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ORIGINAL ARTICLE

Analysis of Measurement and Calculation of MSD Complaint of Chassis Assembly Workers Using OWAS, RULA and REBA Method

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ABSTRACT – Car assembly is a combination of all components that form one completed vehicle unit. The work process is manually done and repeatedly, which contributes to a risk of musculoskeletal disorders (MSD). Chassis assembly is a job with a high level of complexity and associated with MSD risk for its employees. This study consists of 30 assembly activities divided into six groups based on posture and working methods used during the work process. Group A consists of 7 assemblies, Group B consists of 8 assemblies, Group C consists of 5 assemblies, Group D consists of 2 assemblies, Group E consists of 5 assemblies, and Group F consists of 3 assemblies. This study aims to compare the measurement and calculation of the risk level of MSD workers by using the RULA, REBA, and OWAS methods. The results of the measurements and computations acquired using these three approaches yielded the same risk category: 83.33 % medium risk/dangerous in working groups A, C, D, E, and F, and 16.67 % very high risk/highly hazardous in working group B. These six groups, particularly group B, requires immediate attention to reduce worker complaints of MSD.

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INTRODUCTION

The automotive industry is one of the most strategic, most important and most prominent sectors of its kind in the manufacturing world [1]. This industry makes a significant contribution to the country's development and economic growth [2] [3]. Improvements in technology, climate, marketing and national policy are also expected from the automotive industry [4] [5]. Quality products with lower prices and fast delivery of automotive products such as cars are what customers around the world look forward to [6]. The assembly line is a conceptualization of a highly influential automotive production system that can be adapted to increasing and varying demands [7]. The assembly process of automotive products consists of body assembly after painting, interior assembly line, chassis assembly line and terminal assembly line [8]. The chassis assembly line is the part that is vulnerable to certain occupational accidents and hazards as compared to other processes [9]. Musculoskeletal disorder (MSD) is one of the dangers that are felt and experienced directly by workers during the work process.

In general MSD is a complaint, especially for those who have monotonous jobs [10] [11]. Work done repeatedly with the same movements over a long period of time and done manually can cause work fatigue [12] [13]. MSD is a pain felt in the skeletal muscle that workers feel from light to highly painful [14] [15]. This is because the workload performed by the worker exceeds the ability he has, thereby resulting in injury to the body. One approach that can be used to remedy the situation to analyze the work systems of interaction between humans, machines and the environment is ergonomics [16]. Some of the research on ergonomics conducted by researchers in the manufacturing and service industries are MSD risk assessment for filleting workers in the fish packaging industry [17], manual trimming workers [18], job rotation for assembly line workers [19], material handling workers [20], construction industry workers [21], gas power plant maintenance workers [22], and economy class issues on aircraft ergonomic seats [23].

Many ergonomic research has been done related to the automotive industry especially the assembly line such as ergonomic assessment and risk reduction using postural assessment tools [24]; application of technological innovations in the automotive end-sector [25]; ergonomic studies in increasing productivity with MOST (Maynard Operation Sequence Technique) [26] [27]; integration simulation based on DELMIA [28]; balancing of workload with work rotation approach [29]; path change and flexibility with multi-purpose optimization [30]; analysis of ergonomic experiments with several tools such as RULA (Rapid Upper Limb Assessment) and NIOSH (National for Occupational Safety and Health) [31]; assessment of passive upper limb exoskeletons [32] [33]; use of ErgoALWABP in random searches in completing and balancing workers [34]; use of modelling in ergonomic analysis [35]; OWAS (Ovako Working Posture Assessment System), RULA and REBA (Rapid Entire Body Assessment) in assessing WMSD [36]; and MSD risk assessment of the automobile dashboard manufacturing process using a variety of quantitative and qualitative tools (NIOSH, REBA, RULA, WISHA, LIFT, MAC, OWAS, ManTRA, and V3) [37].

Based on previous research conducted in the automotive industry, there is no focus on chassis assembly lines, especially in assembly stations. MSD's complaints that workers on this line impact the smoothness of the production

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process and require longer than the standard time to complete their tasks. Each item of related activity at the chassis line requires human beings as its main source because this process is done manually [13]. Chassis assembly lines have more danger and level of risk for workers than trimming and final lines due to working under the car body. This line has 30 assembly activities that are divided into six major groups, namely A, B, C, D, E and F. One approach that can be used to analyze the working system of interaction between humans, machines, and the environment is ergonomics [16]. Based on the positions and work postures used during the work process, such as back bending, arms reaching and lifting, legs supporting the body, and neck bending. The assembled components have an average weight of over 8 kg, such as axle sets, fuel tanks and water cleaner pipes. The components are picked up, carried and lifted by workers to the car's underside to be assembled manually. These working postures have a severe impact on the limbs of the chassis line assembly workers.

