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Optimizing Ergonomic Evaluation of Heavy Workload in Coffee Roasting to Reduce Operator Injury Risks: A Case Study using Cardiovascular Load, Rula, And Reba Methods

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ABSTRACT: *Coffee production in Indonesia continues to grow along with the increasing demand for specialty coffee. One of the crucial stages in coffee processing is the roasting process, which requires close attention to the physical load and work posture of workers. This study evaluates the ergonomic risks associated with the coffee roasting process at Kedai Koffie Tandjoeng, a small-scale coffee business in Sumedang, Indonesia. Despite operating since 2015, the roasting process had never undergone a structured ergonomic assessment, even though the operator reported frequent discomfort, especially in the upper limbs and lower back. To assess these risks, this study used a combination of Cardiovascular Load (CVL), Rapid Upper Limb Assessment (RULA), and Rapid Entire Body Assessment (REBA) methods. The CVL result of 39.14% indicated a light to moderate physical workload, suggesting the need for workload management to prevent long-term fatigue. The RULA score of 5 and REBA score of 4 revealed moderate ergonomic risks, particularly in the upper arms and wrists during the lifting and pouring stages. Based on these findings, four recommendations were proposed: ergonomic training, the use of assistive tools (e.g., step stools), structured rest periods, and workstation layout adjustments. This study contributes to ergonomic research in the context of micro and small enterprises by applying an integrated assessment approach to a previously unassessed but physically demanding process. The results provide a practical foundation for future ergonomic interventions to reduce injury risks in small-scale coffee production environments.*

Keywords: *Ergonomics, Physical Load, Work Posture, Cardiovascular Load, RULA, REBA, Coffee Roasting*

1. INTRODUCTION

Ergonomics is a discipline that aims to adapt work systems to human capabilities and limitations in order to create safe, comfortable, and efficient working conditions (Mishra & Narendra, 2020). Ergonomics is applied as a rule or standard in a work system and the use of technology to harmonize or balance all the ways used in activities so that it can work properly, effectively safely, and efficiently to achieve increased overall goals (Tarwaka et al, 2004).

Beyond enhancing comfort, ergonomic principles not only serve to create comfort at work, but also contribute to the efficiency and quality of work results. Ergonomics in the world of work focuses on how a person does their job, how the position and movement of the body while working, the tools used, and the impact on the health and comfort of the workforce. An ergonomic work environment is proven to increase productivity and reduce the risk of work accidents (Simanjuntak, 2022). This is especially important in the food and coffee processing industry, which involves physically demanding tasks throughout the production process.

In the context of the agroindustry including coffee processing, ergonomics plays an important role in ensuring that workers can perform their duties safely and optimally. Workers often have to perform repetitive tasks over long periods of time, which can potentially cause musculoskeletal disorders. Therefore, ergonomic workplace design, such as equipment layout, worktable height, and the design of production tools, are crucial factors in maintaining worker health and improving production efficiency (Akbilek, 2017).

One of the crucial stages in coffee production is the roasting process. Roasting is the process of cooking green coffee beans to produce the distinctive flavour and aroma of mature coffee that is ready to be processed into beverages or in powder form (Bactiar, 2020). This process requires special attention to the work posture and physical burden of workers both in operating the machine and in monitoring the quality of the roasting results.

Previous studies have reported that roasting activities, when conducted in awkward or static standing positions without ergonomic consideration, can lead to musculoskeletal problems. (Sachdeva & Gupta, 2011). Workers exposed to these situations are at risk of experiencing pain in areas such as the back, shoulders, and arms, which can reduce productivity and pose long-term health risks if not addressed properly (Suarjana et al., 2022). Implementing ergonomic principles, has been shown to significantly reduce such risks and support better work performance (Suarjana et al., 2023).

This study was conducted at one of Indonesia's local coffee producers, Kedai Koffie Tandjoeng. Established in 2015 by the Mekar Arum Women Farmers Group (KWT), it is a micro, small, and medium enterprise (MSME) located in Tanjungsari, Sumedang. The business operates on a 13-hectare land, processing coffee from cherry to green bean stage. In 2019, it received support from Bank Indonesia in the form of machinery, capital, and training for business development.

Koffie Tandjoeng focuses on producing speciality coffee, such as arabica and robusta, which are available in powder, roasted beans, and green bean. Their products were initially only natural coffee, but later developed into various variants such as natural anaerobic, winey, full wash, honey, lanang, ginger coffee, and palm sugar coffee. In addition to producing coffee, since 2017 the business has also managed a shop that serves coffee and food for customers.

The roasting process at Koffie Tandjoeng uses 3kg capacity roasting machine sponsored by Bank Indonesia. Based on direct observation, the process is performed by a single worker across three sessions each day. In each session, the worker performs three to four roasting cycles, with each cycle lasting approximately 30 minutes. Between each cycle, the worker lifts and pours 3 kg buckets of coffee beans into the machine. This continuous activity can last up to 2 hours per session, followed by a 45 minutes break, before the next session begins. In total, the roasting activity may occupy around six hours daily. While this schedule occurs three times a week during regular periods, it becomes a daily routine during post-harvest seasons when demand increases.

Given the sustained physical demands and the frequency of these tasks, neglecting ergonomic risks could result in long-term musculoskeletal strain and reduced productivity. These conditions indicate the importance of ergonomic evaluation, particularly in labor-intensive, small-scale roasting operations such as this one.

