

# **INVESTIGATION OF ERGONOMICS RISK FACTORS IN THE TYRE MANUFACTURING INDUSTRY**

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Master of Engineering in Manufacturing Systems Engineering

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Thesis / dissertation submitted in partial fulfillment of the requirements for the  
degree Master of Engineering in Mechanical Engineering

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**Declaration:**

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Date: 01/12/2022

Dr. H.K.G. Punchihewa

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Chamila Gamage

December 2022

## **Abstract**

Sri Lankan tyre manufacturing industries are a source of employment for many workers. The incentive production manufacturing system is operating in these industries, and inherited operating systems were used in the present to achieve the outcome. The workers in tyre manufacturing industries associate with job-relevant activities such as material unloading, rubber milling, bead making, calandering, tyre building, curing, and tyre inspection. Semi-automated machines and considerable manual operations have been involved in the manufacturing process, and therefore workers expose to risk of musculoskeletal disorders (MSDs). As a result of awkward posture, health risks are generated and muscles, nerves, tendons, and body structures are affected from that. This research study aimed to determine the prevalence of MSD and assess the ergonomic risk level of workers in the tyre manufacturing industry. Also, introduced the factors that can be used to reduce the risk level relevant to individual operations. In this research, a questionnaire survey was carried out to identify the ergonomic risk factors among workers in the tyre manufacturing industries. The Nordic Musculoskeletal Questionnaire (NMQ) was used in 16 activities covering 3349 workers in 10 different tyre manufacturing plants. Their tasks were also further observed. The survey also captured the discomfort of their body parts according to their job tasks. The Rapid Entire Body Assessment (REBA) analysis tool was used to analyse awkward postures. NMQ results demonstrate that the lower back, upper back, neck, and shoulders were at higher risk of MSD than other body regions. REBA scores behaved between seven and twelve. This analysis showed that job activities need to be restructured to be comfortable and safe for workers.

**Key words:** Musculoskeletal disorders (MSDs), NMQ, REBA (rapid entire body assessment), Tyre manufacturing

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## **1.0 INTRODUCTION**

This chapter gives an overview of the Sri Lankan tyre industry and describes the primary process used in tyre manufacturing. It covers all main process steps, and the chapter narrows it down to process ergonomics relevant to the manufacturing process. In addition, it describes the principles of ergonomics. This chapter further investigates the manufacturing process, and ergonomic issues that are relevant to tyre industries and awkward posture experienced during primary activities.

### **1.1 Background**

Rubber industries involve many activities during manufacturing, such as handling, processing, and storage [1]. In the South Asian region, the growth of rubber-related products manufacturing processes is higher than in other areas in the world [1]. The tyre is an essential rubber product globally because goods and passenger transport processes heavily depend on tyre. In Sri Lanka, tyre manufacturing industries operate under the Ministry of Industries. It is categorized under large-scale heavy industry [2]. The tyre industry sector is vibrant and plays an important role in the economy of Lanka [2]. In addition, it has become a key contributor to the Gross Domestic Product (GDP) and holds a considerable portion of the export market. In 2019, the tyre manufacturing sector contributed 1.2% to the GDP, employing more than 60,000 directly and indirectly [2].

The tyre manufacturing process includes direct human involvement required to achieve its output. Manufacturing plants have many types of heavy machinery and some types of automated machinery relevant to operations. Most heavy types of machinery involve basic manual procedures and manual handling processes. Machine operators are involved in various awkward postures in conducting their tasks. Raw material handling process, semi-finished goods preparation process, tyre building process, curing process, tyre inspection process, and finish goods handling process, all involve machinery and manual tasks.

According to an internal survey of a tyre manufacturing plant, most workers have back pain and shoulder pain, which have developed with time [3]. However, no one considers that this situation is relevant to their job. According to this survey, considering labour fluctuation, 99% received the voluntary retirement scheme pertinent to their medical condition. Most medically unfit workers have back and shoulder pain after continuously working for more than ten years. Most tyre manufacturing plants operate 24 hours with 12-hour shifts continuously on the same

task. Previous studies show that work-related musculoskeletal disorders are caused due to with repetitive motions for long hours. Overbending, lifting objects frequently, reaching using vibrating tools or equipment, and working with a continuous force mainly affect musculoskeletal disorders [3]. According to operations of manufacturing industries, involve overbending, continuously lifting weights, twisting, over-neck bending, non-standard foot working, reaching, and repetitive motion. These awkward postures mainly affect the nerves, muscles, tendons, joints, ligaments, and spinal discs.

Most tyre manufacturing plants do not encourage or allow awkward postures, although they do not have standard operations. They define all tasks as relevant considering their manufacturing operation and available resources. Then, workers are directly exposed to risky operations or awkward postures. Tyre manufacturing plants have many production cells that are different from each other. In addition, workers do not change their tasks outside the cell and, production cell operations are mostly repetitive, where repetitive work is carried out for 12 hours without any changes.

## **1.2 Ergonomic Principles**

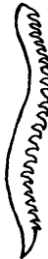
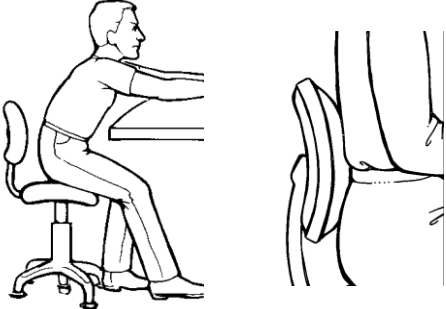
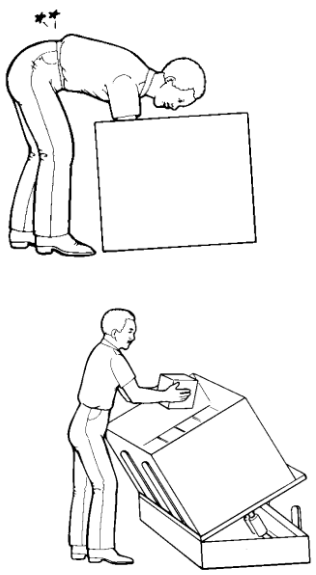
Ergonomic principles are mainly related to workers' work activities and movements. These principles guide, how they perform their tasks with optimum efficiency in a comfortable and safely. The safest working position is an 'In neutral' position of the body when performing work activities. Ergonomic principles are concepts that motivate workers in safer postures and behaviors to avoid ergonomic-related injuries such as musculoskeletal disorders (MSDs). The following are some of the 10 ergonomic principles the were discussed in relevant ergonomics [3].

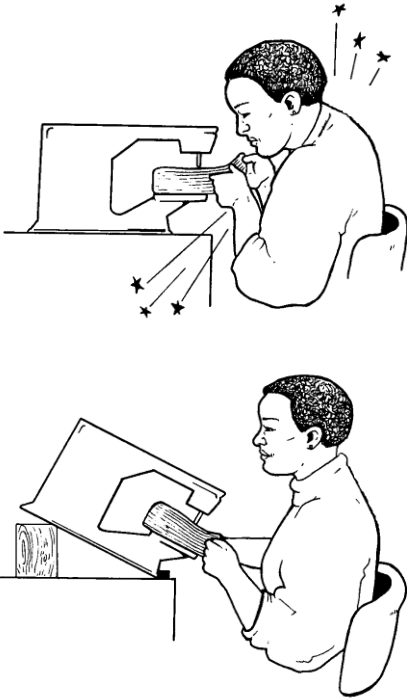
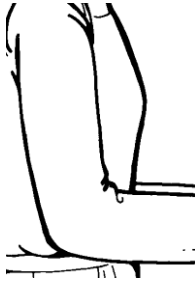
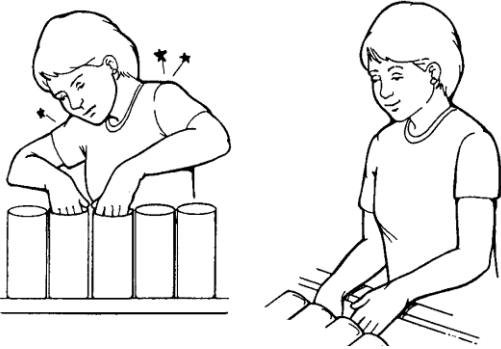
- Using body-neutral posture
- Job rotating or job task rotating avoids musculoskeletal disorders
- Using proper hand tools with a proper gripping mechanism
- Using standard or safe lifting/pulling/pushing/carrying procedures.

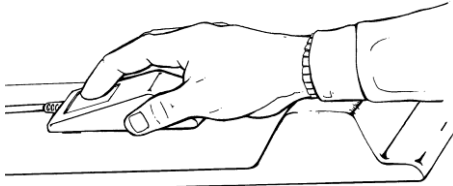
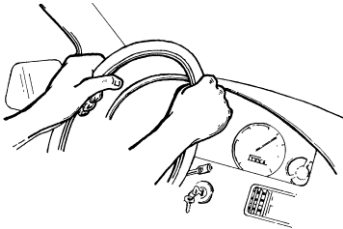
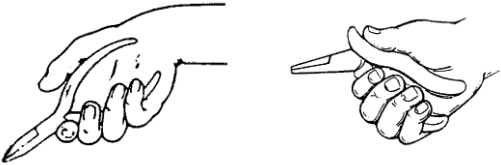
### **1. Work in a Neutral Position**

It's critical to maintain a neutral posture throughout the day whether a person is standing, sitting, or moving around. It's imperative to maintain the S-curve of a healthy spine while working to avoid strain on the human back.

Table 1-1: Neutral postures [4]

| Posture clarification                                                                                                                                                                                                                                                                                                                                                                               | Figure of posture                                                                    |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| <p>The human spine is the most valuable part of the body and is sustained as a 'S' curve.</p> <p>The human spinal shape behaves as closely to the letter "S."</p>                                                                                                                                                                                                                                   |    |
| <p>When sitting or standing, maintain the S curve in the back of the human body. When human standing position, place one foot up on a footrest, then spinal is maintaining proper alignment similar to S curve.</p>                                                                                                                                                                                 |    |
| <p>Long periods of time spent sitting in a chair while working will cause the worker's back to curve in a C shape, straining the spinal column.</p> <p>Comfortable lumbar support is often provided to maintain the correct shape of the spinal.</p>                                                                                                                                                |  |
| <p>The "reverse V-curve" creates even more significant tension at the back. When lifting weights, bending in this way puts a lot of strain on the spine.</p> <p>Considering the expected improvement, a lifting or tilting mechanism can be used to prevent spinal tension. Sometimes, depending on the task of the job, the lifting or tilting methods will be changed with the relevant jobs.</p> |  |

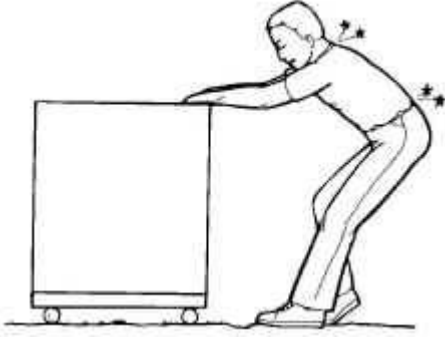
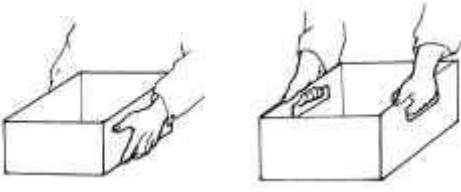
|                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                      |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| <p>Keep the neck aligned.</p> <p>The human neck bone is joined to the spine and is considered part of the spinal. It is supporting to maintain the S curve. Continuous neck bending posture can lead to stress, neck twisting which can be discomforting similarly back pain.</p> <p>Changing the object or equipment position and adjusting the equipment position for best way for neck posture, it will be corresponding to the neck neutral posture.</p> |    |
| <p>Keeping the elbows on the sides</p> <p>When workers are in a relaxed position, the shoulder should be in a relaxed position and arms and elbows on either side.</p>                                                                                                                                                                                                                                                                                       |  |
| <p>As in the provided figure, the worker is maintaining an uncomfortable posture. The shoulder is hunched and raising her elbows deviating from the neutral position of the hands, shoulder, and elbows in this posture. Also, the arms might get into a neutral posture when rearranging the workstation.</p> <p>According to right side figure, workstation has been modified for a relaxed position of the elbows and shoulders.</p>                      |  |

|                                                                                                                                                                                                                                                                                                                                          |                                                                                      |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| <p>Keep the wrists in neutral position</p> <p>When performing tasks using hands and wrists, the wrist should be maintained without bending or twisting. As given in the example figure, the computer mouse operator keeps his hand on the forehead to prevent wrist bending and is supported to keep the wrist in a neutral posture.</p> |    |
| <p>A slightly more accurate approach is to keep your hands more holding the steering wheel of your car at the 10 and 2 clock positions.</p>                                                                                                                                                                                              |   |
| <p>According to this example, different principles are used when designing the tools. Working with pliers can create considerable stress on the wrist as given in the diagram at the left. However, when used with an angled grip, the wrist can be kept in a neutral posture.</p>                                                       |  |

## 2. Reduce Excessive Force

The extreme forces acting on human body parts generate fatigue and will lead to a major failure of human joints. Humans should take steps to lessen the excessive forces to improvement their working postures.

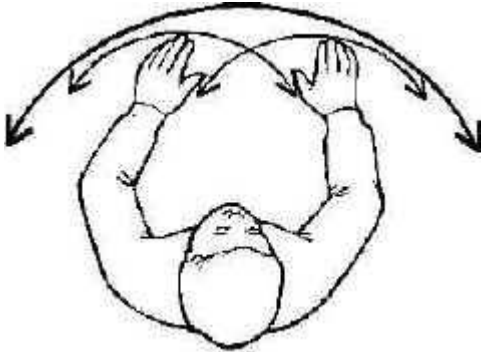
Table 1-2: Excessive force [4]

| Posture clarification                                                                                                                                                                                                                                                                                                                        | Figure of posture                                                                    |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| <p>Pulling motion generates excessive forces on the backside of the neck and the back when moving a manually operated heavy cart, as in the example given. In the improvement project, it should be ensured to create a smooth floor path and freely rotating wheels of cart. In addition, sufficient grip is required to move the foot.</p> |    |
| <p>Another example of power reduction is to use a crane to lift heavy objects, such as the vacuum crane, as shown in the picture.</p>                                                                                                                                                                                                        |   |
| <p>Another example is the holding position of containers or cartons. Compared to the holding posture in the leftmost figure, hand restraints on the rightmost figure minimize the strain on workers hands.</p>                                                                                                                               |  |
| <p>There are many examples for excessive force ergonomics, and it has a lot of information relevant to ergonomics. The important point is to identify excessive force activities and recognize suitable actions to reduce force.</p>                                                                                                         |                                                                                      |

### 3. Keep Everything Easy to Reach

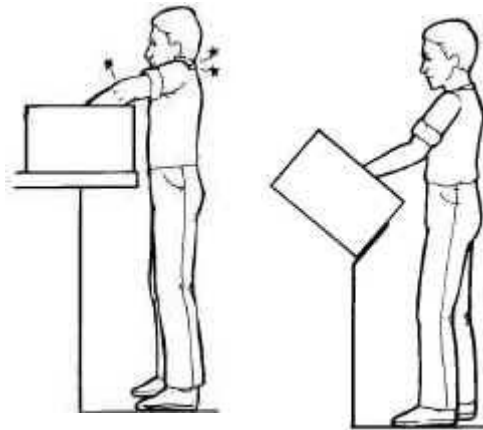
This principle is established to keep everything easily accessible in the area where the employee will be working. It facilitates minimizing pointless movements and preserving proper posture.

Table 1-3: Easily reach working posture [4]

| Posture clarification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Figure of posture                                                                    |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| <p><b>Reach Envelope</b></p> <p>This concept is highlighted as a "reach envelope." This covering area is like a semi-circle that a worker's arms can reach out. Things/ items that are frequently used should be kept within the reach envelope of worker arms. Objects or items that a worker uses less frequently are stored beyond the envelope of worker arms.</p>                                                                                                                                                         |    |
| <p>Many times, this issue is generated due to an uncomfortable reach. When designing the workstation and repositioning the object /item through simple changes, painful posture can be eliminated. This concept is not precisely a complex idea to hold; The hard part is that one should have the mindset to see and transform the position of the object that worker reaches most of time.</p> <p>Often, it is normal - the worker does not realize that the worker is constantly reaching for objects that may be close</p> |   |
| <p>In some situations, when the working area is too big, it produces some difficulties to reach across the objects when working with the workstation. As a solution, the working surface or area can be reduced. Another option is to make a cut-out such that the worker has sufficient space to handle objects.</p>                                                                                                                                                                                                          |  |

Another basic issue is to get an item from a container or a box. An excellent way to fix it is to make the container inclined.

Again, in a working situation, there are many other ways to minimize stretched reaches. There is a point to consider when a worker does stretch reaches, and the right-side picture shows the way to minimize the excessive reach by changing the orientation.

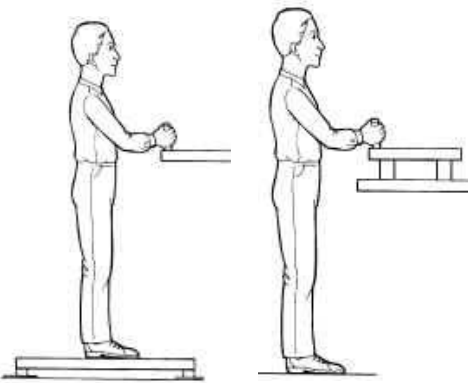


#### 4. Work at Proper Heights

Work surfaces that are too high or low can hurt your back, neck, and shoulders. Whether employees are in seated or standing positions, most of the routing work should be maintained in the correct position with elbow height.

Table 1-4: Proper working heights [4]

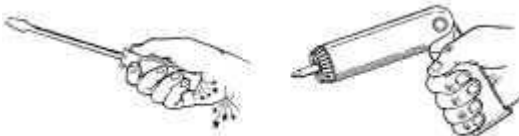
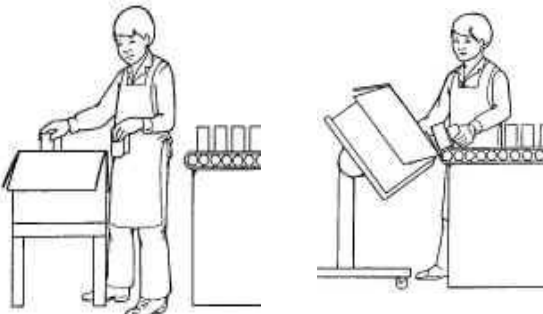
| Posture clarification                                                                                                                                                                                                                                                                             | Figure of posture |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|
| <p>Organize most human work to elbow height</p> <p>Most standard work is defined at elbow height and is effective for sitting and standing. This is a thumb rule.</p> <p>Computer keyboard operation is a good example for this principle. But this rule is applied for many other job tasks.</p> |                   |
| <p>Exceptions to the Rule</p> <p>However, this rule is excluded due to specific reasons where heavy work is carried out below elbow level. In addition to, precision or generally visual job tasks were performed above the elbow.</p>                                                            |                   |

|                                                                                                                                                                                               |                                                                                    |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
| <p>Sometimes the worker can change the height by outspreading the legs to a desk. The platform on the existing table for the operator's hand operating process can be used by the worker.</p> |  |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|

## 5. Reduce Unnecessary Motions.

Excess manual repetitions can lead to injury, so it is essential to think about the movements that workers repeat throughout the day and reduce excessive activity. Example, replacing the screwdriver with a drill will take the manual motion away rather than twisting the worker's wrist to turn a screwdriver.

Table 1-5: Unnecessary Motions [4]

| Posture clarification                                                                                                                                                                                                                      | Figure of posture                                                                    |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| <p>The easiest method is to always use the power tool instead of the manual tool when possible.</p>                                                                                                                                        |  |
| <p>Another method is to modify the layout of the machine or the equipment to reduce movements. As per the example, the box position is changed and is close to the machine. In addition, the box is tilted for easy packing operation.</p> |  |

|                                                                                                                                                                                                                                                         |                                                                                    |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
| <p>The item or product may occasionally be moved while we're working along uneven surfaces or some step-up points. When designing the material path, the above type points (irregular surface and step-up point) should be eliminated from the way.</p> |  |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|

## 6. Minimize Fatigue and Static Load

When working for a longer time with hand-held tools, the static load acting on the hand can cause discomfort or fatigue of the hand, it can be affecting their work.

Table 1-6: Fatigue and static load behavior [4]

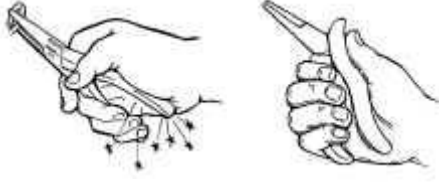
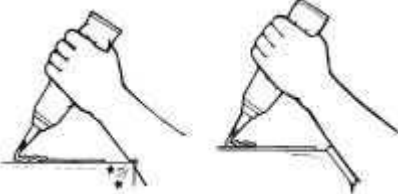
| Posture clarification                                                                                                                                                                                                             | Figure of posture                                                                    |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| <p>The most relevant case of the static burden that every person experiences are the writer's pain. The writer does not hold the pencil tightly for a long period. Although the writing muscles are feeling pain and fatigue.</p> |  |
| <p>In the workplace, continuous use of tools and holding the part by hand may induce static load, resulting in pain.</p> <p>In this application, the fixture can be used to hold the part and reduce the load on the hand.</p>    |  |

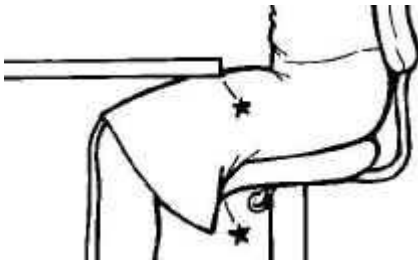
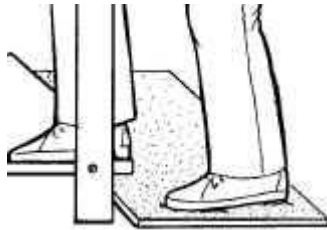
|                                                                                                                                                                                                                                                                                                  |                                                                                    |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
| <p>Holding the worker hands up for considerable time is another typical example of static loading. In that period, the force affects the muscles of the shoulders. The worker can avoid this pain by switching positions at work, and they can also use a tool extension to reduce the pain.</p> |  |
| <p>When standing for a long time, static load may affect the legs. Adding footrest allows one to reposition the legs, and it supports to standing without pain.</p>                                                                                                                              |  |

## 7. Minimize Pressure Points

Contact tension occurs when a tool or surface is in regular contact with the same area of human body. Pressure points are the areas of contacts which can cause discomfort.

Table 1-7: Pressure points [4]

| Posture clarification                                                                                                                                                                  | Figure of posture                                                                    |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| <p>Squeezing hard tool is the best example, for a pair of pliers. Fixing a stretchy grip to handles that take the shape of the hand can eliminate the originating pressure points.</p> |  |
| <p>The tilt of the worker's forearms against the sharp edges of the desk creates pressure points. Rounding or removing sharp edges may reduce pressure force.</p>                      |  |

|                                                                                                                                                                                                                                                                                                                                       |                                                                                    |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
| <p>Anyone sitting at a table with a cushioned chair should be aware of all pressure point information.</p> <p>The most painful spot is located behind the knees of his/her legs when he/she is sitting. The main reason for that is the elevated height of the chair.</p>                                                             |  |
| <p>A considerable amount of indirect pressure points will arise when a person is standing on a hard floor like a concrete floor. Your feet and heels may hurt, and in a matter of minutes, your entire leg may start to feel tired. To eliminate the problem, antifatigue material or special design soles can be used for shoes.</p> |  |

## 8. Provide Clearance

The concept of providing clearance is important for a comfortable work environment. Therefore, a comfortable environment should be considered when designing the workplace.

