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ORIGINAL ARTICLE

DMAIC Steps Application to Improve Ergonomics Problem: A Case Study in Coffee Manufacturing Industry

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Abstract: The health issue related to Musculoskeletal Disorders (MSDs) faced by manufacturing industries' workers affects the work quality and productivity, commonly due to the tasks performed with unsuitable posture. This study was carried out to assess the level of Ergonomics Risk Factors (ERFs) among shop-floor workers in a coffee manufacturing company, located in northern peninsular of Malaysia. The Six Sigma approach was applied based on Define, Measure, Analyze, Improve and Control (DMAIC) steps. Observation, interviews and self-report surveys were conducted in the Define step to identify the potential tasks that lead to the high level of ergonomics risk. In the Measure step, the Rapid Upper Limb Assessment (RULA) and Rapid Entire Body Assessment (REBA) tools were then used to assess the level of ERF on twenty-three tasks that practice at eight workstations. In the Analyze step, assessment results were evaluated, thus identifying that the lifting task (mixing workstation) has the highest ergonomics risk level (score level 11) and follows by root cause identification. Then, the Improve step focuses on a simple invention proposal, where the optimal solution that fulfills the principles of proper height working procedure and reducing excessive force is applied. The proposed solution shows a significant improvement in ergonomics risk level based on the score value of 3. Lastly, the Control step focuses on sustaining the improved version performance by revising the working procedure according to the solution principles proposed in the previous step.

Keywords: Define, Measure, Analyze, Improve and Control (DMAIC), Musculoskeletal Disorders (MSDs), Ergonomics Risk Factors (ERFs), Rapid Upper Limb Assessment (RULA), Rapid Entire Body Assessment (REBA), Case Study.

1.0 INTRODUCTION

When it comes to identifying workplace risks, ergonomics plays a vital role in avoiding or reducing the risk of injuries and accidents by improving workplace society and designing a suitable workplace. Ergonomics is about ensuring people and the tools they associate with that will have a good match. This may include the types of equipment or the environments they used and exposed with. The introduction of ergonomics solutions or inventions makes workers safer, reduces stress and improves their productivity and product quality.

Lack of job-related knowledge and concern about safety and health will increase the risk of accidents among employees at work [1]. It is due to our musculoskeletal system being influenced by the task that has been done. In general, the body is stressed by many factors such as temperature, vibration, heavy lifting, repetitive movement, design of the station, tool design and others [2]. Musculoskeletal or muscular tension is one of the ergonomics concerns that frequently arise in the workplace, linked to human strength and stamina when doing the job [3]. This category of risk factor occurs when uncomfortable working postures are practiced, although no forceful exertion at all [4]. The worker's body position while doing the work is to bend, squat and stand to lift the product. For example, sitting, kneeling and squatting has led to low back pain and lower limb symptoms.

Musculoskeletal Disorders (MSDs) are common illnesses and have been persistently experienced among workers in industrial sectors. MSDs represent a high percentage, particularly in high-risk activities, for example, high task repetition, excessive force and awkward postures of all diagnosed work-related diseases across occupations and worker groups [5]. Workers typically feel an ache in higher body parts, nearly the neck, shoulder, back, forearm and wrist, in most cases of MSDs [6]. The prevalence of MSDs in numerous places in the body depends on the manufacturing process's particular labor. For example, work stances such as leaning over and burden load-lifting are typical in the industry, leading to a high degree of stress on the back. Among Malaysian manufacturing workers, intensive workload and repetitive non-neutral work stances without actual training in ergonomics and well-founded tools had indistinguishable effects on their occupational health [6].

This paper presents a structured ergonomics study that is carried out in the coffee manufacturing industry. The focus of this study is to assess the ergonomic risk factors (ERFs) and a related improvement strategy is then recommended. The DMAIC steps are applied to guide this study in a structured way. This paper is organized as follows. The next section presents the related literature study. It follows Section 3 to present the methodology structure based on the DMAIC steps application. Section 4 presents the results and discussion of case study validation. Finally, the conclusion is presented to summarise the related findings of this study.

2.0 LITERATURE REVIEW

2.1 Musculoskeletal Disorders (MSDs)

The term of MSDs is used to describe disorders relate to muscles, nerves, ligaments, joints, spinal discs, upper and lower limb cartilage, neck and lower back. MSDs are soft tissue injuries caused by unexpected or continual exposure to repetitive movement, force, vibration and awkward posture [7]. MSDs commonly arise depending on the feature of physical motion and mechanical design of work activities when there is a disparity between the job demands and the human physique's ability [8]. MSDs are recorded as the highest work-related injury in the service industry according to the Labour Force Survey 1999 ad hoc module, another source of harmonized results from European surveys [9].