During a preliminary visit to Kedai Koffie Tandjoeng, informal discussions with the roasting operator revealed recurring discomfort in the right leg and wrist. The worker explained that the right leg often bears bears more weight due to an imbalanced standing posture, while wrist pain had occurred from improper lifting techniques. Although these complaints had not been formally documented, they indicate a potentially harmful work pattern that had gone unaddressed over time. Such circumstances are common in small-scale businesses where ergonomic awareness tends to be low and discomfort is normalized. These findings prompted the need for a structured ergonomic assessment to validate whether the existing work postures and routines contribute to musculoskeletal risks. This also reflects a broader shift in MSMEs, where operational maturity has begun to foster greater attention to internal efficiency and worker well-being. Despite the critical role of roasting in determining final product quality, ergonomic risks in this stage are rarely evaluated in small-scale enterprises. The lack of formal evaluation allows harmful postures and routines to persist, potentially leading to chronic health issues, reduced productivity, and inconsistent product quality. Addressing these risks through timely assessment is crucial to prevent long-term negative impacts on both workers and operations.

Although the use of machines has simplified certain tasks, workers are still required to perform physical labor such as lifting and pouring coffee beans. Interviews with the operator revealed recurring physical complaints, particularly soreness in the shoulders and legs due to the repetitive lifting of heavy buckets. The right leg was reported to experience more fatigue, attributed to an unbalanced standing position throughout the roasting process.

These discomforts align with symptoms of Musculoskeletal Disorders (MSDs), which are often associated with repetitive manual handling and prolonged standing without ergonomic support. Such findings reinforce the importance of conducting ergonomic risk assessments and implementing corrective measures in the roasting process (Suarjana et al., 2022). Therefore, ergonomic evaluation using the Rapid Upper Limb Assessment (RULA) and Rapid Entire Body Assessment (REBA) methods is important to identify and reduce ergonomic risks in this work (Tee et al., 2017).

In addition to postural factors, the physical load of workers in the roasting process also needs to be analysed. One method that can be used is Cardiovascular Load (CVL), which calculates the level of physical workload based on the difference between resting and maximum pulse rates (Diniaty & Muliyadi, 2016). This analysis is important to determine whether workers are experiencing excessive workload, which can lead to overexertion and increase the risk of injury. The higher the CVL value, the greater the physical stress experienced by workers, which in turn can have a negative impact on health and productivity (Yasmin et al., 2023).

Knowledge related to workload is very important because a high physical workload that is not balanced with good work posture will cause the risk of musculoskeletal disorders. Poor work posture in the long run can lead to spinal cord injury, muscle pain, and decreased body flexibility which ultimately results in reduced labour productivity (Abobakr et al., 2019). In another study conducted by Deouskar (2017), it was found that an unergonomic work environment will increase worker stress and fatigue which has an impact on high absenteeism and decreased work efficiency. Therefore, evaluation of work posture and physical load in the roasting process is a very important step to reduce the risk of injury and improve worker welfare.

A relevant study by Tiogana and Hartono (2020) also evaluated the work posture of coffee production workers, particularly in the roasting station, using the REBA and RULA methods. Their research, conducted in a labor-intensive coffee processing facility, found that poor ergonomic conditions such as low lifting points, heavy bag handling, and awkward reaching postures led to musculoskeletal complaints in the back, legs, and neck. The REBA score for the roasting station reached a level 8, indicating a high level of risk that requires immediate intervention. The study proposed practical solutions such as the use of adjustable trolleys to reduce the need for lifting and bending (Tiogana & Hartono, 2020). This prior research reinforces the relevance of ergonomic risk analysis in coffee roasting and supports the need for further investigation, especially in small-scale operations such as Kedai Koffie Tandjoeng.

In contrast to the aforementioned studies, this research offers a broader approach by combining Cardiovascular Load (CVL) with RULA and REBA to assess both physical workload and posture. This combination allows for a more holistic evaluation of ergonomic risks, particularly in repetitive and intensive roasting cycles that have not been the primary focus in previous research. While prior studies such as Suarjana et al. (2023) focused solely on posture using RULA in the context of manual roasting, they did not incorporate cardiovascular strain or explore cumulative workload across multiple roasting sessions. Similarly, Tiogana and Hartono (2020) limited their analysis to posture risks using RULA and REBA in large-scale coffee processing, without addressing the physiological load experienced by workers or the unique conditions of micro-scale enterprises.

What differentiates this study from previous works is its integrated assessment that captures both physical and postural burdens through field observation, direct worker feedback, and multiple ergonomic tools. This comprehensive approach enables a deeper understanding of risk exposure in small-scale roasting environments, which remain underexplored despite their prevalence in Indonesia's coffee industry.

This study was conducted to evaluate the physical workload and work posture in the coffee roasting process at Kedai Koffie Tandjoeng to identify ergonomic risks that may affect worker's health and productivity. By combining the Cardiovascular Load (CVL) method to assess physical workload as well as RULA and REBA to analyse work postures, this research offers a comprehensive assessment that covers both cardiovascular strain and musculoskeletal risks an approach that has not been previously applied specifically to roasting activities in small-scale coffee enterprises. Moreover, this study incorporates direct worker feedback and detailed field observations to capture real-world discomforts experienced during repetitive and intensive roasting sessions. The findings are expected to contribute to the development of ergonomic practices tailored for micro and small coffee businesses, promoting safer working environments and sustainable operations.

2. METHODOLOGY

This research is a quantitative descriptive study that aims to evaluate the physical load and work posture in the process of roasting coffee beans at Kedai Koffie Tandjoeng. The evaluation was conducted by measuring the physical workload of workers using the Cardiovascular Load (CVL) and analysing work postures using the Rapid Upper Limb Assessment (RULA) and Rapid Entire Body Assessment (REBA) methods. With this approach, the research is expected to provide an accurate picture of the level of physical burden experienced by workers as well as ergonomic risks associated with work postures during the coffee roasting process.