Table 1-8: Clearance for working area [4]

| Posture clarification                                                                                                                                                                                                                                                                                                                                                        | Figure of posture                                                                    |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| <p>When designing the work area, the room space should be sufficient for the task of the employee. Head, knees, and feet clearance and movement space facilitate easy working operation. A person should not store everything in a way that disturbs his work. If there is not enough space for feet or knees and confusing posture, it can be eliminated for safe work.</p> |  |

|                                                                                                                                                                                                                     |                                                                                    |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
| <p>Considering another version of the above principle is to provide visibility of the path. As an example, when carrying a material cart, the operator view should not be blocked by loaded equipment or items.</p> |  |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|

## 9. Move, Exercise, and Stretch

Exercise and stretching help to maintain the healthy human body

Table 1-9: Exercise and stretch [4]

| Posture clarification                                                                                                                                                                                                                                                                                                                                                                                    | Figure of posture                                                                    |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| <p>After learning about repetition, force and correcting awkward posture, the worker should not believe that it is healthy to press keys all the time. The muscles also need to be loaded, and the heart rate should be checked periodically.</p>                                                                                                                                                        |   |
| <p>Different exercises can be done to ease the pain associated with various types of work.</p> <ul style="list-style-type: none"> <li>• If the worker has performed a physically difficult job, he may want to rest or warm up before any other difficult task.</li> <li>• If worker doing a sedentary job task, he may need to get a quick break mostly so frequently to take few stretches.</li> </ul> |  |

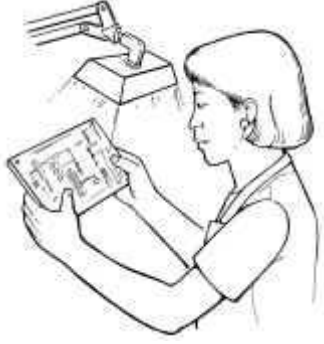
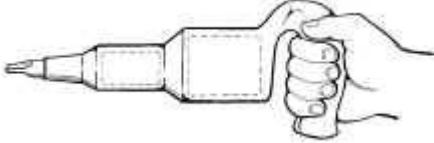
|                                                                                                                                                                                                                                                                           |                                                                                     |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| <p>You might need to adjust your posture if you must sit for an extended period.</p> <ul style="list-style-type: none"> <li>• Change the worker seat position as up and down time to time within day.</li> <li>• Move, stretch, and vary positions frequently.</li> </ul> |   |
| <p>Depending on some job functions, it may be preferable if he/she can alternate between sitting and standing during the day. In customer service center, their desk and chair can be moved up and down depending on their purpose.</p>                                   |  |

## 10. Sustain a Comfortable Environment

This ergonomic principle is very important due to the mainly effect on the physical and mental health of workers and depends on the existing environmental conditions.

Table 1-10: Comfortable environment [4]

| Posture clarification                                                                                                                                                                                                                                                    | Figure of posture                                                                    |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| <p><b>Lighting and Glare</b></p> <p>Lighting is a common issue in an office. When using the computer in the office, lighting is a big issue due to the reflection of rays. The reflection of light from a shiny screen can make the computer operator uncomfortable.</p> |  |

|                                                                                                                                                                                                                                                         |                                                                                    |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
| <p>Low light levels affect many tasks at work. Due to poor lighting, the operator's own shadow will directly affect their visibility.</p> <p>As a solution to this issue, the worker can use an object or job focus light to gain sufficient light.</p> |  |
| <p style="text-align: center;">Vibration</p> <p>Vibration is mainly affected by the human body when using vibrating power tools. According to the evaluation, the vibration level can be reduced of a vibrating tool.</p>                               |  |

### 1.3 Identification of Problems

The tyre manufacturing process is semi-automated, its main activities are operated with direct human involvement, and the workers' ages vary between 20 and 50 years. These industries have many activities without proper ergonomic evaluation, although workers try to do their job tasks with maximum efficiency. Considering most activities, over bending, continuously lifting weight, twisting, over-neck bending, non-standard foot working, reaching, and repetitive motion are commonly used in the tyre manufacturing industries, and they have not studied the risk of the above activities and awkward postures. When constantly working in awkward postures, workers experience back pain, shoulder pain, and neck pain throughout their work tasks.

According to the literature review, most ergonomic research had been relevant to various industries. However, the tyre industries have not conducted a thorough investigation relevant to all tasks in their investigations. However, some tyre industries have taken some steps to reduce ergonomic problems without proper analysis due to complaints of discomfort. According to literary criticism, there is a gap in the current literature review of the ergonomic study in the tyre manufacturing industry. Therefore, there is an opportunity to study the

prevalence of MSDs and assess ergonomic risk factors relevant to the overall process in the tyre manufacturing industries.

#### **1.4 Aim and Objectives**

- Identify the prevalence of MSD in the tyre manufacturing industry
- To assess the musculoskeletal discomfort of employees in the tyre manufacturing industry
- To evaluate ergonomic risk factors in the tyre manufacturing industry.
- Introduce methods to reduce the risk level in the tyre manufacturing industry

#### **1.5 Summary**

According to the main objectives of the research, all tyre manufacturing processes are included in the research scope, excluding solid tyre manufacturing due to the different processes, but the most important processes are covered in the pneumatic tyre manufacturing process. Within this research, all manufacturing operations were covered from raw material stores to finished goods warehouses. The selected samples covered the required functions of all processes in tyre manufacturing. This research is relevant to male workers because approximately 98% of male workers work in Sri Lankan tyre manufacturing plants.

Relevant to the Musculoskeletal Concerns Survey through the NMQ, issues generated by workers or job tasks can be identified by investigating the survey results. The REBA calculation can then be used for the risk factor identification process of the tyre manufacturing industry. This process will explore the required tasks through REBA, and each activity level is not required to be validated by REBA. NMQ survey design, sample selection, data collection, data analysis, and actions recommendation process are included in research, and implementation is not considered.

## **2.0 LITERATURE REVIEW**

### **2.1 Ergonomics**

At the time of the 19th centennial, psychology appeared as a science, concentrating on designing cognitive and psychometric ideas to understand how the mortal brainiac interacted with its surroundings. In the twentieth centennial, a confluence of initiative and support for office- related work led to the creation of a subdivision of psychology, the application of academic sciences to the used field of ergonomics in Europe, and the anthropological psychology of the United States in 2001 [5]. The subdiscipline concentrates on the individual as the middle of a plan to emphasize and improve safety and user pleasure [5]. Some claim that ergonomics is not identical to user-friendly systems but a subfield of human elements. The distinction, if any, claims that user-friendly designs have psychological motivation, positioning a more significant focus on understanding. In recognition, ergonomics emanated from industrial engineering, concentrating better on the workplace and human fit [5][6].

Ergonomics studies the interaction between people and machines and the factors that affect the interaction [6]. The main focus of ergonomics is to improve the overall performance of a system by improving human-machine interaction. In the discipline of ergonomics, system performance is enhanced by incorporating knowledge and experience from different disciplines; physiology, psychology, anthropology, applied medical science, mathematics, and engineering [5].

The word ergonomics is derived from the Greek words “*ergon*”, which means work, and “*nomos*”, which means law. The term was initially coined by the Polish scholar Wojciech Jastrzebowski in 1857 and was later reinvented by KFH Murrell in late 1949 [5]. The seeds of applying ergonomic principles can be traced back to the dawn of human evolution. However, the development of ergonomics as organized science gained momentum during World War II. Many classic examples can be found where the principles of ergonomics are used to minimize human error or to improve human-machine interaction during World War II [7]. Furthermore, after the world war, the science of modern ergonomics flourished with its incorporation into every aspect of engineering designs, from factory layouts and consumer products to even software or website interface design.

In the field of ergonomics, humans are treated as the most important component of system design, and the fact that systems are meant for the benefit of people [5] [7]. Therefore, the human aspect must be fully integrated into the system from the initial design stage [6]. An ergonomically designed work environment will minimize unsafe, unhealthy, and inefficient

working conditions. When considering people in the design process, it should be understood that people are different. Depending on the factors such as physique, intellect, gender, age, and culture, people have different physical and psychological requirements. Ignoring these needs will often lead to costly outcomes in money, human discomfort, and health [5]. However, it may not be practically viable to cater to all human requirements when designing work environments or consumer products. But care should be taken to identify and cater to the target group's needs.

Modern ergonomics focuses on improving four aspects of a product or a work environment; reducing errors, increasing productivity, improving safety, and improving comfort [7]. Ergonomics research is divided into three sections; physical, cognitive, and organizational ergonomics [5]. Physical ergonomics considers human anatomy, anthropometry, physiology, and biomechanics. Cognitive ergonomics deals with mental processes related to activities. These mental processes include human perception, memory, reasoning, and responses. Organizational ergonomics optimize sociotechnical systems that include organizational structures, policies, and processes [5]. Hereafter, emphasis will be given to ergonomics related to the workplace environment.

The tyre manufacturing industry in Sri Lanka consists mainly of semi-automated and labor-intensive processes. In these tasks, workers are required to lift and lower heavy or moderately heavy objects repeatedly during their work shifts. These repetitive tasks combined with difficult postures can cause Musculoskeletal Disorder (MSD). According to [8], MSDs are injuries or disorders of muscles, nerves, tendons, joints, cartilage, and spinal discs. In addition, vibration, noise, and heat emitted in the tyre manufacturing process can exacerbate the effects. The literature on the effects of poor ergonomics in the tyre manufacturing industry is limited to the author's knowledge. However, a study conducted by a group of Malaysian researchers found a high level of risk of MSD among workers in tyre manufacturing plant [9]. Therefore, it was required to have a proper evaluation of the risk associated with ergonomics of workers. Identifying and treating such effects will help to improve overall product performance and to uplift workers physically and psychologically.

## **2.2 Understanding the Burden of Musculoskeletal Conditions**

Musculoskeletal diseases have a massive and extending effect around the world. "Health 21," The World Health Organization (WHO) recognizes health and muscle mass as a target for all policy frameworks for the European region. However, the federal fitness maintenance selection

process was not covered by many European countries and the United Kingdom. To speak of this inequality, the United Nations, the WHO, administrations, and experienced and patient organizations have declared in 2000 10th "bone and joint decade" to improve people's health-related energy grades with musculoskeletal diseases [10].

Although one of the decades aims to enhance the assent and wisdom of the discomfort posture considered by musculoskeletal effect and was shown through the past research data relevant to issues. Musculoskeletal conditions are the top established diseases in the United States [10]. Two out of four surveys in less developed and more developed countries report chronic and chronic muscle pain. Musculoskeletal trouble was the costliest type of condition in Swedish cost of sickness acquaintance; also, 22.6 % cost is considered, it is the total cost relevant to illness [10]. Calculated in terms of disability-adjusted life years (DALYs), osteo- arthritis is the 4th most regularly anticipated reason for fitness cases worldwide in females and men. Rheumatoid arthritis limits the ability of one-third of people to work in the first year [10]. Fractures associated with osteoporosis occur in approximately 40% of all white women over the age of 50 years. The 1-year broad range of low back pain in the UK is almost 50%, 23-24 million people are injured worldwide each year in road traffic accidents and was responsible for 11 million man-days lost in the UK in 1995 [10]. But 5% or less of the costs of National Research Councils are earmarked for muscle and bone conditions in established market principles of finance. Occurrences and outbreaks are large or small and significant in a large area globally. However, epidemiological learning in less developed countries shows that musculoskeletal action is just as extensive as in more developed countries [10]. The impact of musculoskeletal conditions and trauma varies between different regions of the world and is influenced by social structure, anticipation, and economics. However, the burden is increasing with the development of inhabitants, increased longevity, urbanization, and increased use of cars [10].

Why minimize the extent of musculoskeletal disorders? Is it because they are rarely fatal, deemed irreversible, and associated with age? It offers adults a high value for supporting freedom and grace, and there are now preventive measures and practical therapies that can significantly cure muscle diseases. However, the present common usage of hip and knee arthroplasty reflects the lack of knowledge, harmful spirits, and shared anticipations surrounding these situations [10]. The primary goal of the Bone and Arthritis Decade is to provide information on the burden exerted by musculoskeletal disorders to inform discussions of choices and approaches in association with the WHO Global Burden of Disease 2000 project

[10]. In addition, the definition of strategies to count and watch these situations predicts trends and allows analysis and effect, exercise, and investment planning for healthcare.

A current WHO technical level session supposed pain, mobility, and freedom are the considerably applicable parts for musculoskeletal diseases. It recognized the need for additional detailed tools to monitor these elements. The conference expressed the first stage of an international health requirements review training for musculoskeletal diseases, bone, and joint monitoring tasks, seeking to establish what can be accomplished with opportune evidence-based strategies to ease the burden [10] [11]. Realizing the responsibility of musculoskeletal conditions will provide a greater understanding of their widespread impacts on people and their costs to the community. Estimating the responsibility should ensure that they obtain higher stress in fitness systems. The agreed-upon indicators will allow these needs to be observed and interventions considered. In these ways, comprehending responsibility will eventually enhance the work of people [10].

## **2.3 Posture Analysis**

### **2.3.1 Awkward postures**

The embarrassing situation is shown by a body position unfamiliar or difficult to achieve in the human body. However, this awkward situation causes pressure on the human body's muscles, resulting in distress that results in exhaustion and damage. The case of fitness due to an uncomfortable situation is expected, particularly among employees of the fatty initiative, including the automated mass manufacturing company. This awkward stance affects the employee's version, particularly affecting the enterprise. This issue is mainly related to the workstation configuration, which is not ergonomically created. Ergonomics is human-interposed and focuses on evaluating the effectiveness and version of the task of the job when a user interacts with complicated systems, which is performed using a task research process [6]. Ergonomics is also a study or movement planned to investigate and unravel the damage to humans due to operational issues. Similarly, ergonomics is a constant improvement action to create, design changes, and possible modifications to the layout of a cell or the existing workplace. Ergonomics defects policies are derivative of casualty information, which typically names workers as direct reasons for the disaster. The most significant reason for casualties is identified as non-standard workstations with psychophysical issues of workers [11] [12].

Further ergonomics problems relate to human body posture, and ergonomics-related situations, a nuanced analysis of the employee's or human's body stance is essential to get a comfortable workstation. Unsightly human body posture can lead to danger and damage. Previous examinations showed that operating with the arrows outside the shoulders or employing redundant activities and awkward posture related to shoulder and channel discomfort, rotator cuff syndrome, and epicondylitis [5]. In addition to the above, the below points can be considered as threats to ergonomics.

- Perform vibration tasks.
- Over time sitting and overbending
- A prolonged sitting place without support.
- Repetitive task with non-standard posture
- Regular lifting action.
- Staying with an uncomfortable posture.

Additionally, shoulder and channel pain were associated with extreme spread [5] [13].

This scheme surrounded the study of ergonomic-related risk, material-implied uncomfortable posture estimation, and simulation analyses. This task can seriously support employees and enterprises where the health of employees related to work could be improved and prevent any occupational damages. According to previous research, workers could understand ergonomic-related studies to strengthen the community during work and before starting their tasks.

### **2.3.2 Extreme postures**

Hard posture can be observed when the joints are not in impartial functions. The following list supplies uncomfortable postures that may affect the scope of action near extreme cases.

- Neck forward - Over 30 degrees bending
- Lifting the elbow above shoulder height
- Wrist movement downward – above 30 degrees
- Back forward bending - above 45 degrees
- Squatting

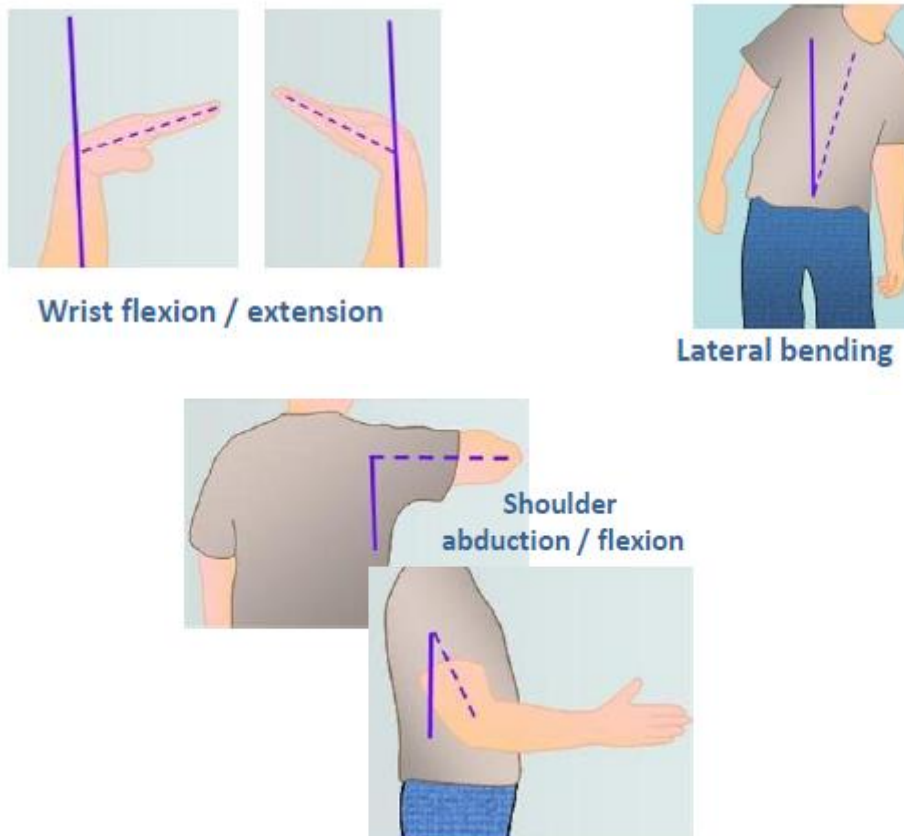


Figure 2-1: Awkward postures of upper body parts [10]

Further joint poses, not necessarily applying excessive activity, are associated with the discomfort of MSDs. These points are mentioned as follows.

- Twisting movement of the trunk
- Bending to either side -trunk, neck
- Turning – forearm and head
- Backward bending - neck
- Bending upward or downward, the wrist and palm maintain the facing downward
- Kneeling

Other awkward postures are caused by the body's orientation to the significance and do not certainly involve exciting movements. These postures usually occur to the worker concerning the job task. For example, the worker may be working under the vehicle for the repair process.

### 2.3.3 Neutral postures

The ideal work schedule provides tasks that can be completed while maintaining a range of neutral positions. An unbiased coverage of position is not only a stance or part of a common but has a degree of poses where these muscles are maintaining their relaxed length and the collective is inherently aligned. Sensible stance fields are typically the most relaxed stance for their joints. Poses within this field:

- Allow to relax and free job mind
- Allow heightening the output
- Minimize muscle pain and reduce stresses and strains
- Maintain comfortable working positions during their job task.

Table 2-1: Neutral posture [8]

| Joints                      | Descriptions of Midpoints for Neutral Range of Postures                                                     |                                                                                       |
|-----------------------------|-------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Head and neck               | Level, or bent slightly forward, forward facing, balanced and in-line with torso                            |  |
| Hands, wrists, and forearms | All are straight and in-line.                                                                               |                                                                                       |
| Elbow                       | Close to the body and bent 90 to 120 degrees.                                                               |  |
| Shoulders                   | Relaxed and upper arms hang normally on the side of the body.                                               |                                                                                       |
| Thighs and hips             | Parallel to the floor when sitting; aligned with the hips and ankles when standing                          |                                                                                       |
| Knees                       | Same height as the hips with feet slightly forward when sitting; aligned with hips and ankles when standing |  |
| Back                        | Vertical or leaning back slightly with lumbar support when sitting; vertical with an S-curve when standing  |                                                                                       |

### **2.3.4 Static postures**

Static posture is a fixed working position that involves small or no action. Because blood flow through the forces that supply energy and clear contaminants depends on the move, a revised view increases the chance of recession and MSD. Impartial stances can cause pain if one posture is held for a long time. Jobs that affect fixed perspectives can induce affliction quickly, mainly if they are mixed with openness to different threat elements, such as uncomfortable stances or caused work.

### **2.3.5 Why awkward postures lead to MSDs**

When a common person is not in their average stance content, their muscles are fastened or extended more than their resting height. When joints are disclosed to jobs that affect a capacity of motion around extreme issues, the tissue near the joint is extended or shortened. Ligaments are pushed, particularly in solid postures, and if divulgence to intense poses is prolonged, the links do not directly return to their resting length. Intense posture can also cause tissue reduction. For instance, excessive wrist stretching increases the stress within the carpal underpass, decreasing the median nerve's ability to pass through the carpal tunnel [8].

When a force is in its average pose content, it can exert a lot of power, but control is important from an objective standpoint. When doing a job that requires a specific part of the muscle, the forces use a lower rate of their highest degree by using that force with the joint and strength in comfortable standing [10]. In distinction, the muscles have less energy when a person is in an awkward posture. Therefore, if they must deliver the same force or load, the forces will work closer to their highest point [12].

## **2.4 Work Observations**

From observations, the behavior of body parts has been identified as relevant to different work activities. Workers frequently bend their backs and necks, and twist pick and place objects frequently using their shoulders and hands. They frequently used their hands to complete the tasks at work while moving their wrists. Physical observation methods are visual inspection or observation, which has limitations due to complex work activities. Video footage can be considered the best observation method to identify the posture of body parts [8]. Also, by taking photographs, it can be estimated the posture angles, bending angles, and some complex positions. In the calculation of the REBA score, the above observation was used for different tasks.

### 2.4.1 PLIBEL checklist and application

Musculoskeletal stress factors with harmful effects can be identified by the PLIBEL checklist. Nine body parts were evaluated with nine questions relevant to discomfort where the questions are standard and in a standard format. According to previous research studies, the PLIBEL checklist was used for identifying fishermen's discomfort. 140 fishermen joined this study, and their ages were kept between 30- 50 years, and their work experience was considered to be more than 10 years [13]. There were five anglers who had more experience, which is more than 20 years. The results of the PLIBEL checklist show the discomfort of various body parts according to Table 2-2 [13].

Table 2-2: Sample PLIBEL checklist [13]

| Questions (rate Y for yes, N for no)                                | 1. Neck | 2. Shoulders | 3.Upper back | 4.Elbows | 5.Lower back | 6. Wrist hands | 7. Hips/Thigh | 8.Knees | 9.Ankles/feet |
|---------------------------------------------------------------------|---------|--------------|--------------|----------|--------------|----------------|---------------|---------|---------------|
| 1. Fatigue because of operation most often                          | 1       | 3            | 19           |          | 12           | 2              |               |         | 3             |
| 2. Which part required for movement most often                      | 2       | 3            | 17           |          | 5            | 8              | 1             | 3       | 1             |
| 3. Which parts need to exert forces most often                      | 1       | 4            | 15           | 1        | 4            | 11             |               |         | 4             |
| 4. Which part required moving repetitively                          | 7       | 1            | 6            |          | 2            | 23             |               |         | 1             |
| 5. Which part feels numb often                                      |         | 4            |              |          |              | 26             |               |         | 10            |
| 6. Parts that feel ache or pain after tasks                         |         |              | 16           |          | 5            | 11             |               |         | 8             |
| 7. Ever consult paramedic because of physical problem               |         |              | 9            |          |              | 13             |               |         | 18            |
| 8. Ever experience problem which affect your job                    |         |              | 9            |          |              | 13             |               |         | 18            |
| 9. Any part which lack of support which leads to discomfort or pain |         | 5            | 17           |          |              | 11             |               |         |               |

As per PLIBEL results, wrist / hand discomfort (118) was highlighted as a major part. However, other body parts had been discomforting as given on the checklist [13].

Because repetitive motion occurred, 23 workers wrist/hand were moved repetitively, and 26 workers wrist/hands felt numb according to past research [13]. The ankle / foot had the most consultations with paramedics due to physical problems (18) and experiences affecting work (18). Workers who engage in manual labor and repetitive tasks are more likely to develop upper limits. Epidemiological studies have found that the onset and severity of hand and wrist pain associated with repetitive force and manual labor can be worsened by awkward or excessive wrist and forearm postures, cold temperatures, and performing these activities.[10][13].

#### **2.4.2 Work role functioning questionnaire (WRFQ)**

The updated Work Role Functioning Questionnaire (WRFQ) process was considered for a new Brazilian version of a study by Gallaschs [14]. Through the WRFQ, the perceived influence of health matters on the ability of workers to perform work tasks was evaluated [14]. The WRFQ contained 27 questions relevant to pain from functions carried out within the past two weeks and is divided into five scales. These 5 scales consider work scheduling, physical, mental, social, and output demands. Demands are directly related to the daily activities of the job when it is the scheduling process to analyze the difficulties of worker activities [14]. Through the scale of physical demands, the physical loads sustained by the worker could be measured as static and dynamic loads while performing duties. Performing job tasks with concentration is directly related to mental health and are assessed using the cognitive demand scale. The scale of Social Demands mainly concentrates on social relations with collaborators and customers. Work efficiency, productivity, job satisfaction, and job quality were assessed through output demand, according to research of Durands in 2004 [14]. A 5-point likert scale was used to score the WRFQ items and calculates the amount of time relevant to health issues that affect the performance of their duties. All demand scales were performed separately by connecting the answer for all items and was converted to a score of 0 to 100 [14] [15].