Related studies on MSDs in an industrial section are presented by many researchers. For instance, Kamble et al. [10] studied the prevalence of MSDs and the risk factors involved among the artisans working in the Bagh hand block printing industry in Madhya Pradesh, India. Their study found that the highly prevalent of MSDs are detected in the neck, shoulders, elbows, wrist/forearm, lower back and hips/thighs. Jukariya and Singh [11] reported a study of MSDs risk assessments among goldsmith workers using RULA and REBA tools. Their study found that a significant proportion of the workers are currently working in uncomfortable and painful postures due to a lack of ergonomics knowledge and awareness. Yusof et al. [12] investigated the incidence of MSDs in Malaysia's medical manufacturing company and the risk levels for men's ergonomics risk factors. The findings showed that, due to uncomfortable and extreme postures, workers who conducted manual lifting and lowering labor exhibited symptoms of MSDs and ergonomics risks. The results showed that MSDs were topmost common in the lower back (83.17%), followed by the upper back (4.38%) and right shoulder (3.49 %). Njaka et al. [13] conducted a cross-sectional study to assess the prevalence of MSDs and their associated factors among male and female quarry workers in Ebonyi State, Nigeria. Their results revealed that the majority of the workers had strong symptoms of MSDs, with the most common types being lower back pain and elbow pain. Thus, a recommendation to increase the workers' awareness of ergonomics is needed. Mallapiang et al [14] studied the relationship between work posture and MSDs complaints in Lipa'Sa'be Mandar weavers. Results showed that all respondents experienced complaints of MSDs with a moderate risk work posture. The 27.0%, 56.7% and 16.2% of respondents experienced complaints of mild, moderate and severe MSDs, respectively. Their study concluded that there is a significant relationship between work posture and MSDs complaints. Thetkathuek et al. [15] studied the factors MSDs among workers at the frozen food manufacturing factories in Thailand. This research found that musculoskeletal complaints were found mainly in this dissecting sector, including neck pain, shoulder pain, elbow pain, wrist and hand pain, low back pain, hip and thigh pain, knee pain and foot and ankle pain. The tasks assigned to the dissecting section were repeated and needed to work for the same posture for a long time, causing tension on the neck and shoulders. Gopinadh et al. [16] reported a survey in the health sector that focuses on the pain felt by the workers and its improvement by implementing the right ergonomics. In their study, 289 (73.9 %) of the participants registered musculoskeletal discomfort and 119 (30.4 %) endured pain in more than one part of the body. More than half of the participants, i.e., 232 (59.3 %), were aware of dental work's proper ergonomics.

2.2 DMAIC Methodology

The DMAIC is a well-known problem-solving methodology under the Six Sigma approach. DMAIC is a structured step to guide the problem-solving process, which is defined as Defines, Measures, Analyzes, Improves and Control. Originally, DMAIC's steps focus to solve quality-related problems in the manufacturing industry. Thus this method is generally claimed that able to improve productivity, consumer satisfaction, cycle time management and market share [17].

Recent studies reveal that the success in implementing the Six Sigma approach to optimize industrial operations through the DMAIC methodology application is not restricted to the manufacturing industry and quality problems only. Singh and Rathi [18] reported that in the last 18 years (2000-2018), the implementation of Six Sigma has spread not only in the manufacturing sector but also in other industrial sectors including health care, human resource, financial and education. Many case studies on the application of DMAIC are reported by researchers. For example, Hakimi et al. [19] adopted the DMAIC methodology to guide the quality improvement project in the plain yogurt production process by adjusting the factors affecting the acidity of the yogurt and determining the optimal level of these factors. Uluskan and Oda [20] applied DMAIC steps to analyze door-panel alignment defects seen in built-in ovens manufactured in one household appliances company's plant.

Their study claimed in reducing the overall alignment defects by 67.7%. Maryani et al. [21] presented the reduction of defects in the casting process using the DMAIC method. The method provides a systematic way to find out the major problem root cause of the aluminum castings by using the defect diagnostic approaches and also cause and effect diagram. The data analysis from their study showed that the process capabilities and product performance were improved.

Rifqi et al. [22] used the DMAIC concept to improve the flow of production workshops in an automotive company. The application of DMAIC steps is claimed to provide a better structuring of the entire project, choosing the right improvement solutions. Nai-Chieh et al. [23] employed the DMAIC method to optimize the company's logistical processes and aims to shorten its transportation time and increase its loading efficiency. They claimed that the application of this systematic management method has significantly enhanced the current monthly average dispatch rate as well as improved the company's logistical performance. Dos Santos et al. [24] improved the public procurement process using the DMAIC methodology. This improvement project directly reflects higher efficiency in public procurement management that can reduce expenses and processing of the purchase processes. Jalham and Al-Ashhab [25] reported the success of the DMAIC approach application to reduce the total time of breakdowns during manufacturing. The results of their study showed that the total breakdown hours for each machine during the study period were reduced between 71.0% and 79.1%, while the average breakdown time per month was reduced by about 59.4%.

3.0 DMAIC STEPS APPLICATION

Figure 1 presents the flow of DMAIC steps application to improve the ergonomics problem proposed in this paper. It starts with the Define step, where, observations, interviews and self-report surveys were used to initially identify the existence of ergonomics risk factors (ERF) on the workstation. The next is the Measure step, where all related information from the previous step will be appraised for further ergonomics assessments using the RULA and REBA tools. The Analyze step was then carried out to evaluate which activities are categorized as a high-risk level, thus root cause identification process is followed to be performed. Then, the Improve step focused to strategize the optimal improvements on the targeted workstation(s). Lastly, after the improvement is implemented, the Control step was performed to ensure the benefit of improvement is sustained. The details description of each of the DMAIC steps is presented in the following sub-sections.