The approach used in this study includes two main aspects, namely the measurement of physical workload through the Cardiovascular Load (CVL) method and analysis of work posture using the RULA and REBA methods. Cardiovascular Load (CVL) is used to determine the level of workload based on the comparison of resting heart rate and working heart rate, so that it can be interpreted in the category of light, medium, or heavy load (Diniaty & Muliyadi, 2016). Meanwhile, the RULA and REBA methods are used to evaluate workers' work postures based on body positions observed during the process of lifting and pouring coffee beans. RULA focuses more on analysing upper body posture, while REBA evaluates overall body posture (Tee et al., 2017). The RULA and REBA methods can see physical fatigue by using posture analysis techniques. using posture analysis techniques that assess work activities. This analysis method records the worker's posture so that it can show the level of risk of musculoskeletal injury in the workplace (Dhiya & Rahmah, 2019).

This study employed the Cardiovascular Load (CVL), Rapid Upper Limb Assessment (RULA), and Rapid Entire Body Assessment (REBA) methods due to their relevance in evaluating both the physical and postural workloads experienced by workers during the coffee roasting process. The CVL method is particularly useful for assessing physiological strain through heart rate data, enabling the classification of workload into light, moderate, or heavy categories (Diniaty & Muliyadi, 2016). It provides objective insight into cardiovascular burden, which is especially important in physically intensive, repetitive tasks involving prolonged standing and manual handling.

The RULA method was chosen for its widespread use and sensitivity in detecting postural risk levels related to upper limb movement and trunk posture. Compared to other observational tools, RULA provides more significant indicators in correlating posture load with musculoskeletal complaints (Kurnia, 2024). This makes it suitable for evaluating repetitive upper body activity such as lifting and pouring coffee beans.

Meanwhile, the REBA method offers a rapid and comprehensive evaluation of whole-body posture, including neck, back, arms, wrists, and legs. It is designed to detect non-ergonomic postures that contribute to high injury risk in dynamic or unstable tasks. REBA also incorporates variables such as load weight, coupling, body angles, and foot stability, producing a detailed risk score that facilitates targeted ergonomic recommendations (Masudha & Enik, 2024). Its structured scoring system and ease of use make it ideal for field applications in small-scale enterprises.

While each method provides valuable information independently, combining CVL, RULA, and REBA allows for a more holistic and integrated analysis of ergonomic risks. CVL captures the internal physical load exerted on the worker's body, while RULA and REBA address the external biomechanical stresses related to posture. This synergy ensures that both cardiovascular strain and musculoskeletal stress are systematically identified, which is critical in roasting activities that involve repetitive motions, prolonged static standing, and awkward body positions. The use of these three methods in tandem thus enhances the comprehensiveness of the assessment and supports more accurate ergonomic intervention strategies in small-scale coffee processing environments.

This study is observational, with data collection conducted directly at the workplace, namely at Kedai Koffie Tandjoeng, located at Cijolang, RT.02 / RW.10, Margaluyu, Kec. Tanjungsari, Sumedang Regency. Observations were made while workers were roasting coffee beans using a roasting machine, where data regarding heart rate and work posture were collected and analysed. The use of this observational approach allows researchers to obtain more accurate and objective data on the working conditions of workers in the real work environment (Abobakr et al., 2019).

The scope of this research is limited to the coffee bean roasting process at Kedai Koffie Tandjoeng, where the roasting stages are analysed and interpreted based on the final scores of the Cardiovascular Load, RULA, and REBA methods. Given that coffee roasting involves dynamic activities such as lifting, pouring, and machine monitoring, this study used video recordings to document the work process in real time. From these recordings, postures were selected at critical phases, particularly when muscular effort and awkward positions were most evident for evaluation using the RULA and REBA tools. This approach ensured that the analysis reflected the true ergonomic risks of dynamic motion, rather than relying solely on static or arbitrary body positions.This study provides a quantitative assessment of the level of physical load and ergonomic risks experienced by workers, and can be the basis for developing ergonomic recommendations to improve worker welfare and production efficiency at Kedai Koffie Tandjoeng.

2.1. Measurement of Physical Load with Cardiovascular Load (CVL)

In work activities, humans are faced with workloads that require physical energy, where muscles act as the main source of power in completing the assigned tasks. Physical workload can be defined as a condition experienced by workers due to the gap between individual physical capacity and the demands of the work that must be completed (Oktavia & Ratih, 2021). This workload arises due to high physical demands during work activities, which can cause changes in the body's physiological functions. These changes include increased oxygen consumption, changes in heart rate, increased respiratory rate, body temperature, lactate levels in the blood, and evaporation of body fluids, all of which can be used as indicators in measuring physical workload (Oktavia & Ratih, 2021).

One method commonly used in ergonomics and occupational physiology to measure physical workload is heart rate measurement. Heart rate is a physiological indicator that can show the level of physical stress and workload of a person. Heart Rate Variability (HRV) can be used to assess the level of mental load experienced by workers. Research shows that the higher the mental workload, the lower the heart rate variability, meaning the cardiovascular system is under greater stress (Mulder, 1992).

In addition to measurements based on heart rate, physical workload can also be evaluated with Cardiovascular Load (CVL). CVL is a method used to estimate and classify workload levels based on an increase in work pulse rate compared to the maximum pulse rate (Yasmin & Rizalmi, 2023). CVL calculation allows the identification of the level of physical burden experienced by workers in a particular activity, so that it can be categorised into light, medium, or heavy workload levels.

Pulse rate measurement in CVL calculations can be done by various methods, including using automatic devices such as heart rate monitors or manually using a stopwatch. In the manual method, measurements are taken by counting the worker's pulse for 15 seconds then multiplying by 4 to get the beats per minute (bpm) value (Yasmin & Rizalmi, 2023). This method is widely used in ergonomics research because it is simple and can be applied directly in the work environment without requiring complex devices.