#### **2.4.3 Nordic musculoskeletal questionnaire (NMQ).**

Musculoskeletal symptoms were evaluated using the Brazilian questionnaire system version. This sample measurement was done by research of De Barros & Alexandre in 2003 and Kuorinka in 1987 [16][17]. The instrument used structural figures and contained questions that mentioned body areas. These body areas are mentioned as the neck, shoulders, upper and lower

back, elbows, wrists/hands, hips/thighs, knees, and ankles/feet. The interview questions were directly related to pain symptoms and discomfort in the past 12 months and should affect the health care of workers [17] [18].

## **2.5 The Standardized Nordic Questionnaire**

Analyzing and identifying musculoskeletal indications of various individuals in various parts of the world using secondary methods requires standard questions for the analysis process. If so, it would not be easy to compare the results of other studies. Considering this requirement NMQ was developed with funding from Nordic Cadinet by Kuorinka [19]. The development of NMQ development was based on the previously received medical questionnaire [16] [17].

The Standardized Nordic Questionnaire is a general questionnaire that identifies internationally recognized symptoms of the neck, back, shoulder, and legs [17]. It raises 28 multiple-choice questions, sometimes fraught with harmful, well-structured, two different parts. The first section covers symptoms that have occurred within the past 12 months in 9 different body parts (the neck, shoulder, elbow, wrist/hand, upper back, lower back, hip/thigh, knee, and ankle/foot). In part 2 covers signs and symptoms specific to the neck, shoulders, and lower back [15][18].

### **2.5.1 Advantages of NMQ**

- Uses Standard questions.
- NMQ has worldwide recognition.
- Zero cost of application
- It is a self-evaluation process.
- It has a quick response for symptom identification.
- Applicable for a large team.
- Taken as input data for other analysis like REBA, RULA etc.

### **2.5.2 Limitations of the NMQ process**

- Answering questions is mandatory.
- Truthfulness depends on the workers honestly
- Translation and validation difficulties occurred in some countries that do not use English.
- Limited to specific body areas.

- Pain symptoms are considered only for job-related problems.
- Evaluation is complex for large groups.

## 2.6 Industrial Applications of the Nordic Questionnaire

In 1583, articles from scholarly journals were used to select 259 studies that were pertinent to the subject and abstracted from actual industrial applications [20]. In 1583, 259 were selected, which were directly relevant to the topic and abstracted to the industrial application process of the questionnaire. This research was published in conferences and scientific journals. However, most industries carried out their work despite the NMQ associated with industrial application of health issues. Furthermore, considering only research articles and papers of conference resources, eliminating used books, it is chapters, or other comparable formats were not registered in this database. The defined working task practiced in NMQ did not attempt entirely to detect the pain of MSDS, and a related questionnaire is a tool that helps identify it. However, it is established with valid information, including various knowledge from different fields with commercial and health-related activities. It is illustrated in Figure 2-2 [20].

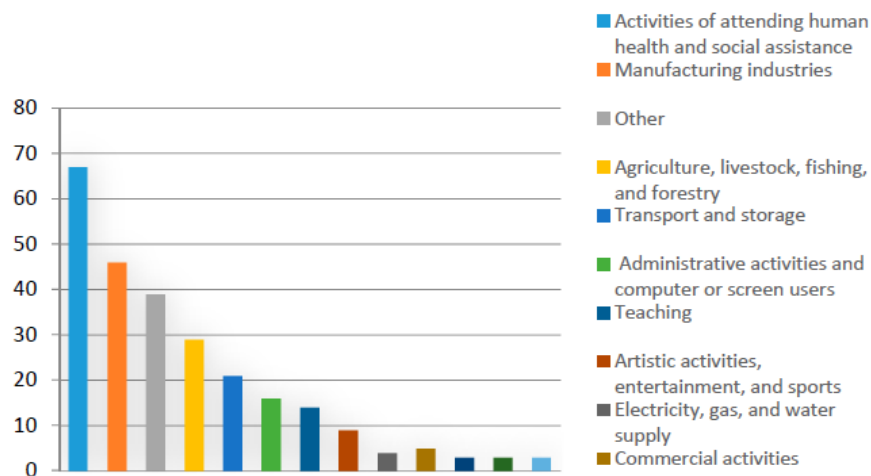


Figure 2-2: Applications of the nordic questionnaire by knowledge categories [20].

### 2.6.1 NMQ - Manufacturing industries

Tables 2-3 demonstrate the past studies in which NMQ has been used in the manufacturing industry.

Table 2-3: NMQ used applications in the world [20]

| Author                | Location       | Observation                                                       |
|-----------------------|----------------|-------------------------------------------------------------------|
| Liss et al. (1995)    | Canada         | Application of the NMQ in dental hygienists and dental assistants |
| Lusted et al. (1996)  | Australia      | Application of the NMQ in nurses of a residential centre          |
| Palmer et al. (1999)  | United Kingdom | Application of the NMQ in patients of an outpatient clinic        |
| Maul et al. (2003)    | Switzerland    | Application of the NMQ in hospital male nurses                    |
| Newell y Kumar (2004) | Canada         | Application of the NMQ in orthodontists                           |
| Smith et al (2004)    | China          | Application of the NMQ in hospital nurses                         |
| Yeung et al. (2005)   | United States  | Application of the NMQ in hospital nurses                         |

### 2.6.2 NMQ-Food products-related manufacturing industry

These studies have linked MSDs indications to low-temperature experiences relevant to their workplace, which are cold storage locations or rooms [20]. Based on the results, it emphasizes the hypothesis that laborer's work is in a very low-temperature environment and had a considerable risk of lumbar pain. In addition, the prevalence of MSD is interrelated with low temperatures. Choobineh studied 116 random workers from sugar factories in Iran and were unable to find any who suffered from knee and lower back injuries [2]. NMQ was handled to inquire about MSD issues among their workers preparing betel nuts. The evaluation results represented that the collection team was at high risk and suggested remediation procedures. In addition, Veiga-Quemelo investigated the MSDs relevant to dairy industry job activities carried out by workers in Brazil [20].

### 2.6.3 NMQ Study related to the mechanical industry

According to previous research studies, 'Bortner' was used for the NMQ survey highlighted by Flodmark and Aase [17] [20]. During the researcher's survey, it was determined that unnecessary competitiveness, irritation, persistence, and hostility seemed to be the most significant cause of musculoskeletal symptoms [20]. In addition, Williams and Dickinson [20] conducted a NMQ survey to identify MSDs in their citizens who are locksmiths and exposed to a higher number of disorders relevant to the upper extremities in the United Kingdom.

Heavy machinery industries have high noise, vibration, and postural stress and have a higher probability of increasing musculoskeletal disorders, as mentioned in the research by Nejad [17] [20]. To reduce the risk of MSD relevant to packing product lines in manufacturing industries, the research studied work activities and used the NMQ tool [16] [17] [20]. These researchers suggested a job rotation program and improved ventilation to reduce musculoskeletal issues.

#### **2.6.4 NMQ Study for the metal industry**

Najarkola [10] considered MSD injuries to the upper part of the body of steel industry workers in Iran and found a significant correlation with the work done, indicating an increased risk in casting job activities. According to research by Aghilinejad [20], an NMQ survey was conducted on musculoskeletal disorders among workers in the Iranian aluminum industry to assess their occurrence. The results show that more than 60% of people were physically abused in last year, and new prevention programs have been recommended for implementation [20]. According to research of Mohammed [20], NMQ was applied to workers at casting workshops in Iran. The most common symptoms (84%) were wrist/wrist symptoms. Furthermore, lifting and lowering weights are considered risk factors, and it was suggested that personalized orthopedics could effectively reduce and prevent MSD in several body parts.

#### **2.7 REBA- Rapid Entire Body Assessment**

Ergonomics evaluation of work-related musculoskeletal disorders (WMSD) assesses the risk of developing several disorders of the upper extremity and lower back muscles, nerves, and joints, primarily related to occupational functions [21]. With rising wage compensation and cost of medical treatment, falling productivity, and decreasing living standards, muscle disorders are among the most common industrial issues in both industry and service, both in developed and developing countries. These disorders are caused by the interaction of various risk factors due to several physical, distinct, and psychosocial factors. The physical weight of a task is generally assessed by analyzing the movement of the body, relevant posture, repetition, and compulsive activity, and maximizing muscle strength over time. Observational feedback and workers' feedback are suggested to measure discomfort level and postural stress according to different body parts [11].

In contrast, continuous body position recordings are made using an instrument joined by a specific worker. Observation methods are widely joined in the manufacturing plant for their ease of use, low cost, and ease of usage, [21]. According to the analysis of different monitoring

systems, their growth is intended for different uses; hence, they can be practiced in multiple workplace situations. Each method considers posture-organizing applications. Also, the posture monitoring and analysis system can be identified and relevant to REBA, and it is varied by other methods that are dissimilar positional force ratios which may be allocated to a given posture depending on their used technology. However, many studies evaluate many techniques regarding their performance and reliability [11][21]. In ergonomics studies, many observations of technical systems are used, such as OWAS, PATH, QEC, RULA, ACGHI TLV, SI, OCRA, and REBA [21].

To achieve ideal results, these programs must be built on the principles of ergonomics and contain a broad range of assessments of all functional system elements (David, 2005) [21]. This research mainly focuses on providing an overview of the Rapid Entire Body Assessment (REBA). The REBA tools are one of the best tools for the ergonomic assessment using the concept of posture observation and its previous applications, the development of relevant tasks, and the limitation of REBA are outlined in the literature.

### **2.7.1 Background and development of REBA**

In the past, workers had many relevant issues with their job tasks due to awkward posture. They have tried to find a suitable method to evaluate the appropriate job tasks. Work-related musculoskeletal injury is directly related to the posture of the worker. The ergonomic consultant can significantly benefit from the convenience of published working activities. Hignett and McAtamney also recommended identifying the moment of posture and analysis using REBA, mainly with sensitivity to the type of adjustable working situations primarily initiated in the healthcare sectors [11]. REBA provides a simple and rapid measuring system to assess different working postures relevant to job tasks for the risk of WMSDs. REBA is mentioned as a system of ideas for muscle activity for the whole body, a staggered, dynamic, rapid movement, unbalanced process, and job tasks where manual handling can occur, named coupling points, which is important in considerable weight handling that it cannot be operated continuously by hands [1][11].

### **2.7.2 Comparison of assessment tools**

In ergonomic studies, many analysis tools were used for the evaluation and assessment process carried out using REBA. Furthermore, other analysis methods were realized by David and Talaka in 2005 and 2010 [20]. Kee and Karwowski compared OWAS, RULA, and REBA

based on the results of an analysis of 301 activities of working posture through industrial-related and medical-treatment activities in a hospital [11][20][21]. The postures were enclosed with different working positions as standing working style and seating working style, and different leg positions as stable and unstable, where posture was verified from photographs taken through the camcorder, and this posture was classified as discomfort for the human body.

The comparison has taken that REBA while rearranging into four action groups or levels and postures were prepared according to commerce, working style, and leg orientations. The REBA ergonomic tool's reliability is greater than other tools discussed above. The OWAS tool and the REBA tool were less sensitive to postural stress compared to RULA and, also, the calculation of postural load or force was blurred with the relevant postures considered [21].

### **2.7.3 REBA uses and applications**

Many researchers used the convenience of REBA for their part of research relevant to the postural evaluation of jobs in some work-related settings, including the manufacturing industry and healthcare activity jobs [11]. Furthermore, Shanahan (2013) referred to the REBA for the construction industry [11]. In 2011, 2014, and 2005, the researchers' (Joseph, Lasotas, and Coylea) findings about the REBA method were applied in the food industry, packaging industry, and supermarket industry [11][21]. According to a computer base working issue, ergonomic analysis was carried out using REBA by Pillastrini in 2007 [21]. Additionally, technicians working in emergency medical units and firefighters were evaluated by Gentzler and Stader in 2010 using the REBA method according to their research [21].

REBA is a tool that assesses physical factors and provides a body assessment that includes all body parts. This method is very useful for occupational safety and health practitioners [11][21]. In 2012, Chiasson investigated eight methods for upper limbs to identify risk factors for WMSDs to assess 224 working areas. It had done so with a range of 0.03 to 18.75 hours of cycle time and 567 tasks in 18 industries within 5 years [11][22].

According to past research, data for the REBA method were collected through posture observation, video clips relevant to posture, and a survey with workers. Sometimes, the analyzing methods are differed in the same workplace. The REBA method was used to capture the uncomfortable postures that are highly observed only in the healthcare nursery sector. This research analyzed bending, sitting on the floor for a long time, twisting, lumber and neck flexion above 45 ° [21]. These analysis results raise good knowledge of their working postures

and risk level of performing tasks. The amount of sample size and observation time depended on better results. Non-highlighted musculoskeletal injuries of fourteen male road workers joined the study with six months of experience. Road workers placed, moved, and tied steel rods to reinforce their activities under various environmental conditions and were exposed to repetitive action with force applied to the hand hammer drill.

Therefore, the recommendations for corrective actions and ergonomic interventions are redesigning work methods and the reorganization of workplaces, reevaluating the REBA score and checking the suitability of the above changes. According to past research studies, RULA, ACGIH HAL TLV, SI,OCRA, and analysis tools are used for jobs based on quantitative exposure measures [11] [21].

### 2.7.3.1 REBA applications for the fishery industry

In Malaysia, the fisheries industry has many ergonomic issues relevant to its previous research [6]. Considering these issues, it was analyzed using REBA. The site selection for this learning was on a dock where fishing boats are arriving and unloading the fish ashore. Various tasks have been observed and some tasks have been observed as ergonomic risks. The PLIBEL checklist questionnaires were administered to 40 dock workers and observations were made on the tasks carried out [6]. The posture, habits, and tasks of the fisherman's work were surveyed. The results of the PLIBEL checklist showed that MSD risks are more frequent in the upper back, arms/wrists, and ankles than in other parts of the body. The REBA analysis was used to assess workers' postural risks in five tasks, and it is shown in Figures 2-3. The REBA analysis showed that some job positions had a higher risk of MSD for workers with relevant REBA scores of 7 to 11 [6][11].



Figure 2-3: Unloading the fish ashore [6]

### **2.7.3.2 REBA applications for the tyre industry**

REBA methods are used mainly in Malaysian tyre industries to minimize and reduce production member grievances due to discomfort of their body parts. The labor force still demands dedicated production systems based on semi-automatic machine equipment [1][23]. Off-road tyre production (OTR) using tyre assembly machines has been recognized as one of the most closely related production methods to the conventional tire industry. A previous research study was conducted among 51 male tyre machine operators [1]. Petaling Jaya and Selangor studied off the road tyre manufacturing process, especially for tyre changer job activities. It aimed to determine the occurrence of Musculoskeletal disorders (MSD) and the risk level of ergonomic exposure to involved employees [1]. According to their results of research, 96.08% of workers experience symptoms of MSD, including pain in the body during work with OTR tyre building machine with shoulder involvement (76.4%), lumbar area (72.55%) and wrist (62.75%) as analyzed using REBA tools [1]. According to the summary of their results, it showed that the OTR tyre building workers were exposed to high MSD (86.27%) and high level of risk (13.73%) according to the REBA analysis [1][10][23].

## **2.8 RULA (Rapid Upper Limb Assessment) Method - Ergonomics Analysis**

RULA is a tool developed to analyze the ergonomic risk factors associated with upper limbs. This RULA tool considers the biomechanical posture and force/load requirement relevant to job activities. In RULA analysis, a single-page work evaluation sheet was used to evaluate neck, trunk, and arm and wrist. But in this evaluation, posture related to lower body parts is not considered. Based on the evaluation, they are mainly classified as groups A and B. In Group A, the lower arm score, the upper arm score, and the wrist score are individually evaluated. In group B, neck scores and trunk scores are evaluated individually, and the final score is calculated with the RULA table. In this score calculation, repetition moment, load, and flexion are considered [22].

### **2.8.1 Level of MSD risks (RULA)**

According to the RULA score, it was classified into four ranges 1-2 ,3-4, 5-6, and above 6. Then the MSD risk level is classified as negligible, low, medium, and very high, relevant to the above score categories. It is shown in Tables 2-4.

Table 2-4: Level of MSD Risk (RULA) [22]

| <b>RULA score</b> | <b>MSD Risk level</b> | <b>Action</b>                      |
|-------------------|-----------------------|------------------------------------|
| 1-2               | Negligible            | No action required                 |
| 3-4               | Low                   | Change may be need                 |
| 5-6               | Medium                | Further investigation, change soon |
| 6+                | Very High             | Implement, change now              |

## 2.8.2 Advantages and disadvantages of rapid upper limb assessment

### **RULA Advantages:**

- Best for upper limb-relevant tasks.
- For mostly static tasks, the RULA tool is good.
- It can measure musculoskeletal risks.
- RULA is reliable and reasonably accurate
- Easy to use quickly
- The pre - post-intervention can be compared
- Productivity improvement can be shown.

### **RULA Disadvantages:**

- Cannot analyse the whole-body tasks
- Difficult to assess with photographs.
- Extreme wrist flexion is not counted for the score.
- It may require several RULA assessments for one task.

## 2.8.3 RULA employee assessment worksheet

In ergonomics evaluation, the following assessment worksheet was used to analyze the final RULA score (Figure 2-4).

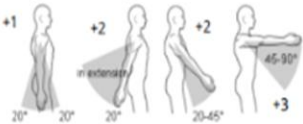


### RULA Employee Assessment Worksheet

Task Name: \_\_\_\_\_ Date: \_\_\_\_\_

#### A. Arm and Wrist Analysis

**Step 1: Locate Upper Arm Position:**



Step 1a: Adjust...  
 If shoulder is raised: +1  
 If upper arm is abducted: +1  
 If arm is supported or person is leaning: -1

**Step 2: Locate Lower Arm Position:**



Step 2a: Adjust...  
 If either arm is working across midline or out to side of body: Add +1

**Step 3: Locate Wrist Position:**



Step 3a: Adjust...  
 If wrist is bent from midline: Add +1

**Step 4: Wrist Twist:**  
 If wrist is twisted in mid-range: +1  
 If wrist is at or near end of range: +2

**Step 5: Look-up Posture Score in Table A:**  
 Using values from steps 1-4 above, locate score in Table A

**Step 6: Add Muscle Use Score**  
 If posture mainly static (i.e. held >10 minutes), Or if action repeated occurs 4X per minute: +1

**Step 7: Add Force/Load Score**  
 If load < 4.4 lbs. (intermittent): +0  
 If load 4.4 to 22 lbs. (intermittent): +1  
 If load 4.4 to 22 lbs. (static or repeated): +2  
 If more than 22 lbs. or repeated or shocks: +3

**Step 8: Find Row in Table C**  
 Add values from steps 5-7 to obtain Wrist and Arm Score. Find row in Table C.

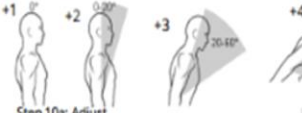
#### B. Neck, Trunk and Leg Analysis

**Step 9: Locate Neck Position:**



Step 9a: Adjust...  
 If neck is twisted: +1  
 If neck is side bending: +1

**Step 10: Locate Trunk Position:**



Step 10a: Adjust...  
 If trunk is twisted: +1  
 If trunk is side bending: +1

**Step 11: Legs:**  
 If legs and feet are supported: +1  
 If not: +2

**Step 12: Look-up Posture Score in Table B:**  
 Using values from steps 9-11 above, locate score in Table B

**Step 13: Add Muscle Use Score**  
 If posture mainly static (i.e. held >10 minutes), Or if action repeated occurs 4X per minute: +1

**Step 14: Add Force/Load Score**  
 If load < 4.4 lbs. (intermittent): +0  
 If load 4.4 to 22 lbs. (intermittent): +1  
 If load 4.4 to 22 lbs. (static or repeated): +2  
 If more than 22 lbs. or repeated or shocks: +3

**Step 15: Find Column in Table C**  
 Add values from steps 12-14 to obtain Neck, Trunk and Leg Score. Find column in Table C.

**Scores**

|           |           | Wrist Score |             |             |             |   |    |
|-----------|-----------|-------------|-------------|-------------|-------------|---|----|
|           |           | 1           | 2           | 3           | 4           |   |    |
| Upper Arm | Lower Arm | Wrist Twist | Wrist Twist | Wrist Twist | Wrist Twist |   |    |
|           | 1         | 1           | 2           | 2           | 2           | 3 | 3  |
|           | 2         | 2           | 2           | 2           | 2           | 3 | 3  |
|           | 3         | 2           | 3           | 3           | 3           | 3 | 4  |
|           | 4         | 1           | 2           | 3           | 3           | 3 | 4  |
|           | 5         | 2           | 3           | 3           | 3           | 3 | 4  |
| Trunk     | Neck      | 1           | 2           | 3           | 4           | 5 | 6  |
|           | 1         | 1           | 2           | 3           | 4           | 5 | 6  |
|           | 2         | 2           | 3           | 4           | 5           | 6 | 7  |
|           | 3         | 3           | 4           | 5           | 6           | 7 | 8  |
|           | 4         | 4           | 5           | 6           | 7           | 8 | 9  |
|           | 5         | 5           | 6           | 7           | 8           | 9 | 10 |
| Legs      | Neck      | 1           | 2           | 3           | 4           | 5 | 6  |
|           | 1         | 1           | 2           | 3           | 4           | 5 | 6  |
|           | 2         | 2           | 3           | 4           | 5           | 6 | 7  |
|           | 3         | 3           | 4           | 5           | 6           | 7 | 8  |
|           | 4         | 4           | 5           | 6           | 7           | 8 | 9  |
|           | 5         | 5           | 6           | 7           | 8           | 9 | 10 |

**Table C: Neck, Trunk, Leg Score**

| Score | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 |
|-------|----|----|----|----|----|----|----|----|----|----|
| 1     | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 |
| 2     | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 |
| 3     | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 |
| 4     | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 |
| 5     | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 |
| 6     | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 |
| 7     | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 8     | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 9     | 9  | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 10    | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |

**Scoring: (final score from Table C)**  
 1-2 = acceptable posture  
 3-4 = further investigation, change may be needed  
 5-6 = further investigation, change soon  
 7 = investigate and implement change

Figure 2-4: RULA employee worksheet [22]

### 3.0 METHODOLOGY

The research methodology scientifically explains the way to approach achieving the research objectives. The initial step presents the identification of the research problem and identifies the research gap. In that section, it discusses the actual ergonomic issues in the tyre manufacturing organization and the problems related to worker health as well as the efficiency of manufacturing operations. This research was conducted especially for the pneumatic off-road tyre manufacturing process to identify the health issue relevant to awkward posture. In Chapter 2, analyzing the literature review data was done and a research gap could be identified with respect to the research topic.

Real situations of industrial application and activities were identified, which develop the stress relevant to their job. In observation, a survey checklist was used to identify ergonomic stresses and ensure that all information would be collected during the NMQ survey. The checklist is helpful, as it provides primary evaluation tasks and critical areas of discomfort to prioritize the attention relevant to the problem. Furthermore, based on these results, analysis was carried out for investigation using analysis tools. In the initial step, musculoskeletal injuries are identified in their body parts through the NMQ questionnaire, which is essential to answer questions that are relevant to the body area [13].

This research study was based on the largest tyre manufacturing plant in Srilanka, and most workers perform various tasks relevant to their job role. All tyre manufacturing activities are processed in this factory in Sri Lanka. Furthermore, the workers who joined the study were men due to the inaccessibility of female workers on the work floor. During the survey, workers' body parts were evaluated as relevant to pain in general. The NMQ checklist was administered verbally. NMQ data was known as musculoskeletal stress and discomfort that can harm numerous parts of the body [20].

According to the NMQ results, further assessment will be discussed based on the above results and photographs and videos that were taken relevant to workers' postures during different job tasks. A Rapid Entire Body Assessment (REBA) investigation was carried out to assess the posture of the workers. The REBA assessment provided a numerical value to the assessment regarding the posture of the job task. REBA assessment is processed through group A and group B, where group A considers the posture of the trunk, neck, and legs and group B on upper arms, lower arms, and wrists. The summary of REBA proved the final score and

mentioned the risk level relevant to the REBA score. Hignett and McAtamney showed the decision table and indicated the level of risk [11].