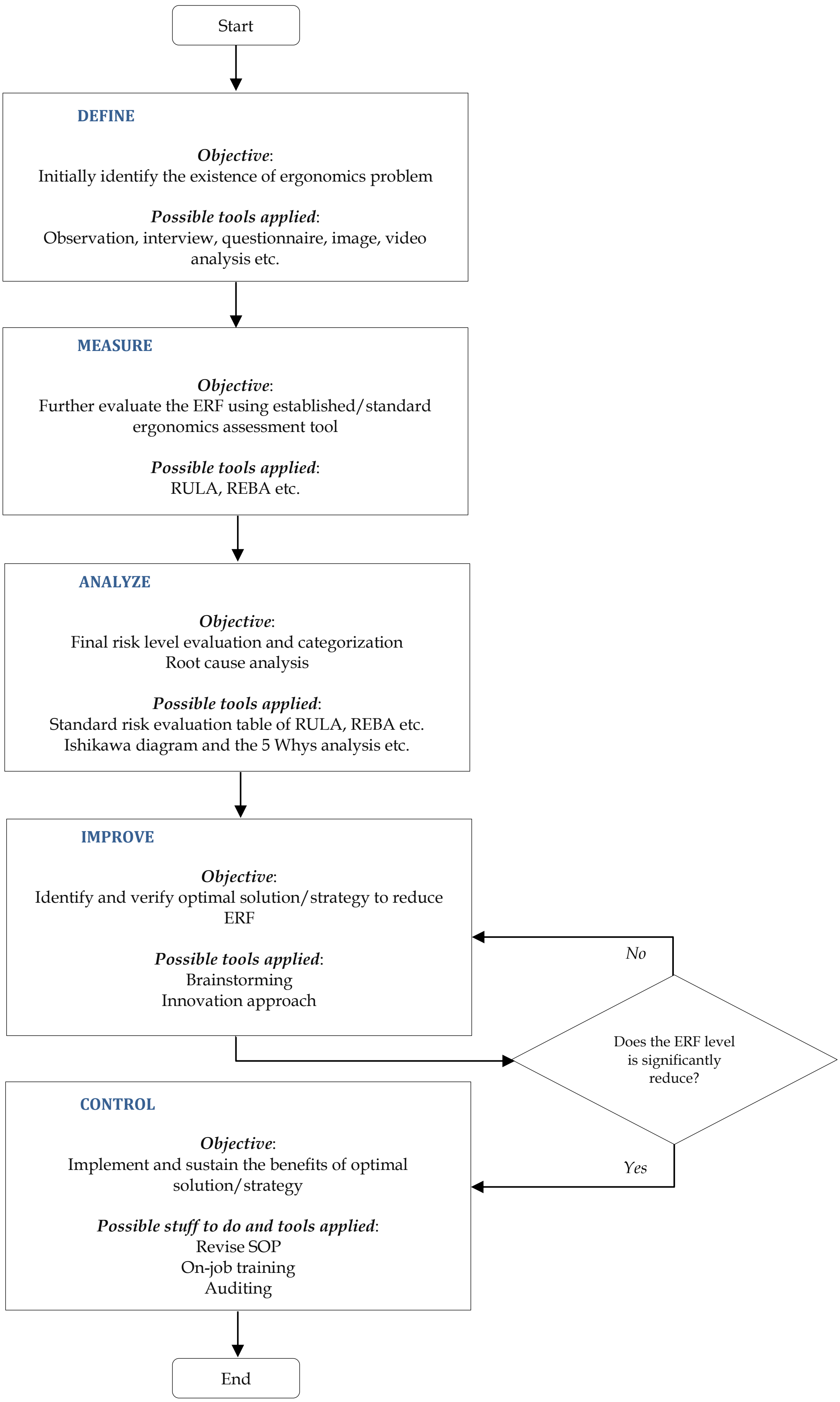
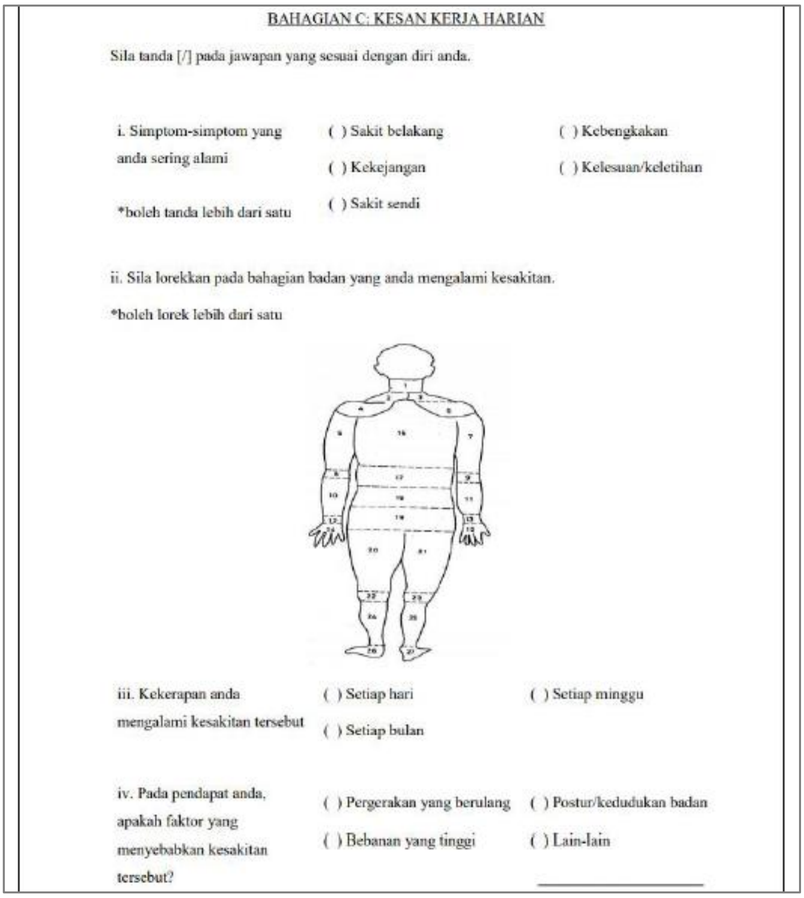


Figure 1: DMAIC steps application flow

3.1 Define

In this step, the focus is given on the initial assessment to identify ERF. Direct evidence from the working areas is analyzed using images and video that are captured and recorded, respectively. The worker's behaviors and their working postures are then closely monitored. Then, semi-structured interviews with related workers are conducted to verify their satisfaction with their current job activities. Few strategic questions were asked, which are related to their work performance, health problems and other interaction factors. Also, a self-report survey (questionnaire-based structure) that needs to be fulfilled by a related employee is given. The questionnaire consists of three sections, noted as Section A: Workers' Details where the workers are needed to fill up related personal details, Section B: Regular Task Information where they need to declare their workstation, the period of work that demands standing and sitting postures and the maximal weight they manage to lift and Section C: Consequences on Musculoskeletal Injury (MSI) where the workers need to highlight their body's part in terms of discomfort or pain during works. The workers must also identify the symptoms and the causes of MSI. Figure 2 shows one of the sections of the questionnaire distributed to the workers.