The CVL calculation method is done by comparing the maximum pulse rate with the working pulse rate. The steps in calculating CVL are as follows:

1. Calculating the Resting Pulse Rate

Resting Pulse Rate rate is the pulse rate when the body feels calm, can be measured before work or during rest periods.

2. Calculating the Work Pulse Rate

Work Pulse Rate is the worker's pulse rate while performing work. This measurement is repeated during the work process, then an average is calculated to get the work pulse.

3. Calculating the Maximal Pulse Rate

According to Tarwaka (2004), the maximum pulse rate formula is:

• Maximum Pulse Rate (Male) = 220 - age
• Maximum Pulse Rate (Female) = 200 - age

4. Calculate %CVL

Calculate Cardiovascular Load to interpret the workload classification based on the increase in work pulse rate with maximum pulse rate.

$$\%CVL = \frac{100\ X\ (Work\ Pulse\ Rate - Resting\ Pulse\ Rate)}{(Maximal\ Pulse\ Rate - Resting\ Pulse\ Rate)} \quad (1)$$

5. Interpretation of %CVL

The %CVL calculation results that have been obtained are then interpreted based on the table below.

Table 1. Classification of Workload Based on %CVL

%CVL	Classification %CVL
≤ 30%	No worker fatigue
30 s.d ≤ 60%	Improvement required but not urgent
60 s.d ≤ 80%	Allowed to work for a short period of time
80 s.d ≤ 100%	Immediate corrective action required
%CVL > 100%	Work activities not allowed

(Source: Tarwaka et al, 2004)

2.1. Work Posture Analysis with the RULA Method

The Rapid Upper Limb Assessment (RULA) method is one of the techniques developed to evaluate the risk of musculoskeletal disorders in the upper limbs caused by non-ergonomic work postures. This method was first developed by Lynn McAtamney and Nigel Corlett as an ergonomic survey tool that can be used to analyse biomechanical loads and risky work postures, especially on the arms, neck and trunk (Lahay, 2017). In its application, RULA is often used to identify static work positions, repetitive movements, and the use of excessive force that can cause muscle fatigue and increase the risk of injury (Singh, 2013).

The RULA method categorises work posture analysis into two main groups. Group A includes upper arm, forearm, and wrist postures, while Group B includes neck, spine, and leg postures (Budiman & Setyaningrum, 2012). By dividing the body into these two categories, the RULA method allows for a more focused assessment of the areas of the body that are most susceptible to impairment due to improper posture. The analysis is conducted based on a specific rating scale, where the final score will determine the level of ergonomic risk faced by the worker and the extent to which corrective action is required to improve the work posture. This measurement does not require special equipment specialized devices in providing posture measurements of the neck, back and upper body in line with muscle function and the external load supported by the body (Maulid & Rahmah, 2019).

The main purpose of using the RULA method in work posture analysis is to provide a rapid evaluation of a population of workers in order to identify ergonomic risks associated with the upper body. The method also aims to analyse the relationship between muscle activity and work posture, physical workload, and repetitive movements that can cause muscle fatigue. The results of the RULA analysis are not only useful in identifying injury risks, but can also serve as a basis for the wider application of ergonomics standards, including in physical, mental, epidemiological, environmental, and work organisation aspects. In addition, this method helps in fulfilling the UK Guidelines, which are ergonomic guidelines used to prevent occupational musculoskeletal disorders (McAtamney & Corlett, 1993).

In analysing work postures using the RULA method, there are several stages that must be carried out systematically so that the evaluation results can provide an accurate picture of the level of ergonomic risk. The stages in the RULA method include the following:

1. Observation and Documentation of Worker Posture

Direct observation of workers' posture while performing their duties. This observation aims to identify how workers use their limbs during work. Documentation in the form of photos or videos is done to ensure that workers' postures can be further analysed in more detail. This documentation is also the basis for determining the angle of movement of each body part in order to obtain more objective data.

2. Body Movement Angle Measurement

Once the documentation of the work posture is obtained, the next step is to analyze the angles of movement of each body part. This angle of movement is measured to determine the extent to which the worker's body position deviates from a neutral position that is considered ergonomic. The body parts analyzed include the upper arms, forearms, wrists, neck, trunk, and legs. This angle measurement is done with the help of software such as Angulus or other movement analysis software.

3. RULA Score Calculation

After obtaining data on body movement angles, the next step is to calculate the RULA score. This score is obtained by entering the measured angle values into the RULA worksheet. This worksheet contains a table that has been developed to classify the level of ergonomic risk based on the worker's body position. This worksheet, which has become a general reference, has the following description:

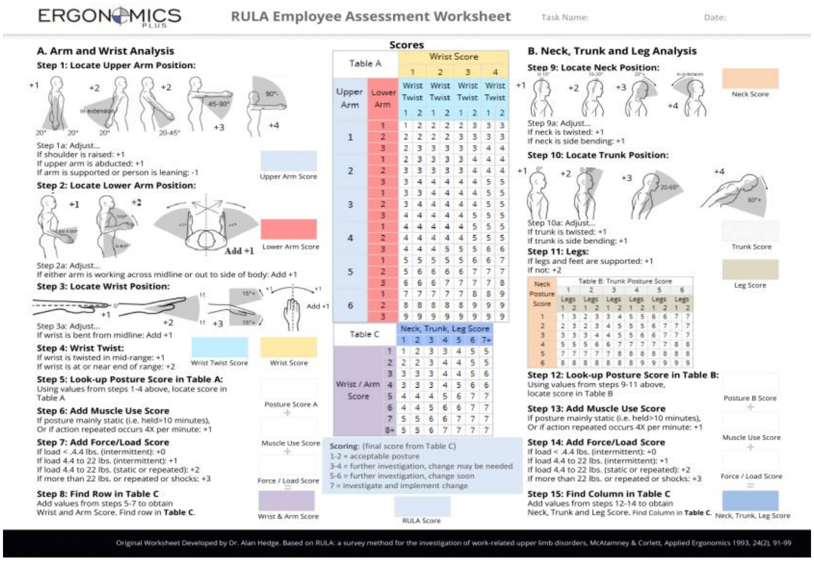

Figure 1. RULA Form
Source: https://ergo-plus.com

4. Determination of Final RULA Score

Once the initial score is determined based on the analysed body position, the final RULA score is obtained from crossing the scores between table C (rows) and table C (columns) in the RULA worksheet. This score describes the level of ergonomic risk experienced by workers during certain activities. The higher the score, the greater the risk posed by the work posture, and the more urgent the need for ergonomic intervention.

5. Score Interpretation and Corrective Action Identification

The final stage in the RULA method is to interpret the final score obtained. This interpretation is done by grouping the scores into various risk levels, which indicate the level of need for corrective action based on the table listed in the RULA worksheet as follows:

Table 2. Level of Need for RULA Evaluation Measures

Final Grade	Risk Level	Action
1-2	Minimum	Safe
3-4	Small	Need to observe for some time to come
5-6	Medium	Need action in the near future
7	High	Action needed now

2.2. Work Posture Analysis with the REBA Method

Rapid Entire Body Assessment (REBA) is an ergonomics method developed to thoroughly assess work postures to identify the risk of musculoskeletal disorders and other ergonomic hazards. The method was first introduced by Dr Sue Hignett and Dr Lynn McAtamney from the University of Nottingham's Institute of Occupational Ergonomics and published in an ergonomics journal in 2000 (Hignett & McAtamney, 2000). REBA was designed as a work posture evaluation tool that is simple, practical, and can be used without the need for expensive equipment or specialised skills. The evaluation is carried out using the REBA worksheet, which allows assessment of posture, force used, type of movement, repetition of movement, and coupling in a work activity (Tiogana & Hartono, 2020).

This method divides postures into two main groups, namely Group A and Group B. Group A includes trunk, neck, and leg postures, while Group B includes upper arm, forearm, and wrist postures. In addition to posture analysis, this method also considers additional factors such as the use of force, object grip, as well as work environment conditions (Hignett S & McAtamney, 2000). With this approach, REBA is able to provide a comprehensive overview of work postures that can cause injuries due to repetitive motion or unergonomic positions. Evaluation using REBA is done through assigning risk scores based on the observed postures. Scores range from 1 to 15, where the higher the score, the greater the level of ergonomic risk faced by the worker. A low score indicates minimal workload and low risk of injury, while a high score indicates the need for immediate corrective action to prevent injury and improve worker comfort (Hignett S & McAtamney, 2000). Therefore, the results of the REBA analysis can be used as a basis for designing effective ergonomic interventions, either through changes in workplace design, worker training, or modification of work tools that are more suited to the physical needs of workers.

This method is very useful in various work scenarios, especially in situations where workers use the whole body in work activities, work in static, dynamic, or unstable postures, perform tasks that involve loading such as lifting or carrying objects, and face changes in workplace conditions or work tools that require evaluation before and after implementation. With its flexibility and ability to provide a comprehensive overview of ergonomic risks in work postures, REBA is a very effective tool in analysing and optimising work postures to reduce the risk of musculoskeletal injuries and improve work efficiency (Hidjrawan & Sobari, 2019).

In analysing work postures using the REBA method, there are several stages that must be carried out systematically to identify ergonomic risks and determine the necessary corrective actions. This method allows a thorough analysis of posture, including an assessment of workload, use of force, and repetition of movement factors. The stages in the REBA method include the following:

1. Observation and Documentation of Worker Posture

The first step in the REBA analysis is to make direct observations of the worker's posture while performing work activities. To make the analysis more accurate, documentation is carried out using photos or videos, so that postures can be clearly identified. This documentation becomes the basis for determining the level of ergonomic risk faced by workers based on their body position.

2. Body Movement Angle Measurement

Once the documentation is obtained, the next step is to measure the angle of movement of each body part to determine how much the posture deviates from an ergonomically neutral position. Measurements are made of all parts of the body. This measurement is done by comparing the position of the body against the vertical and horizontal axes which can be analysed manually or with the help of software such as Angulus. The results of these measurements provide an overview of how much strain each part of the body experiences during work.

3. REBA Score Calculation

After obtaining data on body movement angles, the next step is to calculate the REBA score. This score is obtained using the REBA worksheet, which has been developed to determine the level of risk based on the observed work posture. This worksheet, which has become a general reference, has the following description:

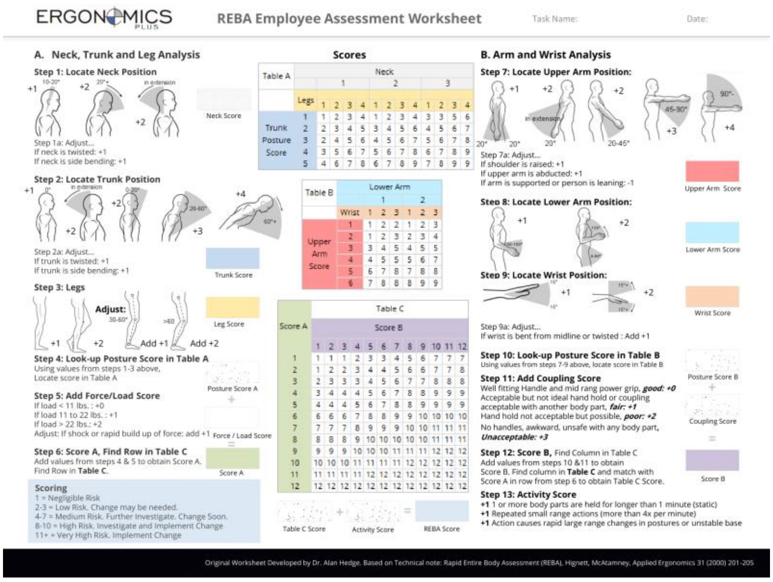

Figure 2. REBA Form
Source: https://ergo-plus.com/

4. Determination of Final REBA Score

After all the scores are calculated, the final score is obtained by summing the C table score in the REBA worksheet with the worker's activity score. The C table score is determined based on the crossing of posture scores between rows and columns in the evaluation table, while the activity score is determined based on the specific conditions at work. Some factors that can add to the activity score include:

- +1 point if one or more body parts are stationary for less than 1 minute.
- +1 point if there is repetitive motion more than 4 times per minute.
- +1 point if the worker performs an action that causes a major change in posture.

5. Score Interpretation and Ergonomic Risk Identification

The final stage in the REBA method is to interpret the final scores obtained to determine the level of risk and corrective action required. Based on the scores obtained, work postures are classified into several risk levels, which reflect the urgency of ergonomic improvements. The risk levels are listed in the REBA worksheet as follows:

Table 3. Level of Need for REBA Evaluation Measures

Final Grade	Risk Level	Action Level	Action
1	Ignored	0	No need
2-3	Low	1	It may be necessary
4-7	Medium	2	Need
8-10	High	3	Immediate need
11-15	Very High	4	Need it now

3. RESULTS AND DISCUSSION

This section presents the results of the analysis of physical workload and work posture in the coffee roasting process at Kedai Koffie Tandjoeng. The evaluation was conducted through Cardiovascular Load (CVL) measurements to assess physical workload and work posture analysis using the RULA and REBA methods to identify potential ergonomic risks. The results obtained were analysed to provide a more comprehensive understanding of the working conditions of coffee roasting workers. The following are the results and discussion.

3.1. Results of Physical Load Measurement with Cardiovascular Load (CVL)

Measurement of physical workload in coffee roasting workers is carried out using the Cardiovascular Load (CVL) method. This method relies on pulse counts to evaluate the level of physical load experienced by workers during the work process. In this study, the subject observed was a 58-year-old male worker who performed coffee roasting activities for 120 minutes. The resting pulse rate was measured when the worker on the rest periods and the result was 68 beats per minute (BPM). During the work process, pulse measurements were taken five times at intervals of every 25 minutes, with a measurement duration of 15 seconds at each time point. The measurement results were multiplied by four to obtain BPM. The average work pulse rate was then calculated based on the five measurements taken, as presented in the following table:

Table 4. Work Pulse Measurement

Calculation	Pulse (15 second)	BPM
1	26	104
2	24	96
3	28	112
4	27	108
5	26	104
Average		104.8

After obtaining the working pulse data, the next step is to calculate the maximum pulse rate using the formula developed by Tarwaka (2004),

$$Maximum\ Pulse\ (Male) = 220 - \text{age}$$

Based on the age of the worker (58 years old), a maximum pulse rate of 162 BPM was obtained.

Furthermore, the percentage of Cardiovascular Load (%CVL) was calculated using the formula (1), by entering the value that has been obtained:

$$\%CVL = \frac{100\ \text{X}\ (104.8\ -\ 68\ )}{(162\ -\ 68)} = 39.14\%$$

The calculation results show that the %CVL value is 39%, which according to the workload classification is still in the "improvement required but not urgent" category.

Based on a previous study by Krisnaningsih et al (2023), this category indicates that although the workload is still within acceptable limits, there is a potential ergonomic risk or long-term fatigue if workers continue to work under these conditions without intervention. Improvements can be made through adjusting work duration, increasing the efficiency of work equipment or applying ergonomic techniques in work postures.

The %CVL value of 39.14% suggests that although the cardiovascular workload is still considered moderate, the physical demands of roasting, such as lifting 3 kg buckets repeatedly while standing for two hours per session contribute significantly to physiological stress. The accumulation of such activities across multiple sessions per day can elevate heart rate consistently, indicating that the workload is not light, particularly for a 58-year-old worker. This cardiovascular strain, while not classified as urgent, highlights the need for better task pacing or assistive tools to minimize long-term fatigue.

3.2. Results of Work Posture Analysis with the RULA Method

Figure 3. Lower Arm and Wrist Angles
Source: personal documentation

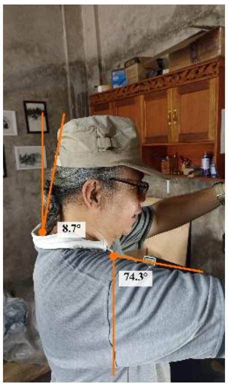

Figure 4. Upper Arm and Neck Angles
Source: personal documentation

Figure 5. Trunk and Leg Angles
Source: personal documentation

Figure 3 shows a worker lifting a bucket of coffee beans with both hands with an angle of 13.2° at the wrist and 120° at the lower arm. In Figure 4, it can be seen that when performing this movement, the worker's neck is slightly bowed at an angle of 8.7° and the angle of the upper arm is 74.3°. The trunk and legs are straight and not bent as shown in Figure 5. Based on the analysis using the RULA method, the following results were obtained:

a. Group A Body Posture

Table 5. Group A Posture Score

Work Posture	Score
Upper arm	3
Lower arm	2
Wrist	2
Wrist twist	1

Table 6. RULA Score Group A

Upper arm	Lower arm	Wrist 1		Wrist 2		Wrist 3		Wrist 4	
		Wrist Twist 1	2	1	2	1	2	1	2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	3	3	3	3	4	4
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	4	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	5	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	4	5	5	5
	2	4	4	4	4	4	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