According to Sri Lankan tyre manufacturing plant processes, most activities are non-standard. As a result, most workers experience musculoskeletal discomfort and pain symptoms in many parts of the body. The respondents were chosen in the data analysis based on their function as rubber mixing, ply cutting, milling, calendaring, tyre building, tyre curing, and tyre inspection inside the Off-the-Road Tyre manufacturing plant. The Nordic Musculoskeletal Questionnaire (NMQ) was used to collect data using interviews in a structured form. The questionnaire was distributed among participating working members in the section connecting their working shifts, with 3349 employees volunteering to participate as respondents. When the NMQ survey was conducted, the minimum number of sample quantities was maintained to meet less than 5% error margin.

### **3.1 Questionnaire Survey Method**

#### **3.1.1 Nordic musculoskeletal questionnaire**

The Nordic Musculoskeletal Questionnaire (NMQ) is used to analyze ergonomic issues using standardized questionnaire practice that allows the evaluation of the shoulder, leg, upper arm, lower arm, low back pain, and general discomfort. This survey is based on questions related to body parts discomfort and considering pain symptoms before the interview. In an interview, the pain was considered within the last 7 days and 12 months.

In this system, 15 areas of the body were considered according to discomfort and pain symptoms in a standardized questionnaire interview. The standard questionnaire format is shown in Tables 3-1(a) and (b). In the questionnaire interview, a direct answer is used for the analysis process because 'Yes' or 'No' indicate the correct path to the relevant symptoms of pain and discomfort.

#### **3.1.2 Nordic musculoskeletal questionnaire (NMQ) material**

A systematic questionnaire sheet was used as the NMQ data sheet and had 15 body parts relevant to the questions. The Yes or No results are marked on the data sheet, and these results depend on the workers. Therefore, during data collection, the sample size should be selected as extreme for greater precision.

Table 3-1(a): NMQ data sheet

| Have you at any time in the last 12 months had trouble (such as aches, pains, discomfort, numbness or tingling) in: (QX.1) | Have you had any trouble during the last 7 days? (QX.2)         | Have you at any time in the last 12 months been prevented from carrying out any of your normal activities (e.g. job, housework, sport) because of this trouble? (QX.3) | In your opinion, do you think this trouble is actively related to the work you do? (QX.4) | In your opinion, what are the main reasons for this problem? (QX.5) |
|----------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|---------------------------------------------------------------------|
| <b>1. Neck</b><br>No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                                          | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/> | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                                                                                                        | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                           |                                                                     |
| <b>2. Shoulders</b><br>No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                                     | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/> | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                                                                                                        | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                           |                                                                     |
| <b>3. Upper arms</b><br>No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                                    | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/> | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                                                                                                        | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                           |                                                                     |
| <b>4. Elbows</b><br>No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                                        | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/> | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                                                                                                        | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                           |                                                                     |
| <b>5. Forearms</b><br>No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                                      | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/> | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                                                                                                        | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                           |                                                                     |
| <b>6. Wrists</b><br>No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                                        | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/> | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                                                                                                        | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                           |                                                                     |
| <b>7. Hands</b><br>No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                                         | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/> | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                                                                                                        | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                           |                                                                     |
| <b>8. Fingers</b><br>No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                                       | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/> | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                                                                                                        | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                           |                                                                     |

Table 3-1(b): NMQ data sheet

| Have you at any time in the last 12 months had trouble (such as aches, pains, discomfort, numbness or tingling) in: (QX.1) | Have you had any trouble during the last 7 days? (QX.2)         | Have you at any time in the last 12 months been prevented from carrying out any of your normal activities (e.g. job, housework, sport) because of this trouble? (QX.3) | In your opinion, do you think this trouble is actively related to the work you do? (QX.4) | In your opinion, what are the main reasons for this problem? (QX.5) |
|----------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|---------------------------------------------------------------------|
| <b>9. Upper/Middle back</b><br>No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                             | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/> | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                                                                                                        | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                           |                                                                     |
| <b>10. Lower back</b><br>No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                                   | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/> | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                                                                                                        | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                           |                                                                     |
| <b>11. Hips or buttocks</b><br>No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                             | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/> | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                                                                                                        | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                           |                                                                     |
| <b>11. Upper legs</b><br>No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                                   | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/> | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                                                                                                        | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                           |                                                                     |
| <b>13. Knees</b><br>No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                                        | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/> | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                                                                                                        | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                           |                                                                     |
| <b>14. Lower legs</b><br>No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                                   | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/> | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                                                                                                        | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                           |                                                                     |
| <b>15. Ankles or feet</b><br>No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                               | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/> | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                                                                                                        | No Yes<br>2 <input type="checkbox"/> 1 <input type="checkbox"/>                           |                                                                     |

### 3.1.3 NMQ method and data collection

The research survey was conducted in the manufacturing environment and considered production cells in Sri Lankan large rubber factory, employing 3349 male workers relevant to 10 production lines of the factory. Their working arrangement is operated based on 12 hour 2 working shifts. A randomly selected team joined this survey to cover the main manufacturing cells. During the survey, they had to express their health issues as to their feeling freely. Most workers delivered their answers relevant to standard questionnaires without any barriers. The questionnaire directly related to body parts and consisted of 15 body parts to examine discomfort. During the survey, some personal details such as name, age, and experience were collected. It mainly discussed the musculoskeletal difficulties in different body areas relevant to the last 7 days and 12 months. The Nordic Questionnaire of Musculoskeletal Symptoms was highlighted through a questionnaire study and cases of MSD were recorded during the study. MSD symptoms were recorded relevant to all main operations through the questionnaire interview with workers.

NMQ survey was conducted through the discomfort of the human body parts of their job task posture. Most of the workers' survey results are valid with the actual situation and try to select a large sample size to minimize the errors. The Trye manufacturing plant operates with 10 nos main cells as raw material, mixing, calandering, beads making, bias cutting, semi-finish goods (SFG) storage, tyre building, thread rolling, tyre curing, and tyre inspection. However, 16 main operations have been included within the above cells and the NMQ survey was conducted for the main operations and both day and night shifts were considered.

Name : Renuka Age : 38 Experience : 15 years

Musculoskeletal symptoms (an extension to NMQ)

Please answer all the questions in the first column (B). If yes, please answer the questions in the other three columns for that body area.

| Have you at any time in the last 12 months had trouble (such as aches, pains, discomfort, numbness or tingling) in: (QX.1) | Have you had any trouble during the last 7 days? (QX.2)                    | Have you at any time in the last 12 months been prevented from carrying out any of your normal activities (e.g. job, housework, sport) because of this trouble? (QX.3) | In your opinion, do you think this trouble is actively related to the work you do? (QX.4) | In your opinion, what are the main reasons for this problem? (QX.5) |
|----------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|---------------------------------------------------------------------|
| 1. Neck<br>No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/>                                      | No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/> | No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/>                                                                                             | No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/>                |                                                                     |
| 2. Shoulders<br>No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/>                                 | No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/> | No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/>                                                                                             | No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/>                |                                                                     |
| 3. Upper arms<br>No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/>                                | No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/> | No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/>                                                                                             | No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/>                |                                                                     |
| 4. Elbows<br>No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/>                                    | No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/> | No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/>                                                                                             | No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/>                |                                                                     |
| 5. Forearms<br>No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/>                                  | No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/> | No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/>                                                                                             | No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/>                |                                                                     |
| 6. Wrists<br>No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/>                                    | No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/> | No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/>                                                                                             | No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/>                |                                                                     |
| 7. Hands<br>No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/>                                     | No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/> | No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/>                                                                                             | No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/>                |                                                                     |
| 8. Fingers<br>No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/>                                   | No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/> | No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/>                                                                                             | No Yes<br>2 <input checked="" type="checkbox"/> 1 <input type="checkbox"/>                |                                                                     |

Figure 3-1: Sample survey sheet (NMQ)

## 3.2 REBA Analysis

Lynn Mc Atamney and Sue Hignett (1995) suggested that the REBA tool provides a comparative means of assessing the risk of task-related overall body injuries [11][21]. Therefore, the tool combines the posture and forces assessments to produce a single value for the REBA score. There are some rewards for REBA, such as:

- The REBA tool is a muscle-sensing tool that categorizes body parts.
- REBA helps to analyze manual tasks and is a risk assessment.
- REBA suggests prioritizing the risk level and correction measures, but REBA has some limitations and weaknesses.
- REBA does not consider biomechanical risk factors combined with discomfort.

The REBA tool is used to evaluate the posture of all parts of the body and can assist in musculoskeletal discomfort due to wrong posture, repetition work, and overweight handling. It helps assess the job operations to which employees may be exposed to basic body diseases. In the analysis, the upper arm, lower arm, wrist, neck, trunk, and leg were considered as body parts. These are divided into groups A and B, and relevant details are contained in the REBA data table.

According to the REBA assessment, trunk, neck & leg assets using the REBA score and zero angle position are considered neutral positions and do not impact pain symptoms. According to the REBA data tables below, the posture of the trunk is evaluated in forward and backward directions, and the calculation will depend on the angle and direction. Also, neck up and down movement is used for the REBA calculation related to the neck, and the angle of the legs around the kneeling is considered the REBA calculation relevant to the legs.

### 3.2.1 Data sheet of REBA tool

REBA is a standard ergonomic analysis tool, and its score is directly exposed to the risk level and the action of REBA. The REBA tool has many data tables relevant to human body parts and their posture angles. In addition to load and grip, they were considered in the analysis. Relevant data are shown in Table 3-2,3-3,3-4,3-5,3-6, and Figure 3-2, 3-3.

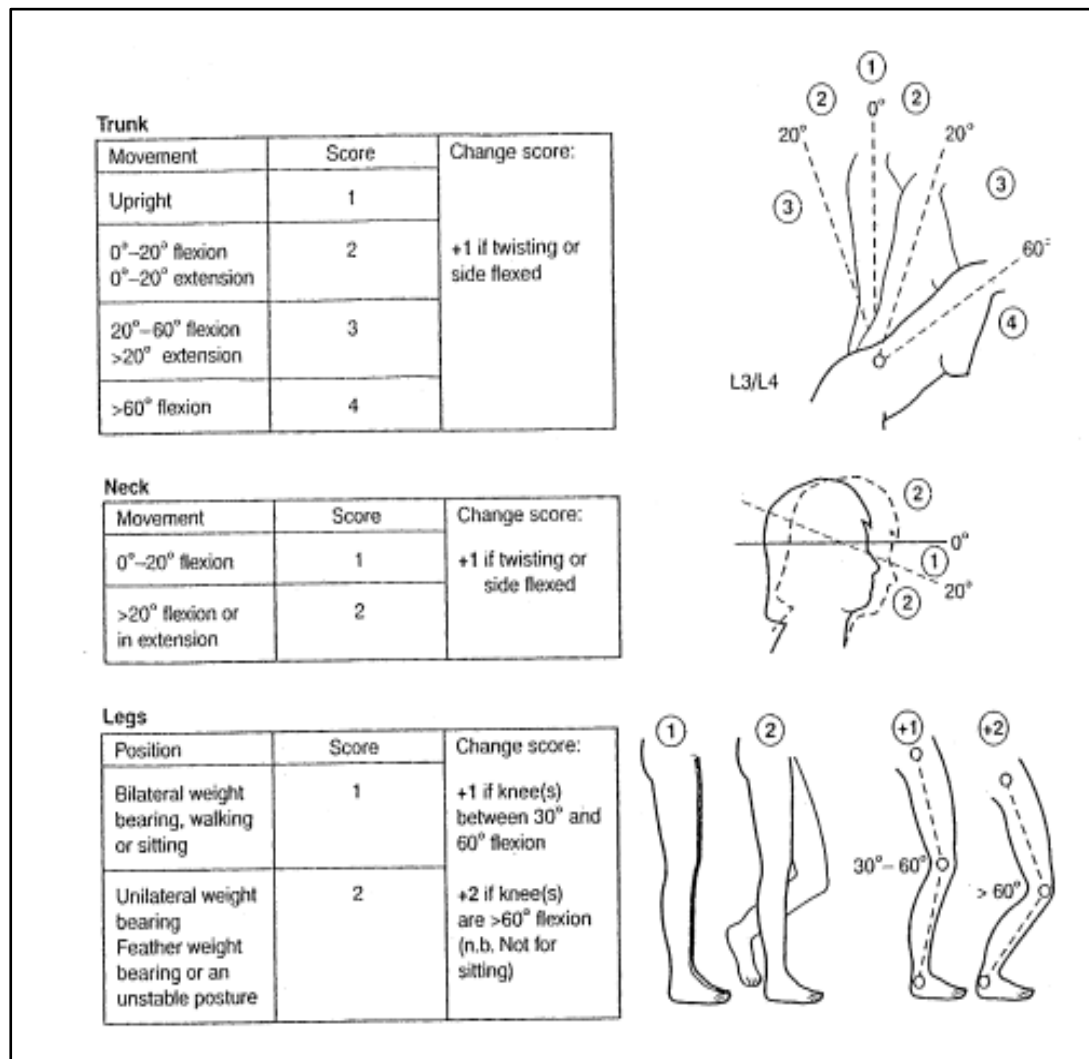


Figure 3-2: REBA data relevant to trunk, neck & leg [11]

Table 3-2: Table A and Load Table [11]

| Table A    |   |           |   |   |   |       |   |   |   |                              |   |   |  |
|------------|---|-----------|---|---|---|-------|---|---|---|------------------------------|---|---|--|
| Trunk      |   | Neck      |   |   |   |       |   |   |   |                              |   |   |  |
|            |   | 1         |   |   |   | 2     |   |   |   | 3                            |   |   |  |
| Leg        | 1 | 2         | 3 | 4 | 1 | 2     | 3 | 4 | 1 | 2                            | 3 | 4 |  |
| 1          | 1 | 2         | 3 | 4 | 1 | 2     | 3 | 4 | 3 | 3                            | 5 | 6 |  |
| 2          | 2 | 3         | 4 | 5 | 3 | 4     | 5 | 6 | 4 | 5                            | 6 | 7 |  |
| 3          | 2 | 4         | 5 | 6 | 4 | 5     | 6 | 7 | 5 | 6                            | 7 | 8 |  |
| 4          | 3 | 5         | 6 | 7 | 5 | 6     | 7 | 8 | 6 | 7                            | 8 | 9 |  |
| 5          | 4 | 6         | 7 | 8 | 6 | 7     | 8 | 9 | 7 | 8                            | 9 | 9 |  |
| Load/force |   |           |   |   |   |       |   |   |   |                              |   |   |  |
| 0          |   | 1         |   |   |   | 2     |   |   |   | Plus 1                       |   |   |  |
| <5kg       |   | 5kg< 10kg |   |   |   | >10kg |   |   |   | Shock or rapid buildup force |   |   |  |

According to the analysis of neck, trunk and legs, the REBA value was shown in Table 3-2 (table A) and added to the load/force factor considering the load.

The posture of the upper arm, lower arm, and wrist were analyzed using a standard manner relevant to REBA. Consider the standard data table [11] when analyzing the working posture and identifying the correct angle. Subsequently, the REBA rating value was taken, referring to the REBA data table. In posture analysis, the vertical position of the upper arm is taken as a neutral position and an increasing angle indicates the score relevant to the REBA calculation. Also, the same conditions are used to score the value of lower arms. In hand posture, wrist behaviors are considered for scoring, and wrist flex angle and twist conditions mainly affect this score.

The results of the lower arm, upper arm, and wrist are shown in Table B, relevant to REBA, and the coupling values add to the score of Table B according to the handgrip. The coupling value depends on the handhold condition.

Table 3-3: Table B of REBA [11]

| <b>Table B</b>  |              |                  |   |   |   |   |   |
|-----------------|--------------|------------------|---|---|---|---|---|
|                 |              | <b>Lower Arm</b> |   |   |   |   |   |
| <b>UpperArm</b> |              | 1                |   |   | 2 |   |   |
|                 | <b>Wrist</b> | 1                | 2 | 3 | 1 | 2 | 3 |
| 1               |              | 1                | 2 | 2 | 1 | 2 | 3 |
| 2               |              | 1                | 2 | 3 | 2 | 3 | 4 |
| 3               |              | 3                | 4 | 5 | 4 | 5 | 5 |
| 4               |              | 4                | 5 | 5 | 5 | 6 | 7 |
| 5               |              | 6                | 7 | 8 | 7 | 8 | 8 |
| 6               |              | 7                | 8 | 8 | 8 | 9 | 9 |

Table 3-4: Coupling table [11]

| 0<br>Good                                        | 1<br>Fair                                                                                 | 2<br>Poor                                  | 3<br>Unacceptable                                                                          |
|--------------------------------------------------|-------------------------------------------------------------------------------------------|--------------------------------------------|--------------------------------------------------------------------------------------------|
| Well-fitting handle and a mid -range, power grip | Hand hold acceptable but not ideal or coupling is acceptable via another part of the body | Hand hold not acceptable although possible | Awkward, unsafe grip, no handles<br>Coupling is unacceptable using other parts of the body |

The values in Tables A and B with the load/force and coupling relations indicate the score values. Score A is calculated using table A value and the load/force factor. The load/force factor is added to the value of Table A and the result will be indicated from Score A. Thus, Score B is calculated using table B value and coupling factor; coupling factor is added to the value of table B and will mention the result in score B. When the value of Table C is calculated, scores A and B are used according to the Table 3-5. The value in Table C is considered to score C, and the activity score depends on the movement and speed of the body part. In the calculation of the REBA score, the activity score is added to the score C.

Table 3-5: Table C and activity score [11]

| <b>Table C</b> |                |    |    |    |    |    |    |    |    |    |    |    |    |
|----------------|----------------|----|----|----|----|----|----|----|----|----|----|----|----|
| <b>Score A</b> | <b>Score B</b> |    |    |    |    |    |    |    |    |    |    |    |    |
|                |                | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 |
|                | 1              | 1  | 1  | 1  | 2  | 3  | 3  | 4  | 5  | 6  | 7  | 7  | 7  |
|                | 2              | 1  | 2  | 2  | 3  | 4  | 4  | 5  | 6  | 6  | 7  | 7  | 8  |
|                | 3              | 2  | 3  | 3  | 3  | 4  | 5  | 6  | 7  | 7  | 8  | 8  | 8  |
|                | 4              | 3  | 4  | 4  | 4  | 5  | 6  | 7  | 8  | 8  | 9  | 9  | 9  |
|                | 5              | 4  | 4  | 4  | 5  | 6  | 7  | 8  | 8  | 9  | 9  | 9  | 9  |
|                | 6              | 6  | 6  | 6  | 7  | 8  | 8  | 9  | 9  | 10 | 10 | 10 | 10 |
|                | 7              | 7  | 7  | 7  | 8  | 9  | 9  | 9  | 10 | 10 | 11 | 11 | 11 |
|                | 8              | 8  | 8  | 8  | 9  | 10 | 10 | 10 | 10 | 10 | 11 | 11 | 11 |
|                | 9              | 9  | 9  | 9  | 10 | 10 | 10 | 11 | 11 | 11 | 12 | 12 | 12 |
|                | 10             | 10 | 10 | 10 | 11 | 11 | 11 | 11 | 12 | 12 | 12 | 12 | 12 |
|                | 11             | 11 | 11 | 11 | 11 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
|                | 12             | 12 | 12 | 12 | 12 | 12 | 12 | 13 | 12 | 12 | 12 | 12 | 12 |

| Activity score |                                                                                                    |
|----------------|----------------------------------------------------------------------------------------------------|
| • + 1          | • 1 or more body parts are static, e.g. held for longer than 1 min                                 |
| • + 1          | • Repeated small range actions, e.g. repeated more than 4 times per minute (not including walking) |
| • (+ 1)        | • Action causes rapid large range changes in postures or an unstable base                          |

According to the REBA score, the action level, the risk level, and the actions are categorized as standards defined earlier [11].

### 3.2.2 REBA method

Body posture analysis using the REBA method involves the following:

- Measurement of joint angles.
- Repetition of force and motion.
- Observation of the occurrence of posture changes.

The behavior of each task and posture on the job may be directly affected by the final REBA score. The score A value characterizes the summary of the posture of body parts relevant to group A and the load / force factor. Group A body element has 60 nos posture combinations for the chest, neck, and legs. The "load/force" score is added to the result of table A. The Table B point are the sum of the posture points for the upper arm, lower arm, and wrist and the connecting points for each component. Wrist, upper and lower arms have 36 nos posture combination relevant to Group B and reducing the "Coupling" score to nine. The final values of the A and B scores are detected as the relevant value through Table C and give the 144 possible combinations for score C. Score C is added with the activity score. The result of the above final REBA score is shown for further action. The activity score expresses relevant to static postures, repetition actions, and rapid movement are limited detained for over 1 minute, a repetition action over four times within a minute, significant quick changes in positions, and an unstable working position, respectively. REBA scores define between 1 and 15. Additionally, REBA action levels were defined between 0 and 4. When the layout or job position/task is changed, workers' working posture is changed relevant to their new job task. In these changes, the earlier defined REBA score will be changed due to control measures. Compare the new REBA score with the previous one, effectiveness may be analyzed as relevant to changes.

As past research studies of care workers, REBA is convenient here to teach the healthcare worker the correct working position as part of the risk evaluation process in handling the patient [11]. Although it was generally accepted, posture was exposed to inappropriate levels, as in Figures 3-3. The reference lines are marked with the actual posture in Figures 3-3. The angle of posture of the trunk is between 20 ° and 60 °, giving a score of 3. The neck is in a neutral position, which gives a score of 1. The estimate of the legs is divided into two parts: in each leg, the weight is taken, which provides the score with 1; the knee is bent at an angle of 30 to 60 degrees, which gives the score +1. The force is maintained between 5-10 kg, which gives 1 point. According to Table A, Group A (Trunk, Neck, and Legs), scores are eligible for three to four score positions. The force/load score is considered as 1 and score A is received as score 5.

Figures 3-3 show that the right arm is visible effectively, and the limb is scored. Also, assume that the left arm position is like the right arm. The posture of the upper arm is maintained between 45° and 90°, which scores 3, and the lower arm are in position from 0 to 60°, which gives a score of 2. The wrist moment was not identified in the photograph, but the working

posture was confirmed through the photograph. Considering wrist posture, it was extended with fingers gripping and obtaining a score of 2, and a coupling score is 1 due to coupling being fair. According to Table B, obtain a summarized score from the lower arm, upper arm, and wrist posture score, the score obtained is 5, which is added to the score 1 as coupling, and the final score B was obtained as score 6. Score C is generated from Table C using score A and score B. According to activity score factors, the activity score is 0. Based on the above results, the REBA score is 7, relevant to the posture of Figures 3-3. The action level is given a medium risk level and is required to act.



Figure 3-3: The posture action of the old care worker [11]

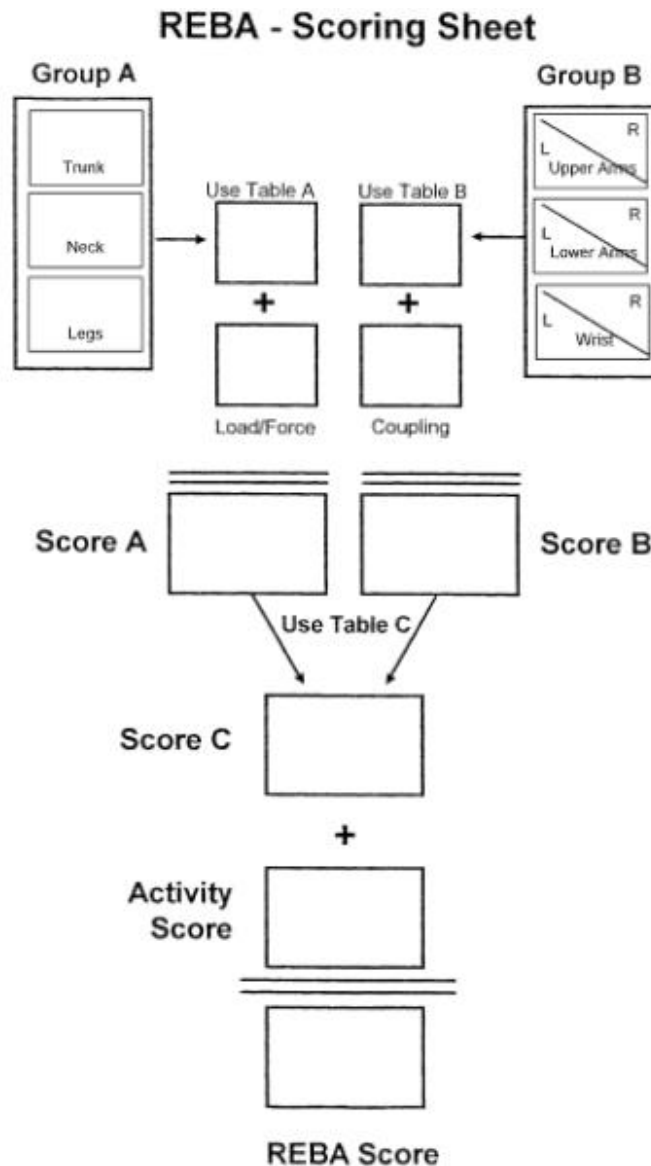


Figure 3-4: REBA score chart

### 3.2.3 Ergonomic risk screening software

Ergonomic risk screening software is a tool that calculates the REBA score. In this system, a manual calculation is not required. The final score will be received with the defined risk level when the required data are entered.