BAHAGIAN C: KESAN KERJA HARIAN

Sila tanda [/] pada jawapan yang sesuai dengan diri anda.

i. Simptom-simptom yang anda sering alami — ( ) Sakit belakang ( ) Kebengkakan ( ) Kekejangan ( ) Kelesuan/keletihan ( ) Sakit sendi

*boleh tanda lebih dari satu

ii. Sila lorekkan pada bahagian badan yang anda mengalami kesakitan.

*boleh lorek lebih dari satu

iii. Kekerapan anda mengalami kesakitan tersebut — ( ) Setiap hari ( ) Setiap minggu ( ) Setiap bulan

iv. Pada pendapat anda, apakah faktor yang menyebabkan kesakitan tersebut? — ( ) Pergerakan yang berulang ( ) Postur/kedudukan badan ( ) Bebanan yang tinggi ( ) Lain-lain ________________

Figure 2: Questionnaire (Section C)

3.2 Measure

This step focused on further and strategic ergonomics assessments related to workers' body posture using RULA and REBA tools. RULA was used to examine body position to examine the discomfort of the arms. It evaluates the level of musculoskeletal burden in labor that causes a danger to a person's body from the stomach to neck or arms. On the RULA Scoring Sheet, they're given a score decided for each movement to evaluate the risk factors [26]. Figure 3 shows the RULA score sheet applied in this study.

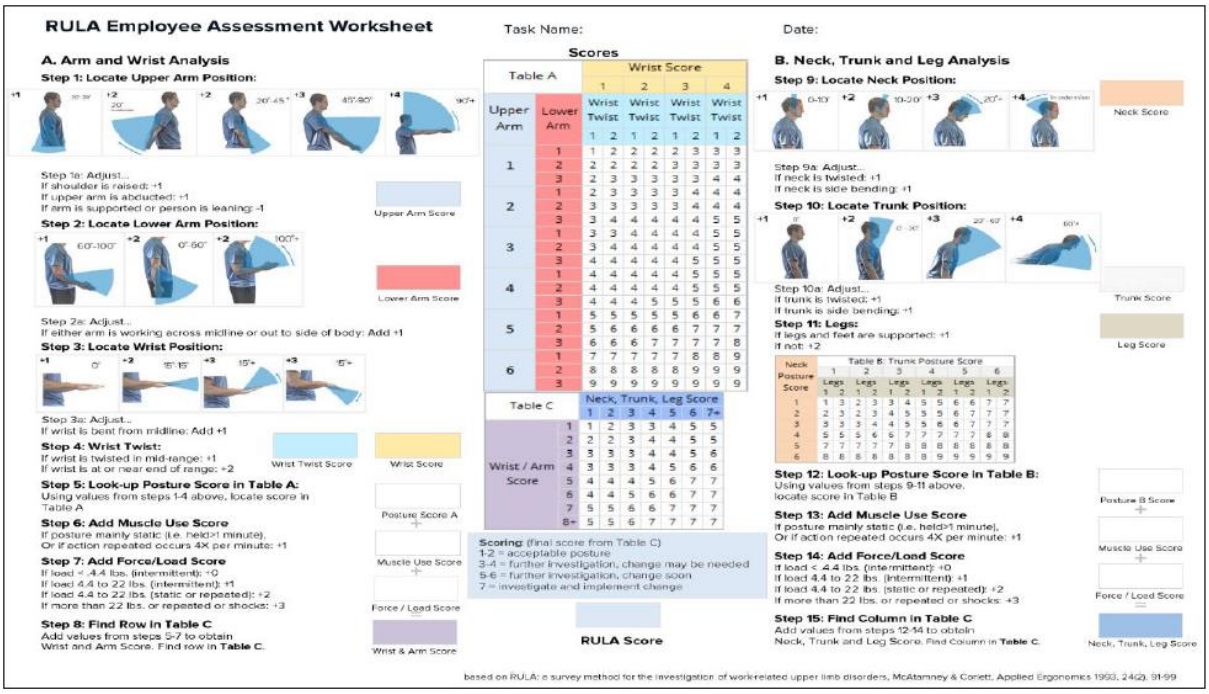


Figure 3: Standard RULA score sheet

Referring to Figure 3, the evaluation measures start in Section A with a score of the upper arm, lower arm, wrist and wrist twist positions, as seen in Table A. The score of Table A is reported in the column labeled Posture Score A. Next, the muscle score and the force/load score are applied to the A number to achieve the wrist and arm value (C score). Meanwhile, Section B describes the inspection of the neck, trunk and leg. Similar to Section A, the scores of each segment of the neck, trunk and leg positions are reported in Table B. Table B's score is documented in the column labeled posture B score together with the muscle and force/load score corresponding to the score of the neck, trunk and leg. RULA will be used in the packaging workstation (seventh process).

Meanwhile, REBA is a tool to analyze a worker's posture for whole-body movements and decided on musculoskeletal risk action levels [27]. This method analyzes work or activities where it seems plausible to cause pain, such as discomfort at the spine, head, legs and others [26]. Figure 4 shows the details of the REBA Scoring Sheet. Based on Figure 4, the evaluation measures commence in Section A, using Table A to grade the neck, trunk and leg positions. The score from Table A is reported in the Posture Score A column. The load/force value is then applied to Posture Score A to determine the cumulative score A. In Section B, the evaluation of the arm and wrist is measured. Table B demonstrates the upper arm, lower arm and wrist position. Meanwhile, in the Pose Score B section, the score from Table B is recorded. The coupling value is applied to determine Score B. Score A and Score B are also counted in Table C to determine Score C. Finally, the REBA score is calculated when the task score was applied to Score C. REBA will be used in process one until process eight.

