awareness in terms of ergonomics safety. The survey in this research showed that less than 40% of respondents have adequate awareness among ergonomics safety.

To emphasize and improve these phenomena, implementation of ergonomics ergonomic awareness program has been carried out based on concept of Hierarchy of Control (HoC) (refer to Figure 4.3). Since there has no any related about hazardous equipment of material in this research and personal protective equipment (PPE); thus, instead of five, there are only three type of risk controls from HoC have been chosen in this research, which are substitution, engineering controls and administrative controls.

After implementation of ergonomics program within 2 months, the prevalence of musculoskeletal disorders has been significantly reduced. Besides of neck pain, the prevalence of body parts of hands, back (upper/lower) and leg have been reduced to less than 30%. At the same time, the awareness of respondents among ergonomic safety have been increased with more than 60%. Thus, it can be concluded that the factor which caused

high prevalence of workers have been identified and the ergonomic safety of workers has been improved significantly.

5.3 Discussion

However, at the end of the study, there was a strictly improvement courses and ergonomic awareness campaigns on safety were carried out after initial observation analysis, recorded awareness of safety relatively low. Therefore, activities on safety awareness at workplaces are launched on lab workers to ensure awareness of the dangers of performing assignments should be emphasized. Not only that the activities launched are safety courses and campaigns involving more than 90% of lab workers. Lab workers are rewarded such as recognition award certificates for employees who practice safety procedures certified by employers.

Our company safety and ergonomic practitioner always prioritizes and takes care of employees' safety and health. This is mostly in how consciously the company is managing ergonomic during the COVID-19 pandemic. Our management put in the effort to ensure the safety and well-being of the employees who are working from home while ensuring safety control measures are in place to protect the employees who are working on-site. also am thankful that our company adopts Wellnomics, a software that can help us achieve safe and healthy work habits, minimize the risks of musculoskeletal disorders (MSDs) and maximize productivity. And they also spotted an employee with ergonomic hazard and coached on how to use Wellnomics. Since then, the employee has been able to work comfortably and productively. We hope employees can all utilize Wellnomics to our benefit.

Lab Safety Message of The Week for Employee and monthly SMBWA in lab and Lab Face to Face Safety Quiz Program for selection employee. Beside that encourage regular and frequent ergonomic safety agenda item in organization meetings. (Ex. department meetings, staff meetings, etc.) Examples include reviewing ergonomic safety incidents at other site, ergonomic safety policies/changes to policy, unsafe acts reported, ergonomic safety audit results, and any other communication regarding ergonomic safety that they feel is necessary to promote an ergonomic safe environment. And also awarded to employees to uplift the spirit, safe work culture, and safe working environment among site workers.

Conduct ergonomic safety briefings to workers in lab on the hazards if the safety aspects are not emphasized. To ensure the explanation of this ergonomic safety aspect is progressing smoothly, a supervisor is assigned the responsibility to ensure that employees understand the ergonomic safety aspects highlighted. Requires employees to attend safety courses annually prior access approval to ensure that all employees attend the safety courses conducted by complete all required training within recommended time frame. Take appropriate action and report any potential ergonomic, hazards, issues, and near misses to their management or owner. Report injuries to your site nurse to ensure comply with all safety requirements and guidelines while working. Will participate in a safety orientation briefing (including ergonomic) and be assigned before receiving an entry access. Must use/provide and operate tools that meet all ergonomic requirements

5.4 Implication and Limitations of study

In this project, we have several limitations. The most problem we faced during the study was that research were less aware of what problem employee face in implementation ergonomics safety and health program on lab sites. Therefore, researchers conducted observations on the lab site to find out the problems and constraints faced. Not only that lack of skill to conduct studies. Time constraint to review the study because the reviewer conducted the research at the same time. The inability to carry out a company study on the cause will affect the reputation of the company at the time of project carry out. Researchers are unable to cooperate with responder accordingly during their studies, this attributed from workers who do not want to give feedback. Lack of respondents due to coronavirus 2019 pandemic (Covid-19), limitation of workers work-on-site caused limitation number of respondents. Reduction of neck pain prevalence is not significant compared with body parts of hands, back (upper/lower) and leg.

5.5 Recommendations for future research

Firstly, the more of involvement of respondents may help to increase the accuracy of survey analysis. Secondly, semiconductor is not the only industry which impacted by ergonomics risks; at the same time, this research can be applied in other sectors such as manufacturing and healthcare industries. Lastly, prevalence of neck pain is the highest from this research. Thus, more studies are needed to reduce the prevalence of neck pain in future.

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