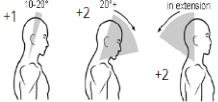
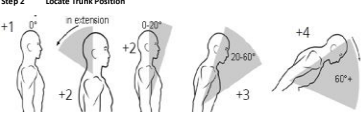
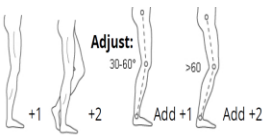
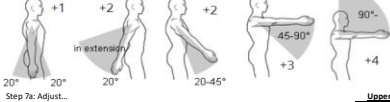
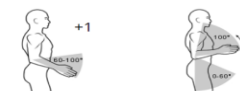
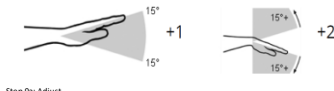
| Ergonomic Risk Screening                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | FS-CS-42-4.0                                                                                                                                                                                                                                                                                                                                                                                                      |       |                   |           |    |                 |                    |       |          |                      |     |             |                                                     |      |           |                                |       |                |                                        |  |  |      |  |  |  |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |         |  |  |  |  |  |  |  |  |  |  |  |  |           |  |  |  |           |  |  |  |       |  |  |  |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |         |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |    |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         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| REBA (Rapid Entire Body Assessment) - Digital Worksheet                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                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| Site: <div style="border: 1px solid black; padding: 2px;">MTD 01</div><br>Assessment Version: <div style="border: 1px solid black; padding: 2px;">Initial</div><br>Assessment Date: <div style="border: 1px solid black; padding: 2px;">February 2, 2022</div>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Department: <div style="border: 1px solid black; padding: 2px;">MOLD Maintenance</div><br>Work Station: <div style="border: 1px solid black; padding: 2px;">Mold repairing</div><br>Task / Activity: <div style="border: 1px solid black; padding: 2px;">Mold polishing</div>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Task / Activity Details: <div style="border: 1px solid black; padding: 5px;">             Mold polishing, Repairing &amp; vent hole cleaning. Use pneumatic tool. 10 hours working per days continuously. Sitting on the mold with cushion padding. Working in normal environment condition (Illumination noise &amp; temperature). Use respirator protection equipment due to dust environment.           </div> |       |                   |           |    |                 |                    |       |          |                      |     |             |                                                     |      |           |                                |       |                |                                        |  |  |      |  |  |  |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |         |  |  |  |  |  |  |  |  |  |  |  |  |           |  |  |  |           |  |  |  |       |  |  |  |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |         |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |    |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <a href="#" style="color: blue; text-decoration: underline;">RESET/CLEAR FORM</a>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      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                                                                                                                                                                                                     |
| <b>A. Neck, Trunk, and Leg Analysis</b><br><br><b>Step 1 Locate Neck Position</b><br> <div style="display: flex; justify-content: space-between; align-items: center;"> <div style="font-size: 8px;">             Step 1a: Adjust...<br/>             If neck is twisted: +1<br/>             If neck is side bending: +1           </div> <div style="border: 1px solid black; padding: 5px; text-align: center;"> <b>Neck Score</b><br/> <div style="background-color: #ccc; width: 40px; margin: 0 auto; text-align: center;">3</div> </div> </div><br><b>Step 2 Locate Trunk Position</b><br> <div style="display: flex; justify-content: space-between; align-items: center;"> <div style="font-size: 8px;">             Step 2a: Adjust...<br/>             If trunk is twisted: +1<br/>             If trunk is side bending: +1           </div> <div style="border: 1px solid black; padding: 5px; text-align: center;"> <b>Trunk Score</b><br/> <div style="background-color: #ccc; width: 40px; margin: 0 auto; text-align: center;">4</div> </div> </div><br><b>Step 3 Legs</b><br> <div style="display: flex; justify-content: space-between; align-items: center;"> <div style="font-size: 8px;">             Step 3a: Adjust...<br/>             If legs are bent: +1<br/>             If legs are side bending: +1           </div> <div style="border: 1px solid black; padding: 5px; text-align: center;"> <b>Legs Score</b><br/> <div style="background-color: #ccc; width: 40px; margin: 0 auto; text-align: center;">4</div> </div> </div><br><b>Step 4: Use Table A to find Score (Automatic)</b><br><div style="border: 1px solid black; padding: 5px; text-align: center;"> <b>Posture Score for Neck, Trunk &amp; Legs</b><br/> <div style="background-color: #ccc; width: 40px; margin: 0 auto; text-align: center;">9</div> </div> | <table border="1" style="width: 100%; border-collapse: collapse; font-size: 8px;"> <tr> <th colspan="12">TABLE A</th> </tr> <tr> <th></th> <th colspan="4">Neck</th> <th colspan="4">Trunk</th> <th colspan="4">Legs</th> </tr> <tr> <th></th> <th>1</th><th>2</th><th>3</th><th>4</th> <th>1</th><th>2</th><th>3</th><th>4</th> <th>1</th><th>2</th><th>3</th><th>4</th> </tr> <tr> <td>1</td><td>1</td><td>2</td><td>3</td><td>4</td> <td>1</td><td>1</td><td>2</td><td>3</td><td>4</td> <td>1</td><td>2</td><td>3</td><td>4</td> </tr> <tr> <td>2</td><td>2</td><td>3</td><td>4</td><td>5</td> <td>2</td><td>3</td><td>4</td><td>5</td> <td>2</td><td>3</td><td>4</td><td>5</td> </tr> <tr> <td>3</td><td>3</td><td>4</td><td>5</td><td>6</td> <td>3</td><td>4</td><td>5</td><td>6</td> <td>3</td><td>4</td><td>5</td><td>6</td> </tr> <tr> <td>4</td><td>4</td><td>5</td><td>6</td><td>7</td> <td>4</td><td>5</td><td>6</td><td>7</td> <td>4</td><td>5</td><td>6</td><td>7</td> </tr> <tr> <td>5</td><td>5</td><td>6</td><td>7</td><td>8</td> <td>5</td><td>6</td><td>7</td><td>8</td> <td>5</td><td>6</td><td>7</td><td>8</td> </tr> </table><br><table border="1" style="width: 100%; border-collapse: collapse; font-size: 8px;"> <tr> <th colspan="12">TABLE B</th> </tr> <tr> <th></th> <th colspan="4">Lower Arm</th> <th colspan="4">Upper Arm</th> <th colspan="4">Wrist</th> </tr> <tr> <th></th> <th>1</th><th>2</th><th>3</th><th>4</th> <th>1</th><th>2</th><th>3</th><th>4</th> <th>1</th><th>2</th><th>3</th><th>4</th> </tr> <tr> <td>1</td><td>1</td><td>2</td><td>3</td><td>4</td> <td>1</td><td>1</td><td>2</td><td>3</td> <td>1</td><td>1</td><td>2</td><td>3</td> </tr> <tr> <td>2</td><td>2</td><td>3</td><td>4</td><td>5</td> <td>2</td><td>2</td><td>3</td><td>4</td> <td>2</td><td>2</td><td>3</td><td>4</td> </tr> <tr> <td>3</td><td>3</td><td>4</td><td>5</td><td>6</td> <td>3</td><td>3</td><td>4</td><td>5</td> <td>3</td><td>3</td><td>4</td><td>5</td> </tr> <tr> <td>4</td><td>4</td><td>5</td><td>6</td><td>7</td> <td>4</td><td>4</td><td>5</td><td>6</td> <td>4</td><td>4</td><td>5</td><td>6</td> </tr> <tr> <td>5</td><td>5</td><td>6</td><td>7</td><td>8</td> <td>5</td><td>5</td><td>6</td><td>7</td> <td>5</td><td>5</td><td>6</td><td>7</td> </tr> <tr> <td>6</td><td>6</td><td>7</td><td>8</td><td>9</td> <td>6</td><td>6</td><td>7</td><td>8</td> <td>6</td><td>6</td><td>7</td><td>8</td> </tr> </table><br><table border="1" style="width: 100%; border-collapse: collapse; font-size: 8px;"> <tr> <th colspan="12">TABLE C</th> </tr> <tr> <th></th> <th colspan="12">SCORE B</th> </tr> <tr> <th></th> <th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th> </tr> <tr> <td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td> </tr> <tr> <td>2</td><td>2</td><td>2</td><td>2</td><td>2</td><td>2</td><td>2</td><td>2</td><td>2</td><td>2</td><td>2</td><td>2</td><td>2</td> </tr> <tr> <td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td> </tr> <tr> <td>4</td><td>4</td><td>4</td><td>4</td><td>4</td><td>4</td><td>4</td><td>4</td><td>4</td><td>4</td><td>4</td><td>4</td><td>4</td> </tr> <tr> <td>5</td><td>5</td><td>5</td><td>5</td><td>5</td><td>5</td><td>5</td><td>5</td><td>5</td><td>5</td><td>5</td><td>5</td><td>5</td> </tr> <tr> <td>6</td><td>6</td><td>6</td><td>6</td><td>6</td><td>6</td><td>6</td><td>6</td><td>6</td><td>6</td><td>6</td><td>6</td><td>6</td> </tr> <tr> <td>7</td><td>7</td><td>7</td><td>7</td><td>7</td><td>7</td><td>7</td><td>7</td><td>7</td><td>7</td><td>7</td><td>7</td><td>7</td> </tr> <tr> <td>8</td><td>8</td><td>8</td><td>8</td><td>8</td><td>8</td><td>8</td><td>8</td><td>8</td><td>8</td><td>8</td><td>8</td><td>8</td> </tr> <tr> <td>9</td><td>9</td><td>9</td><td>9</td><td>9</td><td>9</td><td>9</td><td>9</td><td>9</td><td>9</td><td>9</td><td>9</td><td>9</td> </tr> <tr> <td>10</td><td>10</td><td>10</td><td>10</td><td>10</td><td>10</td><td>10</td><td>10</td><td>10</td><td>10</td><td>10</td><td>10</td><td>10</td> </tr> <tr> <td>11</td><td>11</td><td>11</td><td>11</td><td>11</td><td>11</td><td>11</td><td>11</td><td>11</td><td>11</td><td>11</td><td>11</td><td>11</td> </tr> <tr> <td>12</td><td>12</td><td>12</td><td>12</td><td>12</td><td>12</td><td>12</td><td>12</td><td>12</td><td>12</td><td>12</td><td>12</td><td>12</td> </tr> </table><br><div style="text-align: center;"> <b>REBA TOTAL SCORE</b><br/> <div style="background-color: red; color: white; width: 60px; margin: 0 auto; text-align: center; font-size: 24px; font-weight: bold;">12</div> <div style="font-size: 8px;">Very High Risk<br/>Investigate &amp; implement change quickly</div> </div> | TABLE A                                                                                                                                                                                                                                                                                                                                                                                                           |       |                   |           |    |                 |                    |       |          |                      |     |             |                                                     | Neck |           |                                |       | Trunk          |                                        |  |  | Legs |  |  |  |  | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 1 | 2 | 3 | 4 | 1 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 2 | 2 | 3 | 4 | 5 | 2 | 3 | 4 | 5 | 2 | 3 | 4 | 5 | 3 | 3 | 4 | 5 | 6 | 3 | 4 | 5 | 6 | 3 | 4 | 5 | 6 | 4 | 4 | 5 | 6 | 7 | 4 | 5 | 6 | 7 | 4 | 5 | 6 | 7 | 5 | 5 | 6 | 7 | 8 | 5 | 6 | 7 | 8 | 5 | 6 | 7 | 8 | TABLE B |  |  |  |  |  |  |  |  |  |  |  |  | Lower Arm |  |  |  | Upper Arm |  |  |  | Wrist |  |  |  |  | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 1 | 2 | 3 | 4 | 1 | 1 | 2 | 3 | 1 | 1 | 2 | 3 | 2 | 2 | 3 | 4 | 5 | 2 | 2 | 3 | 4 | 2 | 2 | 3 | 4 | 3 | 3 | 4 | 5 | 6 | 3 | 3 | 4 | 5 | 3 | 3 | 4 | 5 | 4 | 4 | 5 | 6 | 7 | 4 | 4 | 5 | 6 | 4 | 4 | 5 | 6 | 5 | 5 | 6 | 7 | 8 | 5 | 5 | 6 | 7 | 5 | 5 | 6 | 7 | 6 | 6 | 7 | 8 | 9 | 6 | 6 | 7 | 8 | 6 | 6 | 7 | 8 | TABLE C |  |  |  |  |  |  |  |  |  |  |  |  | SCORE B |  |  |  |  |  |  |  |  |  |  |  |  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | <b>B. Arm and Wrist Analysis</b><br><br><b>Step 7 Locate Upper Arm Position</b><br> <div style="display: flex; justify-content: space-between; align-items: center;"> <div style="font-size: 8px;">             Step 7a: Adjust...<br/>             If shoulder is raised: +1<br/>             If upper arm is abducted: +1<br/>             If arm is supported or person is leaning: -1           </div> <div style="border: 1px solid black; padding: 5px; text-align: center;"> <b>Upper Arm Score</b><br/> <div style="background-color: #ccc; width: 40px; margin: 0 auto; text-align: center;">3</div> </div> </div><br><b>Step 8 Locate Lower Arm Position</b><br> <div style="display: flex; justify-content: space-between; align-items: center;"> <div style="font-size: 8px;">             Step 8a: Adjust...<br/>             If wrist is bent from midline or twisted: Add +1           </div> <div style="border: 1px solid black; padding: 5px; text-align: center;"> <b>Lower Arm Score</b><br/> <div style="background-color: #ccc; width: 40px; margin: 0 auto; text-align: center;">2</div> </div> </div><br><b>Step 9 Locate Wrist Position</b><br> <div style="display: flex; justify-content: space-between; align-items: center;"> <div style="font-size: 8px;">             Step 9a: Adjust...<br/>             If wrist is bent from midline or twisted: Add +1           </div> <div style="border: 1px solid black; padding: 5px; text-align: center;"> <b>Wrist Score</b><br/> <div style="background-color: #ccc; width: 40px; margin: 0 auto; text-align: center;">3</div> </div> </div><br><b>Step 10: Use Table B to find Score (Automatic)</b><br><div style="border: 1px solid black; padding: 5px; text-align: center;"> <b>Posture Score for Arm &amp; Wrist</b><br/> <div style="background-color: #ccc; width: 40px; margin: 0 auto; text-align: center;">5</div> </div> |
| TABLE A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                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| <b>Step 5 Add Force / Load Score</b><br><div style="font-size: 8px;">             If load &lt; 11 lbs/5 kgs: +0<br/>             If load 11 to 22 lbs/5 to 10 kgs: +1<br/>             If load &gt; 22 lbs/10 kgs: +2<br/>             Adjust: If shock or rapid build up of force: add +1           </div> <div style="display: flex; justify-content: space-between; align-items: center;"> <div style="font-size: 8px;"> <b>Force / Load Score</b><br/> <div style="background-color: #ccc; width: 40px; margin: 0 auto; text-align: center;">1</div> </div> <div style="border: 1px solid black; padding: 5px; text-align: center;"> <b>SCORE A</b><br/> <div style="background-color: #ccc; width: 40px; margin: 0 auto; text-align: center;">10</div> </div> </div>                                                                                                                                                                                                                                                              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| <b>Step 11 Add Coupling Score</b><br><div style="font-size: 8px;">             Well fitting Handle and mid range power grip: good: +0<br/>             Acceptable but not ideal hand hold or coupling acceptable with another body part: fair: +1<br/>             Hand hold not acceptable but possible: poor: +2<br/>             No handles, awkward, unsafe with any body part, Unacceptable: +3           </div> <div style="display: flex; justify-content: space-between; align-items: center;"> <div style="font-size: 8px;"> <b>Coupling Score</b><br/> <div style="background-color: #ccc; width: 40px; margin: 0 auto; text-align: center;">0</div> </div> <div style="border: 1px solid black; padding: 5px; text-align: center;"> <b>SCORE B</b><br/> <div style="background-color: #ccc; width: 40px; margin: 0 auto; text-align: center;">5</div> </div> </div>                                                                                                                                                         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| <b>Step 12 Calculate Score B (Automatic)</b><br><div style="border: 1px solid black; padding: 5px; text-align: center;"> <b>Activity Score</b><br/> <div style="background-color: #ccc; width: 40px; margin: 0 auto; text-align: center;">1</div> </div>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               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| <b>Step 13 Calculate Activity Score</b><br><div style="font-size: 8px;">             ADD +1 for any of the following:<br/>             If 1 or more body parts are held together for longer than 1 minute (static): +1<br/>             Repeated small range actions (more than 4x per minute): +1<br/>             Action causes rapid large range changes in postures or unstable base: +1           </div>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          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| <table border="1" style="width: 100%; border-collapse: collapse; font-size: 8px;"> <tr> <th>Score</th> <th>Level of MSD Risk</th> <th>Comment</th> </tr> <tr> <td>1</td> <td>negligible risk</td> <td>no action required</td> </tr> <tr> <td>2-3</td> <td>low risk</td> <td>change may be needed</td> </tr> <tr> <td>4-7</td> <td>medium risk</td> <td>further investigation, consider implementing change</td> </tr> <tr> <td>8-10</td> <td>high risk</td> <td>investigate &amp; implement change</td> </tr> <tr> <td>11-12</td> <td>very high risk</td> <td>investigate &amp; implement change quickly</td> </tr> </table>                                                                                                                                                                                                                                                                                                                                                                                                           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                                                                                                                                                                                        | Score | Level of MSD Risk | Comment   | 1  | negligible risk | no action required | 2-3   | low risk | change may be needed | 4-7 | medium risk | further investigation, consider implementing change | 8-10 | high risk | investigate & implement change | 11-12 | very high risk | investigate & implement change quickly |  |  |      |  |  |  |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |         |  |  |  |  |  |  |  |  |  |  |  |  |           |  |  |  |           |  |  |  |       |  |  |  |  |   |   |   |   |   |   |   |   |   |   |   |   |   | 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Figure 3-5: Ergonomic risk screening software

## **4.0 DATA COLLECTION PROCEDURES**

The data collection process is very important, as the accuracy of the research depends on the result of NMQ survey. According to the results of the NMQ survey, different parts of the body where discomfort is felt was identified the participants of the survey were asked to supply answers to pre-defined questions, considering the symptoms and knowledge concerning their body. Within the NMQ survey, 15 body parts were evaluated relevant to pain or discomfort in the last 12 months. All data were gathered according to a standard format and analyzed the data collected to identify the most significant discomfort with the percentage of the sample. In this survey, they were allowed maximum freedom to answer questionnaires based on their experience of pain or discomfort in the past year. These analysis data may be used for REBA score calculation.

### **4.1 Tyre Manufacturing Process**

In the tyre manufacturing process, there are many processes, which can be taken to the main process, or the production cells as described below. In addition, there are many activities and functions within these cells.

- The raw material storage cell
- Compound mixing process
- Bead-making process
- SFG storage process
- Calendering process
- Ply cutting process / Bias cutting cell
- Tyre-building process
- Thread-rolling process
- Tyre curing process
- Tyre grading/ inspection process

### **4.2 NMQ Data Collection of Manufacturing Process**

#### **4.2.1 NMQ of the raw material storage cell**

The raw material storage cell is considered as plant starting cell, including key operations relevant to the tyre manufacturing process. The forklift operation and the stocking process are

considered the main operation of the raw material cell. The NMQ process was carried out relevant to these two operations, and these operations are operated individually.

Figure 4-1: (a) is shown the forklift operation process and operator working posture. Also, stock-taking activity is shown in Figure 4-1: (b).



Figure 4-1: (a) Forklift operation (b) Stock-taking process

Table 4-1: NMQ- Forklift operation

| Total number of people involved in the job | Musculoskeletal symptoms | Number of people with symptoms in last 12 months |     | Number of people with symptoms in last 7 days |     | Number of people who had difficulty performing normal activities in the last 12 months |       | Number of people who think work-related activities are the reason for this |     |
|--------------------------------------------|--------------------------|--------------------------------------------------|-----|-----------------------------------------------|-----|----------------------------------------------------------------------------------------|-------|----------------------------------------------------------------------------|-----|
|                                            |                          | Amount                                           | %   | Amount                                        | %   | Amount                                                                                 | %     | Amount                                                                     | %   |
| 24                                         | Neck                     |                                                  |     |                                               |     |                                                                                        |       |                                                                            |     |
|                                            | Shoulders                | 12                                               | 50% | 17                                            | 71% |                                                                                        |       |                                                                            |     |
|                                            | Upper arms               | 5                                                | 21% | 5                                             | 21% |                                                                                        |       |                                                                            |     |
|                                            | Elbows                   |                                                  |     |                                               |     |                                                                                        |       |                                                                            |     |
|                                            | Forearms                 |                                                  |     |                                               |     |                                                                                        |       |                                                                            |     |
|                                            | Wrists                   |                                                  |     |                                               |     |                                                                                        |       |                                                                            |     |
|                                            | Hands                    | 6                                                | 25% | 8                                             | 33% |                                                                                        |       |                                                                            |     |
|                                            | Fingers                  |                                                  |     |                                               |     |                                                                                        |       |                                                                            |     |
|                                            | Upper/Middle back        |                                                  |     |                                               |     |                                                                                        |       |                                                                            |     |
|                                            | Lower back               | 18                                               | 75% | 20                                            | 83% | 16                                                                                     | 66.7% | 15                                                                         | 63% |
|                                            | Hips or buttocks         |                                                  |     |                                               |     |                                                                                        |       |                                                                            |     |
|                                            | Upper legs               |                                                  |     |                                               |     |                                                                                        |       |                                                                            |     |
|                                            | Knees                    | 12                                               | 50% | 15                                            | 63% | 8                                                                                      | 33.3% | 6                                                                          | 25% |
|                                            | Ankles or feet           |                                                  |     |                                               |     |                                                                                        |       |                                                                            |     |
|                                            | Lower legs               | 5                                                | 21% | 9                                             | 38% | 3                                                                                      | 12.5% | 1                                                                          | 4%  |

Table 4-2: NMQ – Stock-taking operation

| Total number of People involved in the job | Musculoskeletal symptoms | Number of people with symptoms in the last 12 months |     | Number of people with symptoms in last 7 days |      | Number of people who had difficulty performing normal activities in the last 12 months |     | Number of people who think work-related activities are the reason for this |      |
|--------------------------------------------|--------------------------|------------------------------------------------------|-----|-----------------------------------------------|------|----------------------------------------------------------------------------------------|-----|----------------------------------------------------------------------------|------|
|                                            |                          | Amount                                               | %   | Amount                                        | %    | Amount                                                                                 | %   | Amount                                                                     | %    |
| 32                                         | Neck                     | 30                                                   | 94% | 32                                            | 100% | 15                                                                                     | 47% | 15                                                                         | 47%  |
|                                            | Shoulders                | 26                                                   | 81% | 28                                            | 88%  | 12                                                                                     | 38% | 8                                                                          | 100% |
|                                            | Upper arms               | 23                                                   | 72% | 25                                            | 78%  | 3                                                                                      | 9%  | 1                                                                          | 100% |
|                                            | Elbows                   | 12                                                   | 38% | 15                                            | 47%  | 2                                                                                      | 6%  | 1                                                                          | 3%   |
|                                            | Forearms                 |                                                      |     |                                               |      |                                                                                        |     |                                                                            |      |
|                                            | Wrists                   |                                                      |     |                                               |      |                                                                                        |     |                                                                            |      |
|                                            | Hands                    |                                                      |     |                                               |      |                                                                                        |     |                                                                            |      |
|                                            | Fingers                  |                                                      |     |                                               |      |                                                                                        |     |                                                                            |      |
|                                            | Upper/Middle back        |                                                      |     |                                               |      |                                                                                        |     |                                                                            |      |
|                                            | Lower back               |                                                      |     |                                               |      |                                                                                        |     |                                                                            |      |
|                                            | Hips or buttocks         |                                                      |     |                                               |      |                                                                                        |     |                                                                            |      |
|                                            | Upper legs               |                                                      |     |                                               |      |                                                                                        |     |                                                                            |      |
|                                            | Knees                    | 21                                                   | 66% | 24                                            | 75%  | 8                                                                                      | 25% | 2                                                                          | 6%   |
|                                            | Ankles or feet           |                                                      |     |                                               |      |                                                                                        |     |                                                                            |      |
|                                            | Lower legs               |                                                      |     |                                               |      |                                                                                        |     |                                                                            |      |

#### 4.2.2 NMQ of compound mixing cell

In the compound mixing cell, a rubber sheet starts the process and adds chemicals, oil, and other ingredients. This action is done in the mixing machine, and two roll mills and batch-off cooling machines are included relevant to this process. In this cell, the mixer operator, rubber milling operator, batch-off cooler loading operator, and final compound batch unloading operators are working as main operators.