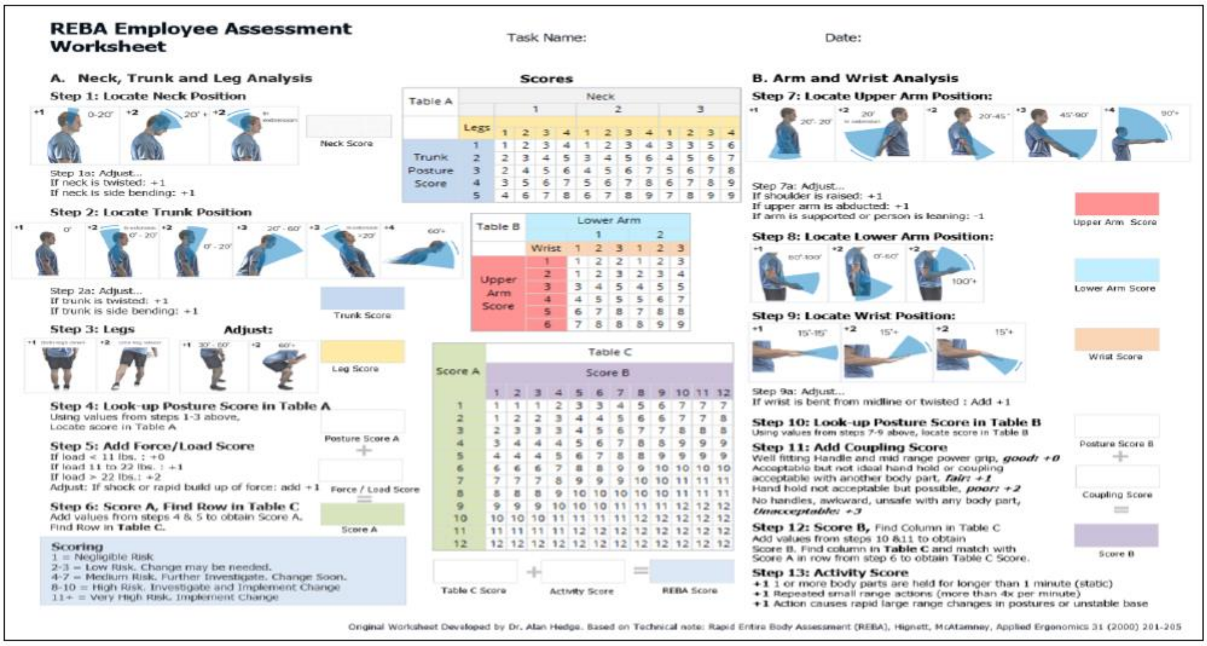


Table A		Neck 1				Neck 2				Neck 3			
	Legs	1	2	3	4	1	2	3	4	1	2	3	4
Trunk Posture Score	1	1	2	3	4	1	2	3	4	3	3	5	6
	2	2	3	4	5	3	4	5	6	4	5	6	7
	3	2	4	5	6	4	5	6	7	5	6	7	8
	4	3	5	6	7	5	6	7	8	6	7	8	9
	5	4	6	7	8	6	7	8	9	7	8	9	9

Table B		Lower Arm 1			Lower Arm 2		
	Wrist	1	2	3	1	2	3
Upper Arm Score	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 C: Score A	Score 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	12	12	12	12	12	12

Figure 4: Standard REBA score sheet

3.3 Analyze

The aims of this step are twofold. The first is to categorize the risk level of each workstation under study. The risk level from both RULA and REBA can be categorized based on standard tables of risk levels as presented in Table 1 and Table 2.

Table 1: Standard risk level of RULA

Action Level	Score	Risk levels	Requirements for action
1	1-2	Low risk	Posture is tolerable if it is not continued or repeated for a long time.
2	3-4	Medium risk	An advance investigation is essential and development may be required.
3	5-6	High risk	Inspection and modifications are needed soon.
4	7	Very high risk	Inspection and modifications are needed straight away.

Table 2: Standard risk level of REBA

Action Level	Score	Risk levels	Requirements for action
0	1	Negligible	No action is required
1	2-3	Low risk	Changes may be required.
2	4-7	Medium risk	Need for measures and further analysis.
3	8-10	High risk	Need to intervene and change in a short time
4	11+	Very high risk	Action is immediately required.

For both Table 1 and Table 2, the risk levels at High and Very High risks will take into account further action, thus related to the second objective accomplishment of this step. Therefore, the second objective is to identify the root cause of production activities that are categorized under these top two high risks. Some common tools that are practical to be applied for this purpose are cause and effect analysis using the Ishikawa diagram and the 5 Whys analysis. Once the root cause is identified and finalized, improvement afford can be taken place.

3.4 Improve

The objective of this step is to identify the optimal improvement solution/strategy to eliminate or reduce the risk levels evaluated in RULA and REBA. This step involves a series of brainstorming processes to generate ideas of improvement based on the context of ergonomics problem defined, identified and analyzed in previous steps. The involvement of workers at a related workstation in this step's activities is highly recommended. Related physical experiments to test and verify improvement ideas might be carried out in this step. The final improvement idea that fulfills criteria such as simple, practical and low cost becomes a top priority of the final improvement solution.

According to Figure 1, the flow of this step is connected with the decision node based on the following question; 'Does the ERF level is significantly reduced?'. If the answer is 'Yes', then the Control step will proceed. Otherwise, if the answer is 'No', then the revision activity in Improve step needs to be carried out. The focus of this activity is on revising the solution/strategy.

3.5 Control

The final is the Control step, in which the objective is to ensure the solution is implemented as planned and to sustain the benefit of the solution. Related activities need to be carried out in this step such as working procedure revision and on-job training sessions. Meanwhile, regular interval audits need to be scheduled to assess and evaluate the consistency of the improved task.

4.0 CASE STUDY

This section presents the applicability of the DMAIC steps proposed in the previous section. A case study carried out in a coffee manufacturing industry was selected for this research project. Further description of the company's background is given in the following sub-section. Then, the precise and concise results and discussion are then presented in the next subsection.

4.1 Company Overview

The company is classified as a small-medium enterprise (SME) that focuses on coffee processing and manufacturing. They currently produce various types of coffee-related products including instance coffee for the local market and also exported to some south Asia countries like Brunei, Indonesia, etc.