Total score:
Posture Score A + Muscle Use Score =
4 + 0 = 4

b. Group B Body Posture

Table 7. Group B Posture Score

Work Posture	Score
Neck	1
Trunk	1
Leg	1

Table 8. RULA Score Group B

Neck	Trunk

	1	2	3	4	5	6
	Leg					

	1	2	1	2	1	2	1	2	1	2	1	2
1	1	3	2	3	3	4	5	5	6	6	7	7
2	2	3	2	3	4	5	5	5	6	7	7	7
3	3	3	3	4	4	5	5	6	6	7	7	7
4	5	5	5	6	6	7	7	7	7	7	8	8
5	7	7	7	7	7	8	8	8	8	8	8	8
6	8	8	8	8	8	8	8	9	9	9	9	9

Total score:
Posture Score B + Muscle Use Score + Force Score = 1 + 0 + 2 = 3

c. Final Score

Table 9. RULA Final Score

		Neck, Trunk, Leg Score						
		1	2	3	4	5	6	7+
Wrist/Arm Score	1	1	2	3	3	4	5	5
	2	2	2	3	4	4	5	5
	3	3	3	3	4	4	5	6
	4	3	3	3	4	5	6	6
	5	4	4	4	5	6	7	7
	6	4	4	5	6	6	7	7
	7	5	5	6	6	7	7	7
	8+	5	5	6	7	7	7	7

Based on the results of calculations using the RULA method, the final score according to table C is 5. This score indicates that the work posture in the coffee roasting process at Koffie Tandjoeng is at medium risk level, which means that further evaluation is needed as well as potential improvements to reduce ergonomic risks. With this score, ergonomic interventions need to be considered to improve work comfort and efficiency.

The final RULA score of 5 primarily stems from the upper arm and wrist posture, with angles measured at 74.3° and 13.2°, respectively. These angles are associated with the act of lifting and pouring coffee beans, which requires repetitive upper limb movement while holding weight. The upper extremities, particularly the deltoids and wrist flexors, experience constant tension due to the lack of variation in motion and sustained elevation of the arms. This activity contributes more heavily to postural strain than trunk or neck movement, positioning the upper limbs as the primary focus area for ergonomic intervention.

3.3. Results of Work Posture Analysis with the REBA Method

The REBA method is similar in principle to RULA in that it is used to evaluate workload based on posture. It considers all parts of the body, both upper and lower, by comparing the observed work position to a neutral posture. This approach allows the identification of ergonomic risk levels that may contribute to potential injuries due to suboptimal work postures (Singh, 2013).

Figure 6. Lower Arm and Wrist Angles
Source: personal documentation

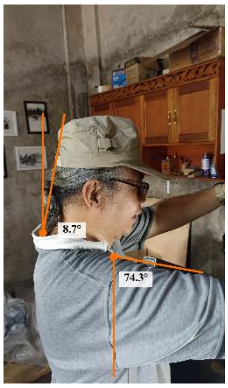

Figure 7. Upper Arm and Neck Angles
Source: personal documentation

Figure 8. Lower Arm and Wrist Angles
Source: personal documentation

Based on the analysis conducted using the REBA method, the results of the work posture evaluation in the coffee roasting process are presented as follows.

a. Group A Body Posture

Table 10. Group A Posture Score

Work Posture	Score
Neck	1
Trunk	1
Leg	1

Table 11. REBA Score Group A

A		Neck 1				2				3			
	Legs	1	2	3	4	1	2	3	4	1	2	3	4
Trunk Posture	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

Total score:
Posture Score A + Force/Load Score =
1 + 0 = 1

b. Group B Body Posture

Table 12. Group B Posture Score

Work Posture	Score
Upper arm	3
Lower arm	2
Wrist	2

Table 13. REBA Score Group B

B		Lower Arm 1			2		
	Wrist	1	2	3	1	2	3
Upper arm	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

Total score:
Posture Score B + Coupling Score =
5 + 0 = 3

c. Final Score

Table 14. REBA Final Score

Score A	Table C Score B 1	2	3	4	5	6
1	1	1	1	2	3	3
2	1	2	2	3	4	4
3	2	3	3	3	4	5
4	3	4	4	4	5	6
5	4	4	4	5	6	7
6	6	6	6	7	8	8
7	7	7	7	8	9	9
8	8	8	8	9	10	10
9	9	9	9	10	10	10
10	10	10	10	11	11	11
11	11	11	11	11	12	12
12	12	12	12	12	12	12

Score A	Table C Score B 7	8	9	10	11	12
1	4	5	6	7	7	7
2	5	6	6	7	7	8
3	6	7	7	8	8	8
4	7	8	8	9	9	9
5	8	8	9	9	9	9
6	9	9	10	10	10	10
7	9	10	10	11	11	11
8	10	10	10	11	11	11
9	11	11	11	12	12	12
10	11	12	12	12	12	12
11	12	12	12	12	12	12
12	12	12	12	12	12	12

Total score:
Table C Score + Activity Score =
3 + 1 = 4

Based on the results of the work posture analysis using the REBA method, a score of 4 was obtained, indicating a medium risk level. According to REBA interpretation standards, this score indicates that the observed work posture requires further evaluation but is not too urgent to reduce the potential risk of injury. Adjustments are needed to make the work posture more ergonomic and reduce the potential for injury due to physical workload. Therefore, corrective measures such as adjustments to body position, the use of assistive devices or changes in work techniques are required with the aim of improving worker comfort and efficiency during the coffee roasting process.