Figure 4-2: Rubber mixing process line

Figure 4-3: (a) is shown the posture of the mixer main operator. After the mixing process, the compound batch move to the rubber milling operation and which is shown in Figure 4-3: (b).



Figure 4-3: (a) Mixer operation process, (b) Rubber mill operation process

Table 4-3: NMQ - Mixer operating process

| Total number of People involved in the job | Musculoskeletal symptoms | Number of people with symptoms in last 12 months |     | Number of people with symptoms in last 7 days |     | Number of people who had difficulty performing normal activities in the last 12 months |     | Number of people who think work-related activities are the reason for this |     |
|--------------------------------------------|--------------------------|--------------------------------------------------|-----|-----------------------------------------------|-----|----------------------------------------------------------------------------------------|-----|----------------------------------------------------------------------------|-----|
|                                            |                          | Amount                                           | %   | Amount                                        | %   | Amount                                                                                 | %   | Amount                                                                     | %   |
| 192                                        | Neck                     | 45                                               | 23% | 89                                            | 46% | 42                                                                                     | 22% | 20                                                                         | 10% |
|                                            | Shoulders                | 56                                               | 29% | 78                                            | 41% | 48                                                                                     | 25% | 17                                                                         | 9%  |
|                                            | Upper arms               | 48                                               | 25% | 85                                            | 44% | 19                                                                                     | 10% | 12                                                                         | 6%  |
|                                            | Elbows                   | 27                                               | 14% | 88                                            | 46% | 12                                                                                     | 6%  | 8                                                                          | 4%  |
|                                            | Forearms                 |                                                  |     |                                               |     |                                                                                        |     |                                                                            |     |
|                                            | Wrists                   |                                                  |     |                                               |     |                                                                                        |     |                                                                            |     |
|                                            | Hands                    | 54                                               | 28% | 66                                            | 34% | 44                                                                                     | 23% | 14                                                                         | 7%  |
|                                            | Fingers                  |                                                  |     |                                               |     |                                                                                        |     |                                                                            |     |
|                                            | Upper/Middle back        |                                                  |     |                                               |     |                                                                                        |     |                                                                            |     |
|                                            | Lower back               | 64                                               | 33% | 79                                            | 41% | 132                                                                                    | 43% | 28                                                                         | 15% |
|                                            | Hips or buttocks         | 72                                               | 38% | 88                                            | 46% | 68                                                                                     | 35% | 6                                                                          | 3%  |
|                                            | Upper legs               |                                                  |     |                                               |     |                                                                                        |     |                                                                            |     |
|                                            | Knees                    | 12                                               | 6%  | 33                                            | 17% | 8                                                                                      | 4%  | 1                                                                          | 1%  |
|                                            | Ankles or feet           |                                                  |     |                                               |     |                                                                                        |     |                                                                            |     |
|                                            | Lower legs               | 34                                               | 18% | 30                                            | 16% | 23                                                                                     | 12% | 6                                                                          | 3%  |

Table 4-4: NMQ - Rubber mill operating process

| Total number of People involved in the job | Musculoskeletal symptoms | Number of people with symptoms in last 12 months |     | Number of people with symptoms in last 7 days |     | Number of people who had difficulty performing normal activities in the last 12 months |     | Number of people who think work-related activities are the reason for this |     |
|--------------------------------------------|--------------------------|--------------------------------------------------|-----|-----------------------------------------------|-----|----------------------------------------------------------------------------------------|-----|----------------------------------------------------------------------------|-----|
|                                            |                          | Amount                                           | %   | Amount                                        | %   | Amount                                                                                 | %   | Amount                                                                     | %   |
| 348                                        | Neck                     | 59                                               | 17% | 64                                            | 18% | 45                                                                                     | 13% | 40                                                                         | 11% |
|                                            | Shoulders                | 309                                              | 89% | 341                                           | 98% | 304                                                                                    | 87% | 270                                                                        | 78% |
|                                            | Upper arms               | 123                                              | 35% | 243                                           | 70% | 121                                                                                    | 35% | 114                                                                        | 33% |
|                                            | Elbows                   | 45                                               | 13% | 74                                            | 21% | 42                                                                                     | 12% | 12                                                                         | 3%  |
|                                            | Forearms                 | 122                                              | 35% | 143                                           | 41% | 118                                                                                    | 34% | 45                                                                         | 13% |
|                                            | Wrists                   | 212                                              | 61% | 267                                           | 77% | 208                                                                                    | 60% | 139                                                                        | 40% |
|                                            | Hands                    | 346                                              | 99% | 346                                           | 99% | 312                                                                                    | 90% | 281                                                                        | 81% |
|                                            | Fingers                  | 89                                               | 26% | 171                                           | 49% | 82                                                                                     | 24% | 17                                                                         | 5%  |
|                                            | Upper/Middle back        | 134                                              | 39% | 267                                           | 77% | 96                                                                                     | 28% | 37                                                                         | 11% |
|                                            | Lower back               | 338                                              | 97% | 341                                           | 98% | 331                                                                                    | 95% | 322                                                                        | 93% |
|                                            | Hips or buttocks         | 185                                              | 53% | 197                                           | 57% | 128                                                                                    | 37% | 66                                                                         | 19% |
|                                            | Upper legs               | 79                                               | 23% | 86                                            | 25% | 65                                                                                     | 19% | 29                                                                         | 8%  |
|                                            | Knees                    | 89                                               | 26% | 152                                           | 44% | 81                                                                                     | 23% | 30                                                                         | 9%  |
|                                            | Ankles or feet           | 12                                               | 3%  | 47                                            | 14% | 8                                                                                      | 2%  | 0                                                                          | 0%  |
|                                            | Lower legs               | 34                                               | 10% | 75                                            | 22% | 28                                                                                     | 8%  | 6                                                                          | 2%  |

Mixing line output comes from the batch-off machine, which has two operations i.e.: batch-off feeding operation and final batch-unloading operation. Those operations postures are shown in Figure 4-4: (a) and (b).



(a)



(b)

Figure 4-4: (a) Batch-off feeding process, (b) Final batch unloading process

Table 4-5: NMQ - Batch off feeding process

| Total number of People involved in the job | Musculoskeletal symptoms | Number of people with symptoms in last 12 months |     | Number of people with symptoms in last 7 days |     | Number of people who had difficulty performing normal activities in the last 12 months |     | Number of people who think work-related activities are the reason for this |     |
|--------------------------------------------|--------------------------|--------------------------------------------------|-----|-----------------------------------------------|-----|----------------------------------------------------------------------------------------|-----|----------------------------------------------------------------------------|-----|
|                                            |                          | Amount                                           | %   | Amount                                        | %   | Amount                                                                                 | %   | Amount                                                                     | %   |
| 126                                        | Neck                     | 62                                               | 49% | 89                                            | 71% | 34                                                                                     | 27% | 28                                                                         | 22% |
|                                            | Shoulders                | 117                                              | 93% | 124                                           | 98% | 76                                                                                     | 60% | 55                                                                         | 44% |
|                                            | Upper arms               | 113                                              | 90% | 118                                           | 94% | 98                                                                                     | 78% | 72                                                                         | 57% |
|                                            | Elbows                   | 45                                               | 36% | 75                                            | 60% | 23                                                                                     | 18% | 12                                                                         | 10% |
|                                            | Forearms                 | 0                                                | 0%  | 23                                            | 18% | 0                                                                                      |     | 0                                                                          |     |
|                                            | Wrists                   | 0                                                | 0%  | 11                                            | 9%  | 0                                                                                      |     | 0                                                                          |     |
|                                            | Hands                    | 66                                               | 52% | 81                                            | 64% | 18                                                                                     | 14% | 3                                                                          | 2%  |
|                                            | Fingers                  | 0                                                | 0%  | 43                                            | 34% | 0                                                                                      |     | 0                                                                          |     |
|                                            | Upper/Middle back        | 29                                               | 23% | 33                                            | 26% | 0                                                                                      |     | 0                                                                          |     |
|                                            | Lower back               | 113                                              | 90% | 120                                           | 95% | 108                                                                                    | 86% | 86                                                                         | 68% |
|                                            | Hips or buttocks         | 26                                               | 21% | 69                                            | 55% | 21                                                                                     | 17% | 4                                                                          | 3%  |
|                                            | Upper legs               | 48                                               | 38% | 67                                            | 53% | 0                                                                                      |     | 0                                                                          |     |
|                                            | Knees                    | 58                                               | 46% | 82                                            | 65% | 45                                                                                     | 36% | 11                                                                         | 9%  |
|                                            | Ankles or feet           | 0                                                | 0%  | 39                                            | 31% | 0                                                                                      |     | 0                                                                          |     |
|                                            | Lower legs               | 0                                                | 0%  | 25                                            | 20% | 0                                                                                      |     | 0                                                                          |     |

Table 4-6: NMQ - Final batch unloading

| Total number of People involved in the job | Musculoskeletal symptoms | Number of people with symptoms in last 12 months |     | Number of people with symptoms in last 7 days |     | Number of people who had difficulty performing normal activities in the last 12 months |     | Number of people who think work-related activities are the reason for this |    |
|--------------------------------------------|--------------------------|--------------------------------------------------|-----|-----------------------------------------------|-----|----------------------------------------------------------------------------------------|-----|----------------------------------------------------------------------------|----|
|                                            |                          | Amount                                           | %   | Amount                                        | %   | Amount                                                                                 | %   | Amount                                                                     | %  |
| 156                                        | Neck                     |                                                  |     | 26                                            | 17% |                                                                                        |     |                                                                            |    |
|                                            | Shoulders                | 22                                               | 14% | 72                                            | 46% | 12                                                                                     | 8%  | 6                                                                          | 4% |
|                                            | Upper arms               | 34                                               | 22% | 74                                            | 47% | 29                                                                                     | 19% | 13                                                                         | 8% |
|                                            | Elbows                   | 53                                               | 34% | 68                                            | 44% | 38                                                                                     | 24% | 12                                                                         | 8% |
|                                            | Forearms                 | 37                                               | 24% | 28                                            | 18% |                                                                                        |     |                                                                            |    |
|                                            | Wrists                   |                                                  |     |                                               |     |                                                                                        |     |                                                                            |    |
|                                            | Hands                    | 11                                               | 7%  | 56                                            | 36% | 8                                                                                      | 5%  | 2                                                                          | 1% |
|                                            | Fingers                  | 8                                                | 5%  | 19                                            | 12% |                                                                                        |     |                                                                            |    |
|                                            | Upper/Middle back        |                                                  |     |                                               |     |                                                                                        |     |                                                                            |    |
|                                            | Lower back               | 10                                               | 6%  | 48                                            | 31% | 4                                                                                      | 3%  | 1                                                                          | 1% |
|                                            | Hips or buttocks         |                                                  |     |                                               |     |                                                                                        |     |                                                                            |    |
|                                            | Upper legs               | 34                                               | 22% | 56                                            | 36% | 16                                                                                     | 10% | 6                                                                          | 4% |
|                                            | Knees                    |                                                  |     |                                               |     |                                                                                        |     |                                                                            |    |
|                                            | Ankles or feet           | 6                                                | 4%  | 21                                            | 13% |                                                                                        |     |                                                                            |    |
|                                            | Lower legs               | 15                                               | 10% | 22                                            | 14% | 9                                                                                      | 6%  | 1                                                                          | 1% |

### 4.2.3 Bead-making cell operations

The beads-making cell is the semi-product line of the tyre manufacturing process. In this cell, bead-making and apex-application activities operate as the semi-automated process. Although apex applies, job activity involves direct human involvement and the same operator joining various activities within their cycle time. In the calculation of NMQ and REBA, all activities will be considered.



Figure 4-5: Bead-making machine

The bead-making cell first operation is bead-making, and after that, it is moved to apex apply operations, and it's postures are shown in Figure 4-6: (a) and (b).



(a)

(b)

Figure 4-6: (a) Bead-making process, (b) Apex apply process

Table 4-7: NMQ – Bead-making process

| Total number of People involved in the job | Musculoskeletal symptoms | Number of people with symptoms in last 12 months |     | Number of people with symptoms in last 7 days |     | Number of people who had difficulty performing normal activities in the last 12 months |     | Number of people who think work-related activities are the reason for this |    |
|--------------------------------------------|--------------------------|--------------------------------------------------|-----|-----------------------------------------------|-----|----------------------------------------------------------------------------------------|-----|----------------------------------------------------------------------------|----|
|                                            |                          | Amount                                           | %   | Amount                                        | %   | Amount                                                                                 | %   | Amount                                                                     | %  |
| 138                                        | Neck                     | 12                                               | 9%  | 72                                            | 52% | 5                                                                                      | 4%  | 0                                                                          | 0% |
|                                            | Shoulders                | 23                                               | 17% | 86                                            | 62% | 9                                                                                      | 7%  | 0                                                                          | 0% |
|                                            | Upper arms               | 16                                               | 12% | 124                                           | 90% | 5                                                                                      | 4%  | 1                                                                          | 1% |
|                                            | Elbows                   | 29                                               | 21% | 118                                           | 86% | 12                                                                                     | 9%  | 5                                                                          | 4% |
|                                            | Forearms                 | 38                                               | 28% | 121                                           | 88% | 14                                                                                     | 10% | 12                                                                         | 9% |
|                                            | Wrists                   | 9                                                | 7%  | 31                                            | 22% | 0                                                                                      | 0%  | 0                                                                          | 0% |
|                                            | Hands                    | 0                                                | 0%  | 92                                            | 67% | 0                                                                                      | 0%  | 0                                                                          | 0% |
|                                            | Fingers                  | 12                                               | 9%  | 48                                            | 35% | 0                                                                                      | 0%  | 0                                                                          | 0% |
|                                            | Upper/Middle back        | 8                                                | 6%  | 23                                            | 17% | 0                                                                                      | 0%  | 0                                                                          | 0% |
|                                            | Lower back               | 13                                               | 9%  | 75                                            | 54% | 4                                                                                      | 3%  | 0                                                                          | 0% |
|                                            | Hips or buttocks         | 48                                               | 35% | 45                                            | 33% | 16                                                                                     | 12% | 8                                                                          | 6% |
|                                            | Upper legs               | 19                                               | 14% | 42                                            | 30% | 8                                                                                      | 6%  | 3                                                                          | 2% |
|                                            | Knees                    | 16                                               | 12% | 30                                            | 22% | 8                                                                                      | 6%  | 2                                                                          | 1% |
|                                            | Ankles or feet           | 8                                                | 6%  | 12                                            | 9%  | 1                                                                                      | 1%  | 0                                                                          | 0% |
|                                            | Lower legs               | 0                                                | 0%  | 6                                             | 4%  | 0                                                                                      | 0%  | 0                                                                          | 0% |

Table 4-8: NMQ – Apex apply process

| Total number of People involved in the job | Musculoskeletal symptoms | Number of people with symptoms in last 12 months |     | Number of people with symptoms in last 7 days |     | Number of people who had difficulty performing normal activities in the last 12 months |     | Number of people who think work-related activities are the reason for this |    |
|--------------------------------------------|--------------------------|--------------------------------------------------|-----|-----------------------------------------------|-----|----------------------------------------------------------------------------------------|-----|----------------------------------------------------------------------------|----|
|                                            |                          | Amount                                           | %   | Amount                                        | %   | Amount                                                                                 | %   | Amount                                                                     | %  |
| 138                                        | Neck                     | 18                                               | 13% | 65                                            | 47% | 6                                                                                      | 4%  | 6                                                                          | 4% |
|                                            | Shoulders                | 21                                               | 15% | 69                                            | 50% | 11                                                                                     | 8%  | 8                                                                          | 6% |
|                                            | Upper arms               | 19                                               | 14% | 65                                            | 47% | 8                                                                                      | 6%  | 8                                                                          | 6% |
|                                            | Elbows                   | 29                                               | 21% | 59                                            | 43% | 22                                                                                     | 16% | 9                                                                          | 7% |
|                                            | Forearms                 | 36                                               | 26% | 61                                            | 44% | 14                                                                                     | 10% | 6                                                                          | 4% |
|                                            | Wrists                   | 11                                               | 8%  | 53                                            | 38% | 10                                                                                     | 7%  | 10                                                                         | 7% |
|                                            | Hands                    | 12                                               | 9%  | 42                                            | 30% | 6                                                                                      | 4%  | 6                                                                          | 4% |
|                                            | Fingers                  | 15                                               | 11% | 55                                            | 40% | 12                                                                                     | 9%  | 8                                                                          | 6% |
|                                            | Upper/Middle back        | 8                                                | 6%  | 29                                            | 21% | 2                                                                                      | 1%  | 2                                                                          | 1% |
|                                            | Lower back               | 10                                               | 7%  | 44                                            | 32% | 6                                                                                      | 4%  | 6                                                                          | 4% |
|                                            | Hips or buttocks         | 26                                               | 19% | 56                                            | 41% | 19                                                                                     | 14% | 11                                                                         | 8% |
|                                            | Upper legs               | 18                                               | 13% | 41                                            | 30% | 9                                                                                      | 7%  | 9                                                                          | 7% |
|                                            | Knees                    | 28                                               | 20% | 32                                            | 23% | 15                                                                                     | 11% | 10                                                                         | 7% |
|                                            | Ankles or feet           | 14                                               | 10% | 16                                            | 12% | 6                                                                                      | 4%  | 5                                                                          | 4% |
|                                            | Lower legs               | 2                                                | 1%  | 14                                            | 10% | 0                                                                                      | 0%  | 0                                                                          | 0% |

#### 4.2.4 Semi finish goods (SFG) storage cell

The SFG storage cell is operated as a temporary storage cell, including material loading and unloading activities with electrical lifting equipment. In the cell, semi-finished material is stored in a large racking system, and material handlers supply the material using the forklift. It is considered a single activity, but it has included the three operations.

Also, the Bias cutting process operates within the semi-finish goods storage cell, which is continuously running for 12 hours. The NMQ survey was carried out individually for both activities and workers. Bias cutter operation has ply roll loading and winding operation, but a single operator carries out both activities. The NMQ survey was carried out relevant to the above bias cutter operator, and both bias cutting operations were considered as single operations relevant to REBA analysis.

Postures were not considered during the NMQ survey, but for further analysis, working posture is very important. Figure 4-7: (a) shows the lifting machine operation relevant to the material loading and unloading process. Also, the postures of bias cutter operation process are shown in Figure 4-7: (b).



(a)



(b)

Figure 4-7: (a) Material loading /unloading, (b) Bias cutter operation

Table 4-9: NMQ – Material loading/ unloading and lifting machine operation

| Total number of People involved in the job | Musculoskeletal symptoms | Number of people with symptoms in last 12 months |      | Number of people with symptoms in last 7 days |      | Number of people who had difficulty performing normal activities in the last 12 months |     | Number of people who think work-related activities are the reason for this |     |
|--------------------------------------------|--------------------------|--------------------------------------------------|------|-----------------------------------------------|------|----------------------------------------------------------------------------------------|-----|----------------------------------------------------------------------------|-----|
|                                            |                          | Amount                                           | %    | Amount                                        | %    | Amount                                                                                 | %   | Amount                                                                     | %   |
| 26                                         | Neck                     | 26                                               | 100% | 26                                            | 100% | 23                                                                                     | 88% | 19                                                                         | 73% |
|                                            | Shoulders                | 8                                                | 31%  | 12                                            | 46%  | 6                                                                                      | 23% | 5                                                                          | 19% |
|                                            | Upper arms               | 12                                               | 46%  | 20                                            | 77%  | 9                                                                                      | 35% | 7                                                                          | 27% |
|                                            | Elbows                   | 3                                                | 12%  | 8                                             | 31%  | 0                                                                                      | 0%  | 0                                                                          | 0%  |
|                                            | Forearms                 | 10                                               | 38%  | 11                                            | 42%  | 6                                                                                      | 23% | 0                                                                          | 0%  |
|                                            | Wrists                   | 22                                               | 85%  | 25                                            | 96%  | 20                                                                                     | 77% | 19                                                                         | 73% |
|                                            | Hands                    | 20                                               | 77%  | 22                                            | 85%  | 19                                                                                     | 73% | 18                                                                         | 69% |
|                                            | Fingers                  | 15                                               | 58%  | 19                                            | 73%  | 14                                                                                     | 54% | 12                                                                         | 46% |
|                                            | Upper/Middle back        | 22                                               | 85%  | 23                                            | 88%  | 18                                                                                     | 69% | 16                                                                         | 62% |
|                                            | Lower back               | 21                                               | 81%  | 24                                            | 92%  | 19                                                                                     | 73% | 18                                                                         | 69% |
|                                            | Hips or buttocks         | 22                                               | 85%  | 22                                            | 85%  | 22                                                                                     | 85% | 21                                                                         | 81% |
|                                            | Upper legs               | 9                                                | 35%  | 12                                            | 46%  | 18                                                                                     | 69% | 17                                                                         | 65% |
|                                            | Knees                    | 8                                                | 31%  | 14                                            | 54%  | 4                                                                                      | 15% | 0                                                                          | 0%  |
|                                            | Ankles or feet           | 19                                               | 73%  | 21                                            | 81%  | 14                                                                                     | 54% | 12                                                                         | 46% |
|                                            | Lower legs               | 4                                                | 15%  | 10                                            | 38%  | 0                                                                                      | 0%  | 0                                                                          | 0%  |

Table 4-10: NMQ -Bias cutter operation

| Total number of People involved in the job | Musculoskeletal symptoms | Number of people with symptoms in last 12 months |     | Number of people with symptoms in last 7 days |     | Number of people who had difficulty performing normal activities in the last 12 months |     | Number of people who think work-related activities are the reason for this |     |
|--------------------------------------------|--------------------------|--------------------------------------------------|-----|-----------------------------------------------|-----|----------------------------------------------------------------------------------------|-----|----------------------------------------------------------------------------|-----|
|                                            |                          | Amount                                           | %   | Amount                                        | %   | Amount                                                                                 | %   | Amount                                                                     | %   |
| 196                                        | Neck                     | 117                                              | 60% | 188                                           | 96% | 23                                                                                     | 12% | 22                                                                         | 11% |
|                                            | Shoulders                | 95                                               | 48% | 128                                           | 65% | 44                                                                                     | 22% | 34                                                                         | 17% |
|                                            | Upper arms               | 123                                              | 63% | 174                                           | 89% | 59                                                                                     | 30% | 56                                                                         | 29% |
|                                            | Elbows                   | 22                                               | 11% | 87                                            | 44% | 2                                                                                      | 1%  | 0                                                                          | 0%  |
|                                            | Forearms                 | 49                                               | 25% | 81                                            | 41% | 0                                                                                      | 0%  | 0                                                                          | 0%  |
|                                            | Wrists                   | 16                                               | 8%  | 44                                            | 22% | 0                                                                                      | 0%  | 0                                                                          | 0%  |
|                                            | Hands                    | 67                                               | 34% | 133                                           | 68% | 16                                                                                     | 8%  | 6                                                                          | 3%  |
|                                            | Fingers                  | 12                                               | 6%  | 38                                            | 19% | 5                                                                                      | 3%  | 3                                                                          | 2%  |
|                                            | Upper/Middle back        | 28                                               | 14% | 43                                            | 22% | 9                                                                                      | 5%  | 4                                                                          | 2%  |
|                                            | Lower back               | 155                                              | 79% | 189                                           | 96% | 106                                                                                    | 54% | 96                                                                         | 49% |
|                                            | Hips or buttocks         | 31                                               | 16% | 66                                            | 34% | 9                                                                                      | 5%  | 0                                                                          | 0%  |
|                                            | Upper legs               | 94                                               | 48% | 129                                           | 66% | 55                                                                                     | 28% | 46                                                                         | 23% |
|                                            | Knees                    | 42                                               | 21% | 98                                            | 50% | 11                                                                                     | 6%  | 4                                                                          | 2%  |
|                                            | Ankles or feet           | 41                                               | 21% | 77                                            | 39% | 18                                                                                     | 9%  | 11                                                                         | 6%  |
|                                            | Lower legs               | 2                                                | 1%  | 25                                            | 13% | 0                                                                                      | 0%  | 0                                                                          | 0%  |

#### 4.2.5 Layer calander cell

A Layer calandering cell is a semi-automated cell with heavy machinery involved in the manufacturing process with minimum human activities. In this process, the main activities are done by the same operator: Those are calander material loading and adjusting the machine settings. Most rubber calanders have semi-auto feeding systems and manual calandering process used for this investigation and it's shown in Figure 4-8.