Currently, this company operates six days per week from 8.00 am to 5 pm daily. Overall, they employed about 50 workers, where 19 of them are distributed in the coffee processing area, 23 are located in the packaging workstation and the remaining are assigned for admin tasks. Figure 5 demonstrates the company's workstations flow that involves many production-related activities (e.g. loading, unloading, etc.) including their six main production processes; roasting, cooking, mixing, grinding, sifting and packaging.

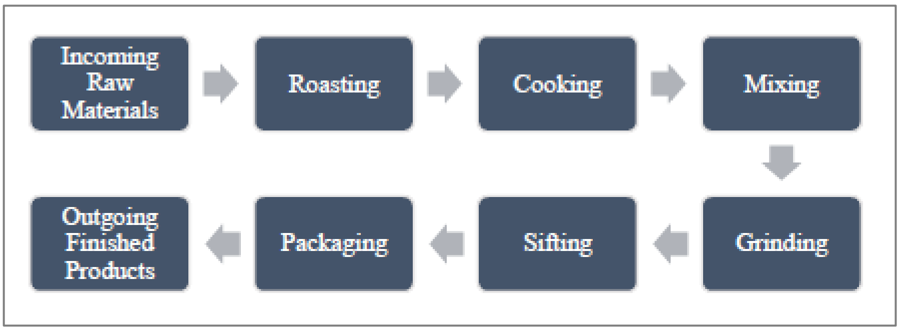


Figure 5: Overall eight workstations

4.2 Results and Discussion

In the Define step, initial analysis results related to the current practice of workers are obtained and revealed. Figure 6 shows images and examples of workers' postures during accomplishing tasks at their workstations. These images reveal that there are varieties of working postures that are currently practiced by the workers depending on their specific tasks assigned.

Figure 6: Examples of workers' postures

To further understand the impact of these working postures, a series of semi-structured interview sessions and surveys were performed. The survey was conducted for all 42 shop-floor workers of the company. Table 3 presents the data obtained from the survey that focused on Section B of the questionnaire. Related interesting findings are summarized as follows. Question B2 shows that 16 workers stood for less than 2 hours without a break, while 26 workers stood for more than 2 hours without a break every day. From question B3, 26 workers sit for less than 30 minutes while the remaining 16 sit for more than 30 minutes. An extended period of sitting has been attributed to a variety of health issues, according to research. Obesity is one of them, as is metabolic syndrome, a set of symptoms characterized by elevated blood pressure, high blood sugar, extra body fat around the neck and abnormal cholesterol levels.

Table 3: Summary of responses (Section B of Questionnaire)

No	Question	Answer	Total Respondent
1	Workstation area	Manage incoming raw materials Roasting Cooking Mixing Grinding and Sifting Packaging Manage outgoing finished products	1 2 10 1 4 23 1
2	Total time you stand in a day	Less than 2 hours More than 2 hours	16 26
3	Total time you sit in a day	Less than 30 minutes More than 30 minutes	26 16
4	Do you often lift heavy loads?	Yes No	37 5
5	How much weight do you often lift?	Less than 5 kg 6-15 kg 16-24 kg 25 kg and above	6 12 4 20
6	Do you ever experience pain or discomfort in any part of body during work?	Yes No	42 0

Following that, questions B4 and B5 inquired as to whether workers engaged in heavy load lifting and, if so, how much weight they are typically lifted to finish their tasks. The study's findings indicate that 37 workers are committed to heavy load carrying, while the other 5 are not. Additionally, 6 workers lift less than 5 kg, 12 workers lift 6-15 kg, 4 workers lift 16-24 kg and 20 workers lift more than 25 kg. According to Cheung et al. [28], the maximum load workers can lift with two hands under optimal conditions for an extended time without increasing their risk of experiencing lower back pain is 23 kg. Therefore, this result shows that almost half of the workers at the case study company work at high risk of MSDs which lift more than 25 kg load. Lastly, all 42 workers agree that they experienced pain or discomfort in any part of their body during work based on question B6.

Meanwhile, Table 4 presents the responses to Section C of the questionnaire. This section focused to explore the signs and causes of Musculoskeletal Injuries (MSI) that workers may experience, the duration when the pain or irritation was perceived, factors that cause the pain and the worker's suggestions, to reduce the pain experienced.

Table 4: Summary of responses (Section C of Questionnaire)

No	Question	Answer	Total Respondent
1	MSI symptoms that you often experience	Backache	30
		Swelling	5
		Cramp	17
		Lethargy/fatigue	2
		Joint pain	12
2	How often you experience such pain	Every day	12
		Every week	12
		Every month	18
3	In your opinion, what are the factors that cause the pain	Repetitive movements	27
		Awkward posture/body position	4
4	What are the suggestions or views of employees to avoid or reduce the pain experienced	• Extend the break time • Prepare medication if necessary • A five-day work per week • Add new workers • Provide comfortable seating • Provide a seat that fits the height of the conveyor	

For Question C1, workers can answer more than one question. 30 workers experienced backache from working, 5 workers experienced swelling, 17 workers experienced cramps, 2 workers experienced fatigue and 12 experienced joint pain. From the data, most workers of various ages have backache problems. Previous research found that after 2 hours of extended standing, 50% of healthy respondents experienced low back pain [29]. Working in a sustained standing posture without adequate rest can cause various health issues, including leg swelling, muscle fatigue, low back pain and other problems [30]. Other than that, data from Question C2 stated that 12 workers endure pain every day, 12 workers every week and 18 workers every month. If the pain happens continuously, it may lead to absenteeism. MSDs have a significant effect on work-related absences, accounting for a large proportion of days missed. As a result, it not only impacts the welfare of employees but also places a strain on the health system, the economic well-being of companies and the social costs associated with dealing with their effects [31].