So, the purpose of this study is to measure and analyze MSD complaints felt by chassis line assembly workers by using three ergonomic measuring tools, namely OWAS, RULA and REBA. These three ergonomic measuring tools are used to measure and compare the results of MSD complaints. They are categorized as low, medium, high or very high based on the limbs and posture positions. From the three ergonomic measuring instruments used, the one that is more appropriate to the situation and condition of the workers in the chassis assembly line will be selected with consideration of the posture used.

METHODOLOGY

Car Production Floor Activities

MSD complaints from the workers in the chassis line assembly process require several stages of work. The production floor activity of car product manufacturing consists of several stages, as shown in Figure 1. Figure 1 provides information on of the automotive product manufacturing process consisting of stamping, body shop, paint shop, assembly, and quality inspection are all typical automotive production lines [38] [39]. The body shop is an assembly line where individual car parts are assembled to form the body frame or white body. The next process is the Paint Shop which includes performing the electro-deposition (ED) process, involving dipping the car body into a chemical tank and conducting electricity to avoid corrosion on the outside of the car body panels. Following the dipping process, ED sanding is used to enhance the appearance and sealing efficiency of the body panel surfaces. Seal quality is critical to avoid leakage, corrosion, dampers, dust and vibration resistance. Any chemicals used in the painting process would have been checked for safety and health, as well as their environmental effects [40]. After the painting is done, the next step is to assemble all the car components together.

Phases of the automotive assembly process are presented in Figure 2. In Figure 2, integrating or assembling automobile parts into a single complete body unit is known as an assembly. Trimming, chassis, and finishing are the three primary processes that make up an assembly line. Trimming is the process of putting together harnesses as well as other electrical parts and accessories. Chassis is the process of integrating different structures, such as installations under the body and other critical components. Finishing is the process of installation of exterior components and completion of car units, such as the installation of seats, lights, doors, and instrument panels.

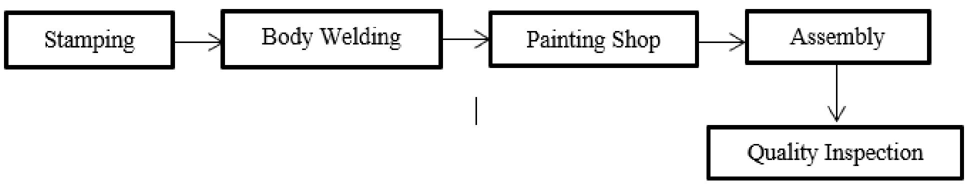


Figure 1. Car manufacturing process flow chart.

Figure 2. Assembly process of automotive products.

Condition of Chassis Assembly Line Workers

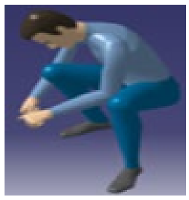
Manpower is needed in assembling the components that make up the entire product in the automotive assembly line [13]. MSD complaints are a common disorder experienced by workers in the automotive assembly department. The work environment is one of the main factors that cause MSD complaints that impact workers' performance [41]. Workers perform rigorous types of work in the assembly process, including lifting of components, neck bending backwards and rotating, raising shoulders, raising arms above the shoulders, back bending forward and backwards, waist rotating, and legs bending [10]. The automotive industry is categorized as a heavy industry, so it requires a proper ergonomic working environment, especially in the assembly line [42]. The complaints mentioned above have an impact on output losses due to non-achievement of production targets, thus requiring overtime hours in order to complete the production [43]. The extra time required to achieve productivity will have an impact on the swelling of production costs experienced by automaker companies.

The chassis process is a work that marries together the various external components of the car. The chassis process consists of installing cables coupling, parking brake clamps, radiator fan, fuel tank, radiator hose, house canister, pipe air cleaner, stabilizers, tire and many more [4]. The actual condition of workers when doing chassis line assembly work requires limb movements such as looking up and down, the back bending forward and sometimes backwards. It also involves the arms that are consistently above the shoulders and the slightly bent legs on one side.