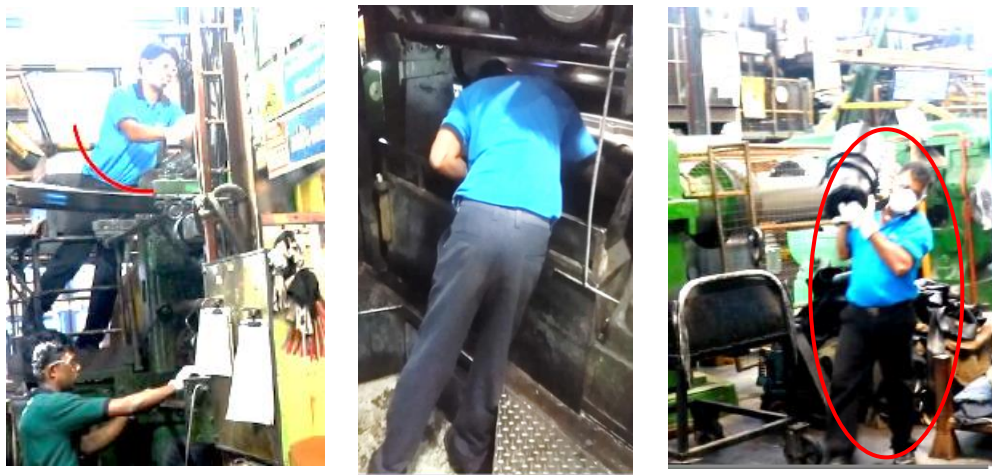


Figure 4-8: Rubber layer calandering operation

Table 4-11: NMQ – Layer calander operation

| Total number of People involved in the job | Musculoskeletal symptoms | Number of people with symptoms in last 12 months |     | Number of people with symptoms in last 7 days |     | Number of people who had difficulty performing normal activities in the last 12 months |     | Number of people who think work-related activities are the reason for this |     |
|--------------------------------------------|--------------------------|--------------------------------------------------|-----|-----------------------------------------------|-----|----------------------------------------------------------------------------------------|-----|----------------------------------------------------------------------------|-----|
|                                            |                          | Amount                                           | %   | Amount                                        | %   | Amount                                                                                 | %   | Amount                                                                     | %   |
| 194                                        | Neck                     | 112                                              | 58% | 122                                           | 63% | 98                                                                                     | 51% | 94                                                                         | 48% |
|                                            | Shoulders                | 146                                              | 75% | 180                                           | 93% | 122                                                                                    | 63% | 122                                                                        | 63% |
|                                            | Upper arms               | 152                                              | 78% | 178                                           | 92% | 132                                                                                    | 68% | 128                                                                        | 66% |
|                                            | Elbows                   | 89                                               | 46% | 169                                           | 87% | 41                                                                                     | 21% | 40                                                                         | 21% |
|                                            | Forearms                 | 94                                               | 48% | 138                                           | 71% | 56                                                                                     | 29% | 48                                                                         | 25% |
|                                            | Wrists                   | 112                                              | 58% | 189                                           | 97% | 85                                                                                     | 44% | 62                                                                         | 32% |
|                                            | Hands                    | 116                                              | 60% | 164                                           | 85% | 39                                                                                     | 20% | 39                                                                         | 20% |
|                                            | Fingers                  | 45                                               | 23% | 80                                            | 41% | 0                                                                                      | 0%  | 0                                                                          | 0%  |
|                                            | Upper/Middle back        | 149                                              | 77% | 168                                           | 87% | 117                                                                                    | 60% | 116                                                                        | 60% |
|                                            | Lower back               | 143                                              | 74% | 173                                           | 89% | 96                                                                                     | 49% | 93                                                                         | 48% |
|                                            | Hips or buttocks         | 62                                               | 32% | 114                                           | 59% | 0                                                                                      | 0%  | 0                                                                          | 0%  |
|                                            | Upper legs               | 81                                               | 42% | 161                                           | 83% | 49                                                                                     | 25% | 46                                                                         | 24% |
|                                            | Knees                    | 149                                              | 77% | 175                                           | 90% | 94                                                                                     | 48% | 88                                                                         | 45% |
|                                            | Ankles or feet           | 161                                              | 83% | 182                                           | 94% | 103                                                                                    | 53% | 100                                                                        | 52% |
|                                            | Lower legs               | 38                                               | 20% | 84                                            | 43% | 2                                                                                      | 1%  | 0                                                                          | 0%  |

#### 4.2.5 Green tyre building cell

The green tyre building cell is the largest cell in the manufacturing process, and many major processes relevant to the green tyre building process are carried out there. Physical tyre manufacturing is beginning in this cell. It has many activities relevant to tyre building and is classified as follows.

The major operations are the pocket manufacturing process, tyre building, and thread rolling process. NMQ surveys were carried out for the above operations separately, and the above operations operate from separate working teams, and they do not change with other operations.



Figure 4-9: Pocket manufacturing operation

Table 4-12: NMQ- Pocket manufacturing operation

| Total number of People involved in the job | Musculoskeletal symptoms | Number of people with symptoms in last 12 months |     | Number of people with symptoms in last 7 days |     | Number of people who had difficulty performing normal activities in the last 12 months |     | Number of people who think work-related activities are the reason for this |     |
|--------------------------------------------|--------------------------|--------------------------------------------------|-----|-----------------------------------------------|-----|----------------------------------------------------------------------------------------|-----|----------------------------------------------------------------------------|-----|
|                                            |                          | Amount                                           | %   | Amount                                        | %   | Amount                                                                                 | %   | Amount                                                                     | %   |
| 270                                        | Neck                     | 36                                               | 13% | 124                                           | 46% | 5                                                                                      | 2%  | 0                                                                          | 0%  |
|                                            | Shoulders                | 142                                              | 53% | 255                                           | 94% | 21                                                                                     | 8%  | 12                                                                         | 4%  |
|                                            | Upper arms               | 69                                               | 26% | 148                                           | 55% | 14                                                                                     | 5%  | 4                                                                          | 1%  |
|                                            | Elbows                   | 74                                               | 27% | 189                                           | 70% | 22                                                                                     | 8%  | 14                                                                         | 5%  |
|                                            | Forearms                 | 26                                               | 10% | 84                                            | 31% | 0                                                                                      | 0%  | 0                                                                          | 0%  |
|                                            | Wrists                   | 13                                               | 5%  | 45                                            | 17% | 1                                                                                      | 0%  | 0                                                                          | 0%  |
|                                            | Hands                    | 76                                               | 28% | 166                                           | 61% | 9                                                                                      | 3%  | 3                                                                          | 1%  |
|                                            | Fingers                  | 31                                               | 11% | 56                                            | 21% | 0                                                                                      | 0%  | 0                                                                          | 0%  |
|                                            | Upper/Middle back        | 21                                               | 8%  | 71                                            | 26% | 0                                                                                      | 0%  | 0                                                                          | 0%  |
|                                            | Lower back               | 79                                               | 29% | 198                                           | 73% | 52                                                                                     | 19% | 19                                                                         | 7%  |
|                                            | Hips or buttocks         | 22                                               | 8%  | 81                                            | 30% | 0                                                                                      | 0%  | 0                                                                          | 0%  |
|                                            | Upper legs               | 17                                               | 6%  | 48                                            | 18% | 4                                                                                      | 1%  | 1                                                                          | 0%  |
|                                            | Knees                    | 95                                               | 35% | 162                                           | 60% | 25                                                                                     | 9%  | 11                                                                         | 4%  |
|                                            | Ankles or feet           | 124                                              | 46% | 238                                           | 88% | 71                                                                                     | 26% | 42                                                                         | 16% |
|                                            | Lower legs               | 79                                               | 29% | 183                                           | 68% | 11                                                                                     | 4%  | 4                                                                          | 1%  |

Considering tyre building operation, operator postures mainly affect their discomfort level. Figure 4-10 shows the tyre building machine operator's postures.

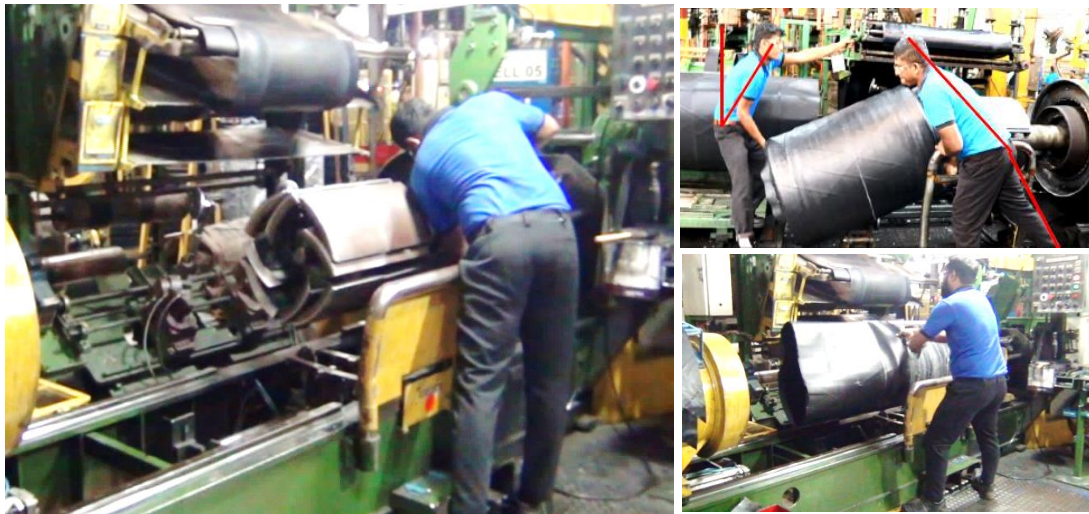


Figure 4-10: Tyre building machine operation

Table 4-13: NMQ- Tyre building process

| Total number of People involved in the job | Musculoskeletal symptoms | Number of people with symptoms in last 12 months |     | Number of people with symptoms in last 7 days |     | Number of people who had difficulty performing normal activities in the last 12 months |     | Number of people who think work-related activities are the reason for this |     |
|--------------------------------------------|--------------------------|--------------------------------------------------|-----|-----------------------------------------------|-----|----------------------------------------------------------------------------------------|-----|----------------------------------------------------------------------------|-----|
|                                            |                          | Amount                                           | %   | Amount                                        | %   | Amount                                                                                 | %   | Amount                                                                     | %   |
| 284                                        | Neck                     | 116                                              | 41% | 164                                           | 58% | 86                                                                                     | 30% | 41                                                                         | 14% |
|                                            | Shoulders                | 248                                              | 87% | 272                                           | 96% | 44                                                                                     | 15% | 21                                                                         | 7%  |
|                                            | Upper arms               | 133                                              | 47% | 149                                           | 52% | 263                                                                                    | 93% | 244                                                                        | 86% |
|                                            | Elbows                   | 139                                              | 49% | 194                                           | 68% | 98                                                                                     | 35% | 52                                                                         | 18% |
|                                            | Forearms                 | 74                                               | 26% | 102                                           | 36% | 60                                                                                     | 21% | 31                                                                         | 11% |
|                                            | Wrists                   | 45                                               | 16% | 97                                            | 34% | 12                                                                                     | 4%  | 0                                                                          | 0%  |
|                                            | Hands                    | 122                                              | 43% | 192                                           | 68% | 108                                                                                    | 38% | 58                                                                         | 20% |
|                                            | Fingers                  | 29                                               | 10% | 63                                            | 22% | 5                                                                                      | 2%  | 0                                                                          | 0%  |
|                                            | Upper/Middle back        | 231                                              | 81% | 252                                           | 89% | 212                                                                                    | 75% | 201                                                                        | 71% |
|                                            | Lower back               | 244                                              | 86% | 261                                           | 92% | 208                                                                                    | 73% | 186                                                                        | 65% |
|                                            | Hips or buttocks         | 48                                               | 17% | 93                                            | 33% | 12                                                                                     | 4%  | 0                                                                          | 0%  |
|                                            | Upper legs               | 88                                               | 31% | 102                                           | 36% | 24                                                                                     | 8%  | 2                                                                          | 1%  |
|                                            | Knees                    | 163                                              | 57% | 179                                           | 63% | 132                                                                                    | 46% | 79                                                                         | 28% |
|                                            | Ankles or feet           | 224                                              | 79% | 236                                           | 83% | 201                                                                                    | 71% | 158                                                                        | 56% |
|                                            | Lower legs               | 106                                              | 37% | 182                                           | 64% | 67                                                                                     | 24% | 12                                                                         | 4%  |

Thread rolling process is carried out by a single operator throughout the operation. Operator's postures are shown in Figure 4-11. Furthermore, they have to get the assistance of a helper for this activity sometimes. However, the helper's feedback was not considered in NMQ because it's not included in standard operation.



Figure 4-11: Thread rolling process

Table 4-14: NMQ- Thread rolling process

| Total number of People involved in the job | Musculoskeletal symptoms | Number of people with symptoms in last 12 months |     | Number of people with symptoms in last 7 days |     | Number of people who had difficulty performing normal activities in the last 12 months |     | Number of people who think work-related activities are the reason for this |     |
|--------------------------------------------|--------------------------|--------------------------------------------------|-----|-----------------------------------------------|-----|----------------------------------------------------------------------------------------|-----|----------------------------------------------------------------------------|-----|
|                                            |                          | Amount                                           | %   | Amount                                        | %   | Amount                                                                                 | %   | Amount                                                                     | %   |
| 295                                        | Neck                     | 41                                               | 14% | 146                                           | 49% | 22                                                                                     | 7%  | 11                                                                         | 4%  |
|                                            | Shoulders                | 102                                              | 35% | 128                                           | 43% | 46                                                                                     | 16% | 18                                                                         | 6%  |
|                                            | Upper arms               | 92                                               | 31% | 139                                           | 47% | 39                                                                                     | 13% | 19                                                                         | 6%  |
|                                            | Elbows                   | 72                                               | 24% | 98                                            | 33% | 42                                                                                     | 14% | 16                                                                         | 5%  |
|                                            | Forearms                 | 26                                               | 9%  | 88                                            | 30% | 12                                                                                     | 4%  | 2                                                                          | 1%  |
|                                            | Wrists                   | 6                                                | 2%  | 61                                            | 21% | 1                                                                                      | 0%  | 0                                                                          | 0%  |
|                                            | Hands                    | 62                                               | 21% | 242                                           | 82% | 26                                                                                     | 9%  | 11                                                                         | 4%  |
|                                            | Fingers                  | 38                                               | 13% | 55                                            | 19% | 14                                                                                     | 5%  | 3                                                                          | 1%  |
|                                            | Upper/Middle back        | 8                                                | 3%  | 87                                            | 29% | 2                                                                                      | 1%  | 0                                                                          | 0%  |
|                                            | Lower back               | 119                                              | 40% | 122                                           | 41% | 66                                                                                     | 22% | 24                                                                         | 8%  |
|                                            | Hips or buttocks         | 21                                               | 7%  | 81                                            | 27% | 5                                                                                      | 2%  | 0                                                                          | 0%  |
|                                            | Upper legs               | 6                                                | 2%  | 48                                            | 16% | 2                                                                                      | 1%  | 0                                                                          | 0%  |
|                                            | Knees                    | 91                                               | 31% | 141                                           | 48% | 45                                                                                     | 15% | 15                                                                         | 5%  |
|                                            | Ankles or feet           | 144                                              | 49% | 136                                           | 46% | 82                                                                                     | 28% | 33                                                                         | 11% |
|                                            | Lower legs               | 36                                               | 12% | 148                                           | 50% | 6                                                                                      | 2%  | 1                                                                          | 0%  |

#### 4.2.6 Tyre curing process

Tyre curing cell is a critical cell among other manufacturing cells and is considered a tyre output cell before final grading. In this cell environment, conditions badly affect their efficiency due to hot environments condition. A semi-automated machine performed the tyre curing process and tyre loading and unloading activities are operated with direct human involvement.



Figure 4-12: Tyre curing process

Table 4-15: NMQ – Tyre curing process

| Total number of People involved in the job | Musculoskeletal symptoms | Number of people with symptoms in last 12 months |       | Number of people with symptoms in last 7 days |     | Number of people who had difficulty performing normal activities in the last 12 months |       | Number of people who think work-related activities are the reason for this |     |
|--------------------------------------------|--------------------------|--------------------------------------------------|-------|-----------------------------------------------|-----|----------------------------------------------------------------------------------------|-------|----------------------------------------------------------------------------|-----|
|                                            |                          | Amount                                           | %     | Amount                                        | %   | Amount                                                                                 | %     | Amount                                                                     | %   |
| 482                                        | Neck                     | 88                                               | 18.3% | 132                                           | 27% | 43                                                                                     | 8.9%  | 23                                                                         | 5%  |
|                                            | Shoulders                | 368                                              | 76.3% | 466                                           | 97% | 312                                                                                    | 64.7% | 306                                                                        | 63% |
|                                            | Upper arms               | 156                                              | 32.4% | 196                                           | 41% | 108                                                                                    | 22.4% | 104                                                                        | 22% |
|                                            | Elbows                   | 137                                              | 28.4% | 198                                           | 41% | 111                                                                                    | 23.0% | 42                                                                         | 9%  |
|                                            | Forearms                 | 51                                               | 10.6% | 86                                            | 18% | 32                                                                                     | 6.6%  | 0                                                                          | 0%  |
|                                            | Wrists                   | 394                                              | 81.7% | 413                                           | 86% | 378                                                                                    | 78.4% | 372                                                                        | 77% |
|                                            | Hands                    | 404                                              | 83.8% | 438                                           | 91% | 385                                                                                    | 79.9% | 381                                                                        | 79% |
|                                            | Fingers                  | 52                                               | 10.8% | 89                                            | 18% | 12                                                                                     | 2.5%  | 0                                                                          | 0%  |
|                                            | Upper/Middle back        | 312                                              | 64.7% | 363                                           | 75% | 287                                                                                    | 59.5% | 277                                                                        | 57% |
|                                            | Lower back               | 401                                              | 83.2% | 468                                           | 97% | 385                                                                                    | 79.9% | 385                                                                        | 80% |
|                                            | Hips or buttocks         | 105                                              | 21.8% | 155                                           | 32% | 41                                                                                     | 8.5%  | 8                                                                          | 2%  |
|                                            | Upper legs               | 16                                               | 3.3%  | 77                                            | 16% | 0                                                                                      | 0.0%  | 0                                                                          | 0%  |
|                                            | Knees                    | 28                                               | 5.8%  | 126                                           | 26% | 11                                                                                     | 2.3%  | 0                                                                          | 0%  |
|                                            | Ankles or feet           | 11                                               | 2.3%  | 58                                            | 12% | 2                                                                                      | 0.4%  | 0                                                                          | 0%  |
|                                            | Lower legs               | 19                                               | 3.9%  | 88                                            | 18% | 2                                                                                      | 0.4%  | 0                                                                          | 0%  |

#### 4.2.7 Tyre inspection process/ final QC cell

The final quality assurance (QC) cell is the last cell of the tyre manufacturing process and is the most valuable cell relevant to the quality of the product. According to the high-quality inspection process, the worker should work without any ergonomic issues. The tyre repair, trimming, painting, and inspection process were carried out within this cell. Above all activities are performed by the same worker. Many QC lines are running depending on the production capacity. The NMQ survey was carried out above that was relevant to all activities in this operating cell.



Figure 4-13: Tyre inspection process

Table 4-16: NMQ – Tyre inspection process /final QC cell

| Total number of People involved in the job | Musculoskeletal symptoms | Number of people with symptoms in last 12 months |       | Number of people with symptoms in last 7 days |     | Number of people who had difficulty performing normal activities in the last 12 months |       | Number of people who think work-related activities are the reason for this |     |
|--------------------------------------------|--------------------------|--------------------------------------------------|-------|-----------------------------------------------|-----|----------------------------------------------------------------------------------------|-------|----------------------------------------------------------------------------|-----|
|                                            |                          | Amount                                           | %     | Amount                                        | %   | Amount                                                                                 | %     | Amount                                                                     | %   |
| 448                                        | Neck                     | 385                                              | 85.9% | 392                                           | 88% | 371                                                                                    | 82.8% | 361                                                                        | 81% |
|                                            | Shoulders                | 404                                              | 90.2% | 424                                           | 95% | 383                                                                                    | 85.5% | 381                                                                        | 85% |
|                                            | Upper arms               | 378                                              | 84.4% | 396                                           | 88% | 266                                                                                    | 59.4% | 255                                                                        | 57% |
|                                            | Elbows                   | 116                                              | 25.9% | 128                                           | 29% | 108                                                                                    | 24.1% | 101                                                                        | 23% |
|                                            | Forearms                 | 125                                              | 27.9% | 146                                           | 33% | 112                                                                                    | 25.0% | 82                                                                         | 18% |
|                                            | Wrists                   | 91                                               | 20.3% | 173                                           | 39% | 86                                                                                     | 19.2% | 48                                                                         | 11% |
|                                            | Hands                    | 181                                              | 40.4% | 219                                           | 49% | 176                                                                                    | 39.3% | 116                                                                        | 26% |
|                                            | Fingers                  | 76                                               | 17.0% | 158                                           | 35% | 62                                                                                     | 13.8% | 11                                                                         | 2%  |
|                                            | Upper/Middle back        | 303                                              | 67.6% | 378                                           | 84% | 294                                                                                    | 65.6% | 272                                                                        | 61% |
|                                            | Lower back               | 402                                              | 89.7% | 422                                           | 94% | 391                                                                                    | 87.3% | 381                                                                        | 85% |
|                                            | Hips or buttocks         | 366                                              | 81.7% | 378                                           | 84% | 361                                                                                    | 80.6% | 359                                                                        | 80% |
|                                            | Upper legs               | 198                                              | 44.2% | 249                                           | 56% | 103                                                                                    | 23.0% | 71                                                                         | 16% |
|                                            | Knees                    | 105                                              | 23.4% | 194                                           | 43% | 66                                                                                     | 14.7% | 28                                                                         | 6%  |
|                                            | Ankles or feet           | 35                                               | 7.8%  | 85                                            | 19% | 12                                                                                     | 2.7%  | 0                                                                          | 0%  |
|                                            | Lower legs               | 42                                               | 9.4%  | 108                                           | 24% | 18                                                                                     | 4.0%  | 6                                                                          | 1%  |

## 5.0 DATA ANALYSIS AND RESULTS

In this chapter, NMQ data was taken to analyze the worker's MSD symptoms relevant to job tasks. The NMQ survey method is the best data collection process and is used for further analysis. Also, discomfort posture or activities could be identified from NMQ without a detailed analysis. In this NMQ survey, fifteen body parts have been considered to analyze their discomfort. After the analysis of the data, the highlighted activities were carried out for further investigation using REBA.