Furthermore, from Question C3, 27 workers think the causes of the pain or discomfort that occur come from repetitive movements, 4 workers believe it is from awkward posture, 9 workers for forceful exertion and 2 workers think of others. This shows that the company's workers seem to be unaware of the ergonomics risk factors contributing to their pain/discomfort when performing the process. Finally, Question C4 invites respondents to express their perspectives on alleviating any pain or distress they might be experiencing. The opinions are to extend break time and prepare medicine if required, to work five days a week, to hire additional staff, to provide a comfortable seat for seating workers and to provide a seat that suits the height of the conveyor for workers who operate conveyor machines in packaging workstations.

Figure 6 presents the overall distribution of workload effects on body parts experienced by workers at the company. Pain/discomfort in the lower back received the most responses (38 workers), followed by 36 workers experiencing pain/discomfort in the mid-back, 25 workers experiencing neck discomfort, 25 workers experiencing discomfort in both left and right shoulder and also 12 workers who felt discomfort in both left and right leg. This data shows that the current work design does not offer any ease, pleasure, fitness, or protection from the risks of MSDs.

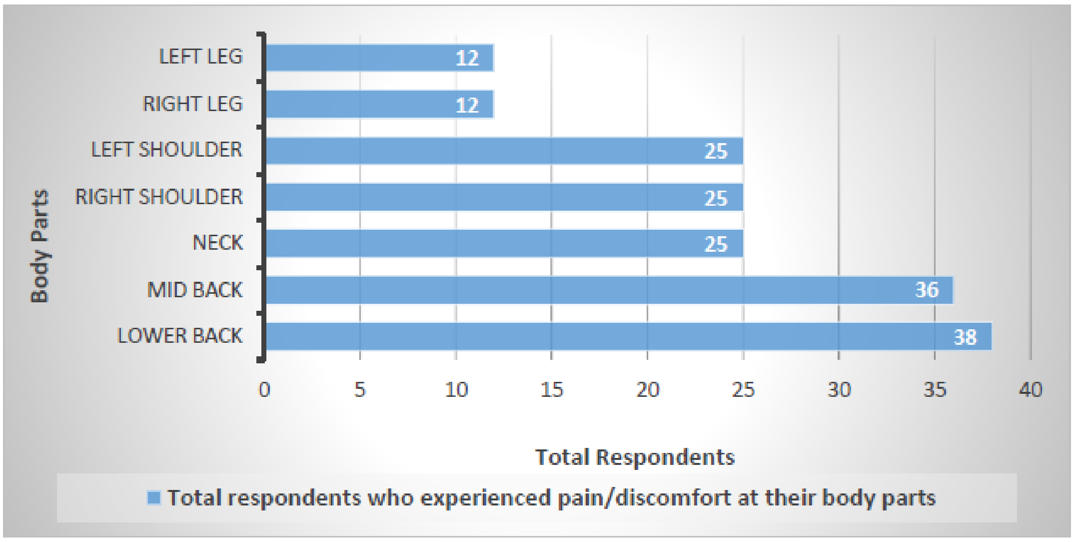


Figure 6: Distribution of pain/discomfort

In the Measure and Analyze steps, further measurement and analysis were planned and carried out, respectively. Based on the initial analysis presented in the previous step (Define), twenty-three tasks that are currently practiced at eight workstations are further considered. Measurement tools from the application RULA and REBA were then assigned for respective tasks. Due to the nature of the tasks of all eight workstations under study, the RULA is only applied for sitting posture that is currently practiced in the packaging process (Task no. 20). The majority of tasks are evaluated using the REBA application. Table 5 summarizes the overall results of RULA and REBA applications.

Table 5: Results' summary of RULA and REBA

Workstation	No.	Tasks	Tools Used	Score	Risk Level	Recommendation
Incoming raw materials	1	Moves sacks of raw coffee beans from the lorry and put them onto the pallet	REBA	10	High	Need to intervene and change in a short time
Roasting	2	Scoop roasted coffee into sacks	REBA	6	Medium	Need for measures and further analysis
	3	Tie the sacks	REBA	3	Low	Changes may be required
	4	Arranged sacks onto a pallet	REBA	9	High	Need to intervene and change in a short time
Cooking	5	Lift sacks of coffee and tins of sugar	REBA	8	High	Need to intervene and change in a short time
	6	Pour sacks of coffee and tins of sugar into a crater	REBA	5	Medium	Need for measures and further analysis
	7	Poured cooked coffee onto the table	REBA	5	Medium	Need for measures and further analysis
	8	Cooling	REBA	5	Medium	Need for measures and further analysis
	9	Push cooled coffee into the mixer	REBA	6	Medium	Need for measures and further analysis
	10	Scoop cooked coffee	REBA	6	Medium	Need for measures and further analysis
	11	Tie the sacks	REBA	5	Medium	Need for measures and further analysis

Mixing	12	Lift coffee sacks	REBA	11	Very High	Action is immediately required
	13	Pour coffee into the mixer	REBA	9	High	Need to intervene and change in a short time
	14	Pull out the bucket trolley from the mixer	REBA	9	High	Need to intervene and change in a short time
Grinding	15	Scoop coffee from the bucket trolley	REBA	6	Medium	Need for measures and further analysis
	16	Pour coffee into the grinder	REBA	7	Medium	Need for measures and further analysis
	17	Lift tin filled with grind coffee	REBA	3	Low	Changes may be required
Sifting	18	Pour grind coffee into the sifter	REBA	6	Medium	Need for measures and further analysis
	19	Lift tin filled with sifted coffee	REBA	3	Low	Changes may be required
Packaging	20	Sit while operating bucket conveyor machine	RULA	3	Low	Changes may be required
	21	Lift the sealed box	REBA	9	High	Need to intervene and change in a short time
	22	Arranged box onto a pallet	REBA	10	High	Need to intervene and change in a short time
Outgoing finished products	23	Moves boxes from a pallet onto the lorry	REBA	6	Medium	Need for measures and further analysis

The summary of the results in this step is given as follows. The risk level of low was recorded for tasks 3, 7, 19 and 20 that are practiced in four workstations such as roasting, grinding, sifting and packaging, respectively. Then, eleven tasks are classified under medium risk, which currently practices at roasting, cooking, grinding, sifting and outgoing finished products workstations. This category of risk recommends that these tasks need measures and further analysis. However, there are seven tasks (1, 4, 5, 13, 14, 21 and 22) at the workstations of incoming raw materials, roasting, cooking, mixing and packaging, thus recommending the need to intervene and change in a short time. Finally, the very high-risk level given on task no. 12 is currently practiced at the mixing workstation, thus this is classified as the critical task that recommends immediate action to be done.