The REBA score of 4 reflects medium risk, primarily driven by the combined scores from upper arm and wrist posture (Score B = 3) and activity modifiers such as repetitive movement. Although lower limb postures appear neutral, the repetitive lifting motion involving both arms contribute significantly to the risk score. Unlike the RULA analysis, which isolates upper body strain, the REBA score provides insight into the cumulative impact of full-body mechanics, though in this case, it confirms that the primary source of ergonomic risk remains the repetitive upper limb activity. This consistency across methods reinforces that arm and wrist positions are the dominant contributors to ergonomic stress in the roasting task.

3.4. Interpretation and Recommendations

Based on the analysis of the coffee roasting process and data interpretation, it was found that the Cardiovascular Load (CVL) value was 39%. This value indicates that the physical workload is still within acceptable limits but requires improvement, even though it is not considered urgent. According to Tarwaka (2004), a CVL value below 40% is categorized as light to moderate workload, while values above 40% may indicate an increased risk of long-term fatigue. If left unaddressed, this condition can lead to cumulative muscle fatigue, decreased productivity, and a higher risk of musculoskeletal injuries due to repeated physiological stress.

In the work posture analysis using the RULA method, a score of 5 was obtained, indicating a medium risk level that requires evaluation in the near future to prevent injury. The body parts most at risk were the upper arms and forearms, primarily due to the constant lifting of 3 kg loads. This repetitive strain may cause excessive muscle tension in the upper extremities, increasing the likelihood of injuries such as tendinitis or myofascial pain syndrome (McAtamney & Corlett, 1993). Therefore, the recommended improvements must focus on optimizing lifting techniques and providing tools to reduce the arm load.

Additionally, the RULA method is often compared with the REBA method in posture assessment. The main difference is that RULA focuses more on the upper body, while REBA offers a more comprehensive evaluation of the entire body, including the lower limbs and trunk (Hignett & McAtamney, 2000). In this study, the REBA score of 4 also indicated a medium risk level, suggesting that while immediate action is not required, evaluation and adjustment are still necessary to reduce long-term injury potential.

To reduce the physical workload risks identified in this study, four specific ergonomic interventions are proposed. Each recommendation is directly derived from the ergonomic risk data obtained through the RULA assessment and is supported by validated scientific evidence. The RULA score of 5 indicated moderate risk in the upper arm and wrist regions, primarily due to repetitive lifting above shoulder level, excessive arm elevation, and wrist deviation. The first recommendation is to provide targeted ergonomic training that focuses on safe lifting techniques and maintaining neutral joint positions, particularly at the shoulder and wrist. Ergonomic education has been shown to significantly reduce musculoskeletal disorder (MSD) risks in repetitive manual handling tasks (Rahmahwati, 2021).

The REBA score of 4 further supported the need for postural intervention by highlighting the cumulative effect of full-body movements and activity modifiers. The second recommendation is to use assistive tools, such as a mini step stool or ergonomic platform, to help the operator lift and pour beans at a more neutral shoulder height. Adjusting vertical reach has been shown to lower upper limb stress and reduce ergonomic risk scores (Cremasco et al., 2019). Suryajana et al. (2023) also observed that shoulder flexion in coffee roasting could be mitigated by elevation tools that improve worker posture.

Although this study did not use direct CVL measurement, the extended duration of repetitive motion without sufficient recovery indicates likely cumulative fatigue. The third recommendation, therefore, is to implement structured rest breaks and reorganize task sequences to reduce physiological overload. Studies have shown that micro-breaks and alternating tasks reduce fatigue and increase endurance in physically demanding environments (Dhiya & Rahmah, 2019).

Lastly, to reduce overreaching and trunk flexion, the fourth recommendation is to redesign the workstation layout by placing the bean containers closer to and lower than the operator's body height. These adjustments aim to reduce awkward postures, which were a major contributor to the RULA score. Prior studies have reported that lowering machine or container height can reduce postural risk scores significantly, for example from 6 to 3 (Rahmahwati, 2021), and that unassisted floor-level lifting led to extreme RULA and REBA scores, which were effectively reduced after workstation redesign (Wibowo & Mawadati, 2021).

4. CONCLUSIONS

This study was conducted to evaluate the ergonomic risks associated with the coffee roasting process at Kedai Koffie Tandjoeng by applying a comprehensive assessment combining the Cardiovascular Load (CVL), Rapid Upper Limb Assessment (RULA), and Rapid Entire Body Assessment (REBA) methods. The purpose of this analysis is to adapt the work system to human capabilities in order to create a safe, comfortable, and efficient work environment.

The results obtained showed that the CVL was 39%, which falls into the category of light to moderate workload, but still requires improvement to prevent the accumulation of fatigue and the risk of long-term injury. The posture assessments yielded a RULA score of 5 and a REBA score of 4, both of which indicate medium risk levels that require timely ergonomic interventions.

The findings confirm that the most significant ergonomic risks are associated with repetitive upper limb activity, particularly involving the upper arms and wrists during manual lifting and pouring of coffee beans. This study also highlights that even moderate levels of physical and postural strain, if performed continuously without correction, may lead to musculoskeletal disorders.

To address these risks, four data-driven ergonomic interventions are proposed: ergonomic training focused on lifting posture, provision of assistive devices such as step stools, structured rest breaks, and workstation layout redesign. These recommendations are not only based on the assessment results but are also supported by previous studies that have demonstrated their effectiveness in similar industrial settings.

Overall, this study contributes to the growing body of ergonomic research in small-scale coffee processing operations by offering an integrated analysis approach that captures both physiological and biomechanical stress factors. The implementation of these findings is expected to reduce injury risk, improve worker well-being, and enhance productivity in the coffee roasting sector.

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