### 5.1 NMQ Data Analysis

The NMQ data analysis process was carried out to define the major activities /job tasks of the tyre manufacturing plant earlier. All NMQ data were collected and then analyzed and identified the significant pain activity occurring relevant to the whole-body parts.

Table 5-1: Symptoms of worker's percentage

| Nos | Major Operations               | Cells              | Max % of symptoms workers |
|-----|--------------------------------|--------------------|---------------------------|
| 1   | Forklift operation             | Material unloading | 50                        |
| 2   | Stock taking operation         | Material unloading | 100                       |
| 3   | Rubber Mixer operating process | Mixing             | 46                        |
| 4   | Mill Operating process         | Mixing             | 99                        |
| 5   | Batch off feeding process      | Mixing             | 98                        |
| 6   | Final batch unloading Process  | Mixing             | 47.5                      |
| 7   | Bead-making process            | Bead               | 90                        |
| 8   | Apex apply process             | Bead               | 50                        |
| 9   | Lifting machine operation      | SFG                | 100                       |
| 10  | Bias cutter operation          | SFG                | 96                        |
| 11  | Layer calander operation       | Calander           | 97                        |
| 12  | Pocket manufacturing operation | Tyre building      | 94                        |
| 13  | Tyre building process          | Tyre building      | 96                        |
| 14  | Thread rolling process         | Tyre building      | 49                        |
| 15  | Tyre curing process            | Tyre curing        | 97                        |
| 16  | Tyre inspection process        | QA                 | 95                        |

According to previous research, nobody has performed further analysis of low-frequency discomfort or pain. In addition, some researchers used specific percentages of symptoms of their activities or tasks that are further analyzed as REBA [5]. According to previous studies,

researchers have used 50% or 60% value of worker's symptoms percentage relevant to all periods as 7 days and one year. If the percentage of symptoms for all symptoms is not exceeded 50% or 60%, no further analysis was considered [5] [6]. This percentage depends on their judgment. When referring Table 5-1 research data, five activities were shown as below 50% of workers' symptoms percentage. Therefore, these activities were not further analyzed relevant to ergonomics and the activities in Table 5-2 were analyzed for REBA analysis.

Table 5-2: REBA analysis activities/tasks

| Nos | Major Operations                       | Cell               |
|-----|----------------------------------------|--------------------|
| 1   | Stock taking Operation                 | Material unloading |
| 2   | Mill Operating Process                 | Mixing             |
| 3   | Batch off feeding Process              | Mixing             |
| 4   | Bead making process                    | Bead               |
| 5   | Lifting machine operation              | SFG                |
| 6   | Bias cutter operation                  | SFG                |
| 7   | Layer calander operation               | Calander           |
| 8   | Pocket manufacturing operation         | Tyre building      |
| 9   | Tyre building process                  | Tyre building      |
| 10  | Tyre curing process                    | Tyre curing        |
| 11  | Tyre inspection process /Final QC cell | QA                 |

## 5.2 Analysis of the Preferred Hand

In manufacturing plants, various types of workers work with the same tasks, which have not varied relevant to product capacity or output quality. As an example, most of the workers used their right hand as their preferred hand. However, some workers used their left hand as their preferred hand to perform their job activities. In this research, the preferred hand technique was analyzed with the workers and their job activities. Figure 5-1 is shown as an example.



Figure 5-1: Calander winding process

Also, preferred hand-analyzed data are shown in Tables 5-3, and these results are related to the REBA analysis process. According to Table 5-3, most workers used the right hand as their preferred hand. In the further REBA analysis process, the left hand was ignored in the investigation process.

Table 5-3: Preferred hand analysis data

| <b>Nos</b> | <b>Major Operations</b>        | <b>Cell</b>        | <b>% Of preferred hand -Right</b> |
|------------|--------------------------------|--------------------|-----------------------------------|
| 1          | Forklift Operating process     | Material unloading | 100                               |
| 2          | Stock taking Operating process | Material unloading | 99.1                              |
| 3          | Rubber Mixer Operating Process | Mixing             | 98.5                              |
| 4          | Mill Operating Process         | Mixing             | 99                                |
| 5          | Batch off feeding Process      | Mixing             | 99.2                              |
| 6          | Final batch unloading Process  | Mixing             | 99.4                              |
| 7          | Bead making process            | Bead               | 99.8                              |
| 8          | Apex apply process             | Bead               | 100                               |
| 9          | Lifting machine operation      | SFG                | 99.6                              |
| 10         | Bias cutter operation          | SFG                | 99.3                              |
| 11         | Layer calander operation       | Calander           | 99.1                              |
| 12         | Pocket manufacturing operation | Tyre building      | 98.2                              |
| 13         | Tyre building process          | Tyre building      | 99.4                              |
| 14         | Thread rolling process         | Tyre building      | 99.2                              |
| 15         | Tyre curing process            | Tyre curing        | 99.3                              |
| 16         | Tyre inspection process        | QA                 | 99.1                              |

### 5.3 REBA Analysis

REBA analysis was conducted relevant to the NMQ results. Eleven activities were selected out of sixteen for REBA analysis. Eleven activities were selected based on the maximum percentage of symptoms of workers, and it is considered above the 50% of symptoms of workers relevant to any body parts or periods. This 50% specific value was selected based on past literature and judgment of discomfort.

The REBA method was used as an analysis tool and was directed to evaluate the workers' awkward postures, muscle pain, and load activities relevant to their job tasks. All analyzed job activities have the potential to contribute to musculoskeletal disorders, as indicated by the NMQ survey. Based on observation, taking photos and videos were used to analyze the postures relevant to REBA calculation. Each task was analyzed and scored. In this analysis,

REBA was conducted considering the preferred hand base in Table 5-3. Ergonomic risk screening was used to analyze the score and sample of the calculation shown in Figure 5-2. The tasks analyzed and the REBA score summarize the results are shown in Tables 5-5.

| <b>Ergonomic Risk Screening</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                     |                                                     | FS-CS-42-4.0 |       |                   |         |   |                 |                    |     |          |                      |     |             |                                                     |      |           |                                |       |                |                                        |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|--------------|-------|-------------------|---------|---|-----------------|--------------------|-----|----------|----------------------|-----|-------------|-----------------------------------------------------|------|-----------|--------------------------------|-------|----------------|----------------------------------------|
| REBA (Rapid Entire Body Assessment) - Digital Worksheet                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                     |                                                     |              |       |                   |         |   |                 |                    |     |          |                      |     |             |                                                     |      |           |                                |       |                |                                        |
| Site: Tyre manufacturing plant<br>Assessment Version: Initial<br>Assessment Date: April 4, 2022                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Department: Production<br>Work Station: Tyre inspection<br>Task / Activity: Tyre trimming, repairing and inspection | Task / Activity Details:                            |              |       |                   |         |   |                 |                    |     |          |                      |     |             |                                                     |      |           |                                |       |                |                                        |
| <a href="#">RESET/CLEAR FORM</a>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                     |                                                     |              |       |                   |         |   |                 |                    |     |          |                      |     |             |                                                     |      |           |                                |       |                |                                        |
| <div style="display: flex; justify-content: space-between;"> <div style="width: 48%;"> <p><b>A. Neck, Trunk, and Leg Analysis</b></p> <p><b>Step 1: Locate Neck Position</b></p> <p>Neck Score: <span style="border: 1px solid black; padding: 2px;">2</span></p> <p><b>Step 2: Locate Trunk Position</b></p> <p>Trunk Score: <span style="border: 1px solid black; padding: 2px;">4</span></p> <p><b>Step 3: Legs</b></p> <p>Legs Score: <span style="border: 1px solid black; padding: 2px;">4</span></p> <p><b>Step 4: Use Table A to find Score (Automatic)</b></p> <p>Posture Score for Neck, Trunk &amp; Legs: <span style="border: 1px solid black; padding: 2px;">8</span></p> <p><b>Step 5: Add Force / Load Score</b></p> <p>Force / Load Score: <span style="border: 1px solid black; padding: 2px;">1</span></p> <p><b>Step 6: Calculate Score A (Automatic)</b></p> <p><b>SCORE A</b> <span style="border: 1px solid black; padding: 2px;">9</span></p> </div> <div style="width: 48%;"> <p><b>B. Arm and Wrist Analysis</b></p> <p><b>Step 7: Locate Upper Arm Position</b></p> <p>Upper Arm Score: <span style="border: 1px solid black; padding: 2px;">2</span></p> <p><b>Step 8: Locate Lower Arm Position</b></p> <p>Lower Arm Score: <span style="border: 1px solid black; padding: 2px;">2</span></p> <p><b>Step 9: Locate Wrist Position</b></p> <p>Wrist Score: <span style="border: 1px solid black; padding: 2px;">2</span></p> <p><b>Step 10: Use Table B to find Score (Automatic)</b></p> <p>Posture Score for Arm &amp; Wrist: <span style="border: 1px solid black; padding: 2px;">3</span></p> <p><b>Step 11: Add Coupling Score</b></p> <p>Coupling Score: <span style="border: 1px solid black; padding: 2px;">1</span></p> <p><b>Step 12: Calculate Score B (Automatic)</b></p> <p><b>SCORE B</b> <span style="border: 1px solid black; padding: 2px;">4</span></p> <p><b>Step 13: Calculate Activity Score</b></p> <p>Activity Score: <span style="border: 1px solid black; padding: 2px;">1</span></p> </div> </div> <div style="text-align: center; margin-top: 10px;"> <p><b>REBA TOTAL SCORE</b></p> <p><span style="border: 2px solid red; padding: 5px; font-size: 1.5em; color: white;">11</span></p> <p style="color: red; font-weight: bold;">Very High Risk<br/>Investigate &amp; implement change quickly</p> </div> |                                                                                                                     |                                                     |              |       |                   |         |   |                 |                    |     |          |                      |     |             |                                                     |      |           |                                |       |                |                                        |
| <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th>Score</th> <th>Level of MSD Risk</th> <th>Comment</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>negligible risk</td> <td>no action required</td> </tr> <tr> <td>2-3</td> <td>low risk</td> <td>change may be needed</td> </tr> <tr> <td>4-7</td> <td>medium risk</td> <td>further investigation, consider implementing change</td> </tr> <tr> <td>8-10</td> <td>high risk</td> <td>investigate &amp; implement change</td> </tr> <tr> <td>11-15</td> <td>very high risk</td> <td>investigate &amp; implement change quickly</td> </tr> </tbody> </table>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                     |                                                     |              | Score | Level of MSD Risk | Comment | 1 | negligible risk | no action required | 2-3 | low risk | change may be needed | 4-7 | medium risk | further investigation, consider implementing change | 8-10 | high risk | investigate & implement change | 11-15 | very high risk | investigate & implement change quickly |
| Score                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Level of MSD Risk                                                                                                   | Comment                                             |              |       |                   |         |   |                 |                    |     |          |                      |     |             |                                                     |      |           |                                |       |                |                                        |
| 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | negligible risk                                                                                                     | no action required                                  |              |       |                   |         |   |                 |                    |     |          |                      |     |             |                                                     |      |           |                                |       |                |                                        |
| 2-3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | low risk                                                                                                            | change may be needed                                |              |       |                   |         |   |                 |                    |     |          |                      |     |             |                                                     |      |           |                                |       |                |                                        |
| 4-7                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | medium risk                                                                                                         | further investigation, consider implementing change |              |       |                   |         |   |                 |                    |     |          |                      |     |             |                                                     |      |           |                                |       |                |                                        |
| 8-10                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | high risk                                                                                                           | investigate & implement change                      |              |       |                   |         |   |                 |                    |     |          |                      |     |             |                                                     |      |           |                                |       |                |                                        |
| 11-15                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | very high risk                                                                                                      | investigate & implement change quickly              |              |       |                   |         |   |                 |                    |     |          |                      |     |             |                                                     |      |           |                                |       |                |                                        |

Figure 5-2: Ergonomic risk screening

Ergonomic risk screening is a digital worksheet for rapid assessment of the whole body (REBA) and it is an easy method for the REBA calculation relevant to postures. In the REBA calculation process, all postures must be identified through observation, capture, or video. This research used these three criteria to identify the posture relevant to job tasks.

When analyzing the REBA score, the risk level and action were selected relevant to the REBA score and are given in the REBA action level table (Table 5-4).

Table 5-4: REBA action level

| Action level | REBA score | Risk level | Action          |
|--------------|------------|------------|-----------------|
| 0            | 1          | Negligible | Not necessary   |
| 1            | 2-3        | Low        | Maybe necessary |
| 2            | 4-7        | Medium     | Necessary       |
| 3            | 8-10       | High       | Necessary soon  |
| 4            | 11-15      | Very high  | Necessary NOW   |

Table 5-5: REBA score of operations

| Nos | Major Operations               | REBA Score | Level of MSD risk |
|-----|--------------------------------|------------|-------------------|
| 1   | Stock taking Operation         | 9          | High              |
| 2   | Mill Operating Process         | 11         | Very high         |
| 3   | Batch off feeding Process      | 8          | High              |
| 4   | Bead making process            | 7          | Medium            |
| 5   | lifting machine operation      | 11         | Very high         |
| 6   | Bias cutter operation          | 10         | High              |
| 7   | Layer calander operation       | 12         | Very high         |
| 8   | Pocket manufacturing operation | 7          | Medium            |
| 9   | Tyre building process          | 11         | Very high         |
| 10  | Tyre curing process            | 12         | Very high         |
| 11  | Tyre inspection process        | 11         | Very high         |

All workers' postures were involved in the REBA analysis, and overbending, turning, twisting, over-neck moving, and the use of the hands and wrist directly affected the REBA score values. Additionally, force and hand grip were considered. Considering this study, the REBA score for 11 jobs tasks were two 7, one 8, one 9, one 10, four 11, and other 12. The level of MSD risks was indicated with the REBA score value. 1-6 values have not appeared in the results and the lowest score value was shown as 7 and as risk level consider as medium and requires taking the necessary action. Scores 8,9, and 10 activities were considered high-risk activities and action should be taken immediately for them. Also, scores 11 & 12 job activities were considered very high risk and action should be taken now. It is shown in Tables 5-5.

## 5.4 Comparison of REBA Results and NMQ Survey Results

The comparison of the REBA results and the NMQ survey results have similarities due to the same discomfort and is persuaded in Tables 5-6.

Table 5-6: REBA and NMQ results comparison

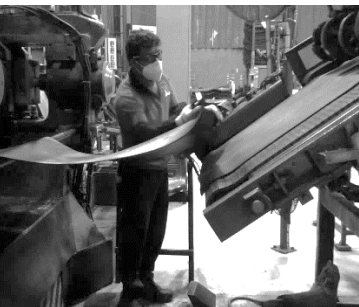
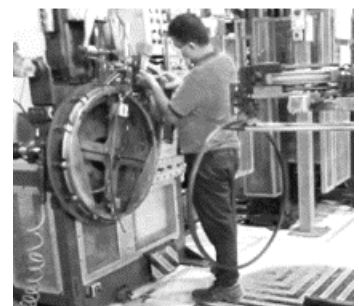
| Major Operations               | Cell               | REBA Score | Level of MSD Risk | NMQ Result-<br>Max % of symptoms |
|--------------------------------|--------------------|------------|-------------------|----------------------------------|
| Stocktaking Operation          | Material unloading | 9          | High              | 100                              |
| Mill Operating Process         | Mixing             | 11         | Very high         | 99                               |
| Batch off feeding Process      | Mixing             | 8          | High              | 98                               |
| Bead making process            | Bead               | 7          | Medium            | 90                               |
| Lifting machine operation      | SFG                | 11         | Very high         | 100                              |
| Bias cutter operation          | SFG                | 10         | High              | 96                               |
| Layer calander operation       | Calander           | 12         | Very high         | 97                               |
| Pocket manufacturing operation | Tyre building      | 7          | Medium            | 94                               |
| Tyre building process          | Tyre building      | 11         | Very high         | 96                               |
| Tyre curing process            | Tyre curing        | 12         | Very high         | 97                               |
| Tyre inspection process        | QA                 | 11         | Very high         | 95                               |

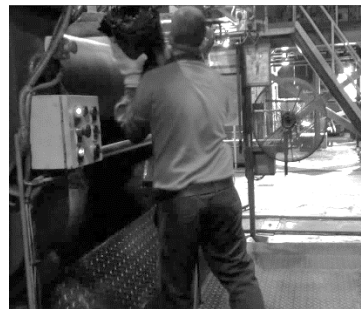
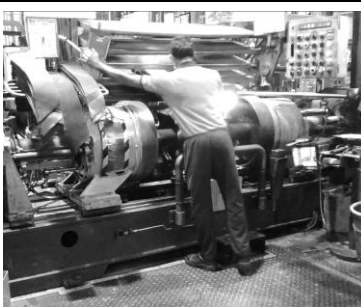
According to the comparison results, the high percentage of symptoms (100%, 99%) of job tasks were highlighted as a very high-risk level of REBA.

## 5.5 Recommended Actions

The recommended actions are considered relevant to the risk level of their job tasks. According to the REBA scores, the recommended actions depend on job tasks and posture. Depending on the operation process, some risk levels can be eliminated through the new types of machinery technology, and some risk levels can be minimized by changing the layout, adjusting the machine height, and using some automation processes. Although some job activities should be added to the job rotation mechanism reduce to discomfort levels. Tables 5-7 show the recommended actions relevant to the risk level to minimize the risk level and the level of discomfort.

Table 5-7: Recommended actions relevant to risk level

| Nos | Major Operation,                                                          | Recommended Actions                                                                                                                          | Current working posture                                                               |
|-----|---------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| 1   | Stock taking Operation<br><br>REBA Score -9<br>Risk level - High          | 1. Identification card should be read at the eye level of the member and recommend to the lifting machine for the required height.           |    |
| 2   | Mill Operating Process<br>REBA Score -11<br>Risk level - very high        | 1. Stock blender can be used to reduce the risk level<br>2. Recommend to Rubber extruder to eliminate the risk                               |    |
| 3   | Batch off feeding Process<br><br>REBA Score -8<br>Risk level - High       | 1. Adjust the machine height considering elbow height<br>2. Propose to feeding conveyer (mill to batch-off) to eliminate the twisting action |   |
| 4   | Bead making process<br><br>REBA Score -7<br>Risk level - Medium           | 1. Adjust the machine height considering elbow height                                                                                        |  |
| 5   | Lifting machine operation<br><br>REBA Score -11<br>Risk level - Very high | 1. Recommend using a very narrow aisle truck to reduce the risk level<br>2. Propose the job rotating methods to minimize the discomfort      |  |

|    |                                                                                |                                                                                                                                                                                                                           |                                                                                       |
|----|--------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| 6  | <p>Bias cutter operation</p> <p>REBA Score -10 Risk level - high</p>           | <p>1. Adjust the machine height considering elbow height</p> <p>2. Propose to change the layout of the Bias cutter table to eliminate the twisting action.</p>                                                            |    |
| 7  | <p>Layer calander operation</p> <p>REBA Score -12 Risk level - Very high</p>   | <p>1. Recommend an auto strip feeding system for the calander rubber feeding process to eliminate manual feeding.</p> <p>2. Proposed an automation system for the ply centering process to eliminate manual centering</p> |    |
| 8  | <p>Pocket manufacturing operation</p> <p>REBA Score -7 Risk level - Medium</p> | <p>1. The foot paddle level should be reduced to the floor level.</p>                                                                                                                                                     |   |
| 9  | <p>Tyre building process</p> <p>REBA Score -11 Risk level - Very high</p>      | <p>1. The level of the foot paddle should be reduced to floor level</p> <p>2. Propose to auto ply cutting system to reduce for awkward hand moments</p> <p>3. Use job rotating methods to minimize the discomfort</p>     |  |
| 10 | <p>Tyre curing process</p> <p>REBA Score -12 Risk level - Very high</p>        | <p>1. Recommend using an automatic tyre loading unloading mechanism</p> <p>2. Recommend the Bag O Matic tyre curing press including vertical chuck loader and auto post curing inflater to minimize the risk level</p>    |  |

|    |                                                                                    |                                                                                                                                                                                                                                                  |                                                                                     |
|----|------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| 11 | <p>Tyre inspection process</p> <p>REBA Score -11</p> <p>Risk level - Very high</p> | <ol style="list-style-type: none"> <li>1. Propose the rotatable table with adjustable height chair.</li> <li>2. Table should be modified with a tilting mechanism</li> <li>3. Propose job-rotation methods to minimize the discomfort</li> </ol> |  |
|----|------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|

## 6.0 CONCLUSIONS

Tyre manufacturing activities create various health and safety issues relevant to ergonomics. Due to the lack of considerations to process, it has not been identified for further analysis. If the tyre manufacturing process is not improved, the risk of muscular disorders will be increased to a dangerous level for workers. The employer should make the appropriate investment and focus on preventing or reducing this risk. To minimize exposure to ergonomic risks, employers should provide support and leadership for the recommended actions identified in this research. Important association between the level of ergonomic risk and work performance, he specified that the exposure was at a very high level. Ergonomic risks reduce the motivation of employees to work and the quality of the product. Poor performance is directly related to employer profit. Therefore, employers and employees must establish methods and solutions to minimize the risk level and approach the best ergonomic culture.

According to this analysis, the tyre manufacturing process has several issues. Sixteen main activities have been used the NMQ survey, and eleven activities were selected for REBA analysis. According to REBA results, it has six numbers of very high risks, three numbers of high risks, and two numbers of medium risk job activities. In the current situation, the results of the ergonomic investigation showed that approximately 53.2% of the workers work with activities of very high risk relevant to ergonomics. It is reflected in the analyzed REBA score data relevant to activities and increasing musculoskeletal discomfort could be induced with the results of the NMQ survey. In this study, non-standard seats, non-adjustable chairs, and awkward postures such as neck flexion, overbending, wrist flexion, awkward leg posture, twisting, over lifting were commonly observed as risk factors.

### 6.1 Key Findings

- In this study, an NMQ survey was carried out for 16 job activities of tyre manufacturing process to identify the prevalence of MSDs. As per the NMQ result, eleven number of process activities were highlighted above 50% of discomfort.
- REBA analysis was carried out that highlighted the risks of MSDs as the result of NMQ. According to the result, eleven activities were evaluated as relevant to REBA scores.
- Stock taking, mill operating, batch off feeding, bead making, lifting machine operation, bias cutting, layer calander operation, pocket manufacturing, tyre building, tyre curing, and tyre inspection job activities were considered for REBA analysis based on the highest percentage of symptoms.

- Six job activities were identified as very high risk and recommended to be taken for immediate actions (necessary now). These manufacturing activities include mill operation, lifting machine operation, layer calander operation, tyre building, tyre curing, and tyre inspection.
- Three job activities were identified as high risk and recommended taking necessary action soon. These tyre manufacturing job activities are stock-taking, batch-off feeding process, and bias cutter operation.
- Two job activities were identified as medium risk and recommended for necessary action to downrate the risk level. These tyre manufacturing job activities are bead-making process and pocket manufacturing operations.
- The recommended actions are proposed to very high, high, and medium risk to reduce the current risk level.

## **6.2 Limitations**

This research design mainly considers the off-road (OTR) and large-range tyre manufacturing processes. Bicycle, motor bike, and passenger car radial tyre manufacturing processes were limited for this research, although main job activities are relevant to the above tyre manufacturing process. Because a few job activities are different from the OTR tyre manufacturing process. NMQ survey was limited to male workers due to the OTR tyre manufacturing process were carried out by male workers. In addition, NMQ results depend on the worker's working period. This research considered the 12-hour working shift.

Additionally, machine conditions, technology use, and working environment are directly related to ergonomic issues. The old machines are not comprised of novel technology and included many manual operations. Machine heat, vibration, and noise mainly were affected to increase the level of discomfort of workers. In this tyre manufacturing process, semiautomated machines, old but upgraded, were used, and these machines do not have abnormal vibration, heat, light level, and noise. These parameters are maintained relevant to ISO safety regulations.

## **6.3 Future Work**

In future work, it is recommended to go through the manufacturing process, including all the tyre manufacturing, such as the bicycle, motor bike, passenger car radial, and truck bus radial, because of some special activities including their manufacturing operation. Additionally,

mixed-working manufacturing environments for male and female workers should be considered in future analysis. Past research has not identified the above considerations.

This research aims to identify high-risk job activities and has considered the recommended action to minimize the risk level. Then future research studies can proceed with implementing standard processes, tools, or methods that facilitate the minimization or elimination of MSD symptoms.

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