Specifically, task (no. 12) required workers to lift coffee sacks with an average weight of 25kg per sack from the floor area to the mixing machine loading area as shown in Figure 7. This figure shows the high-risk impact on the mid and low back area which may cause to backache to workers. This visual proves that the response of workers on their backache experience as recorded in Table 4 is reliable, thus the recommendation to eliminate/reduce it immediately is critically required. Therefore, this task was chosen for further consideration to lower the ergonomics risk level.

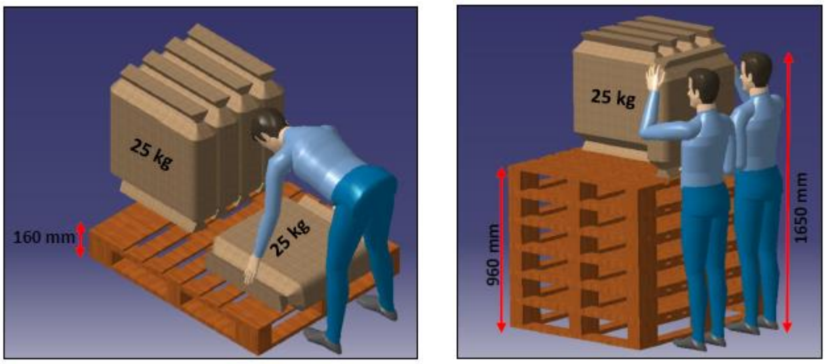
Figure 7: Worker lift the coffee sacks

In Analyze step, brainstorming sessions were then performed to systematically identify the root cause of this ERF problem (awkward posture in the back area of the worker). Many factors are taken into account to be analyzed to be the possible causes of the problem including the weight of lifting material, distance, lifting technique, etc. The research project team has finalized that the root cause of this ERF problem is the height factor, where currently workers should take a sack from the low area before it lifts to the mixing machine loading area at a certain height. In the next step, this identified root cause is used as one of the fundamental considerations for improvement strategy.

In Improve step, the focus is given to identifying the optimal solution that can eliminate or reduce the targeted ERF. According to the principles of ergonomics (OSHA) [32], three principles can be applied to ERF solutions design: work in neutral postures, reduce excessive force and work at proper heights. Following principle number one, which is to work in neutral postures, where the posture in Figure 7 shows the worker working in an awkward posture which is bending down 90 degrees to pick coffee sacks on the pallet placed on the floor. Next, principle number two, which reduces excessive force, is required because the worker must lift 4 or 5 sacks of 25 kg of cooked coffee beans repetitively. Lastly, principle number three is to work at proper heights, which is the main problem of high-risk level during the task, where the worker is exposed to dangerous working heights.

To address this ERF, by considering these three principles and the root cause identified in the previous step, the key solution objective is to ensure that workers perform the task at appropriate working heights thus benefits in maintaining neutral working postures and reducing excessive force. Following are the description of the simple invention that fulfill these benefits. As the worker lifts 25 kg of sacks, it includes heavy work. The proposed solution is to increase pallet height by stacking other unused pallets 65 cm to 96 cm from the floor. Considering there are some unused pallets, it can be used by stacking the pallets onto each other following the worker's comfortable waist height and appropriate working height to maintain neutral postures. Then, since the company requires to produce 25 kg per sack, the weight cannot be changed or reduced. To reduce excessive force, two workers shall work together to lift the sacks. The sack can be less burdened because the load is divided. Handling by two or more persons may allow an operation that would be impossible for a single person to complete and it will decrease the danger of injury to a single handler [33].

Figure 8 presents a graphical solution comparison before and after improvement. Before improvement, the worker needs to bend 90 degrees to lift the sacks because the pallet is placed on the floor (as shown in Figure 7). Meanwhile, the improvement solution applied the unused pallets that are stacked onto each other following the worker's comfortable waist height and to reduce excessive force, two workers shall work together to lift the sacks. Before the improvement, lifting the sacks has a REBA score of 11 (very high level of risk), while the REBA score of 3 (low level of risk) is given after the improvement. The improvement revealed a considerable risk reduction at 72.73%.



Before Improvement After Improvement

Figure 8: Graphical solution before and after improvement

Finally in Control step, the working procedure to accomplish the task was revised. Since the improvement strategy required two workers to lift the sacks, thus this becomes the new working procedure that the workers must commit to.

5.0 CONCLUSION

This study presented the ergonomics study in a coffee manufacturing industry in Malaysia. The objective of this study is to assess the level of ergonomics risk factors (ERFs) using related ergonomics assessment tools and guided by the DMAIC steps application. This study also included simple inventions to reduce the risk level of identified task that is classified as a very high level of risk.

In the Define step, twenty-three tasks that currently practice the awkward working posture were identified as the primary ERF. In the Measure step, the RULA and REBA tools were utilized to further examine these tasks. In the Analyze step, the highest risk level was measured for the task of lifting sacks at the mixing workstation and the strategy root cause analysis was followed to be carried out. The next step, which is the Improve step demonstrated the optimal solution principles identification process and a simple invention is proposed. The REBA showed that the proposed solution has significantly reduced the risk level to 72.7% based on risk score reduction from 11(very high risk) to 3 (low risk). Finally, in Control step the related activities such as working procedure revision, on-job training and regular audit of the improved version task were strategically planned to ensure the solution is consistently implemented and the maximum benefits from the solution are sustained.

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