Data Collection: Observations and Interviews of Chassis Process Assembly Workers

Direct observation is required in this case study because it relates to the work and the way it works with the work posture used during the assembly process. This observation is done to get the details of the flow of the work process performed by workers in the chassis assembly line. The description obtained is the type of assembly activities in the chassis line, the method and posture of work, the placement of facilities used, the distance required from the retrieval of facilities, and the components to be assembled to the bottom of the automotive unit. Data from the observation of the working postures of chassis line assembly workers is shown in Table 1.

Table 1. Observation data of work posture of chassis line assembly workers.

No	Job Description	Working group	Way of work	Working Posture
1	Install the Parking Brake clamp	A	The components are assembled to the lower body of the car with the arms slightly raised, arms up, legs bent on one side, the head slightly tilted and bent and the back slightly bent backwards.	
2	Install Cable Coupling			
3	Install Nepel axcel			
4	Install the Front (FR) Bumper Bracket			
5	Install the Stabilizer Bracket			
6	Install the Stabilizer			
7	Install Molt FR Susp Member			
8	Install Fuel Tank	B	Components are taken from the side of the post and brought to the underside of the car to be assembled using positioning Body bent forward, bent sideways, neck up and tilted, wrists twisted	
9	Install the Propeller			
10	Fill the transmission oil			
11	Install Pipe air cleaner			
12	Install Pipe Exhaust tail			
13	Install the shift lever cable clamp			
14	Install the Mudguard left fender			
15	Install the Mudguard right fender			
16	Install House Radiator	C	Components assembled with posture position Body bent forward, wrists above head, legs bent	
17	Attach Arm to Left Knuckle			
18	Attach Arm to right knuckle			
19	Install Socket relay block			
20	Install Bolt tube			
21	Install Pedaling machine	D	The assembled components are already in the car and workers perform the assembly process by connecting them all to a sitting body position with legs bent hands down, arms slightly open and head bent down.	
22	Install Adjust hand brake			
23	Install the carpet	E	The components were taken from the side of the post and placed in the inside of the car using the posture of one leg forward kedeoan with standing upright, body bent about 90, arms and hands bent down positioning and ignoring everything.	
24	Install Hose canister			
25	Fill the brake oil			
26	Fill Long life Coolant (LLC)			
27	Fill Freon Alternating Current (AC)			
28	Install the left front and rear left tires	F	The components are taken from the side of the post using both hands pointing straight forward, both legs are bent with one forward and the wrists are twisted following the assembly process.	
29	Install the right front and rear tires			
30	Install Tire FR Right Hand (RH)			

Observational methods are usually used to assess workplace ergonomic risks [44]. Observations can be combined with interview activities. Interviews were conducted by asking chassis line assembly workers about their names, age, length of work in the current department, and complaints felt. The interviews were completed by filling out a Nordic Body Map (NBM) questionnaire answered by employees using a Likert scale. The Likert scale consists of points 1 to 4, meaning that no pain is at point 1, little pain is at point 2, pain is at point 3, and severe pain is at point 4. This NBM questionnaire consists of 27 limbs assessed by workers based on what is felt during the work. The number of respondents used in this study which became the object of observation and interviewed was 30 workers according to the number of assembly activities on the chassis line. Risks in the workplace can be identified by conducting interviews with the people involved [2] [45].

Table 1 shows the observation data on the working posture used repeatedly during the work process. There are 30 assembly activities performed on the chassis line, divided into six workgroups, namely A, B, C, D, E and F, based on the limbs used and the body's position during the work process. Each workgroup selects different assembly activities according to the work posture. Groups A, B and C carry parts from the side storage of the line manually and then brought to the car's underbody, which is above the worker's head. Group D performed assembly activities inside the car with squat, bent, and forward body. Group E took the components from the side storage, then carried them and assembled them into the body. While working group F, assembled the left and right tires, including the absorbers.

MSD Complaint Data Processing using Ergonomic Assessment Tools

Measurement of MSD complaints assessment experienced by chassis line assembly workers in this study was done using three ergonomic assessment tools. The three ergonomic assessment tools used were REBA, RULA and OWAS.

RULA method

RULA is a method used in assessing posture, style and movements of work activities related to the upper limbs [46]. RULA was created to assess individual worker exposure to ergonomic risk factors linked to upper extremity MSD. The biomechanical and postural load needs of job tasks/demands on the neck, trunk, and upper extremities are considered by the RULA ergonomic assessment instrument [47]. RULA measurements and calculations were performed using CATIA software. CATIA software is a tool that can be used for the analysis and ergonomic design of workstations and environments [48]. Figure 3 below shows the steps for calculating RULA.

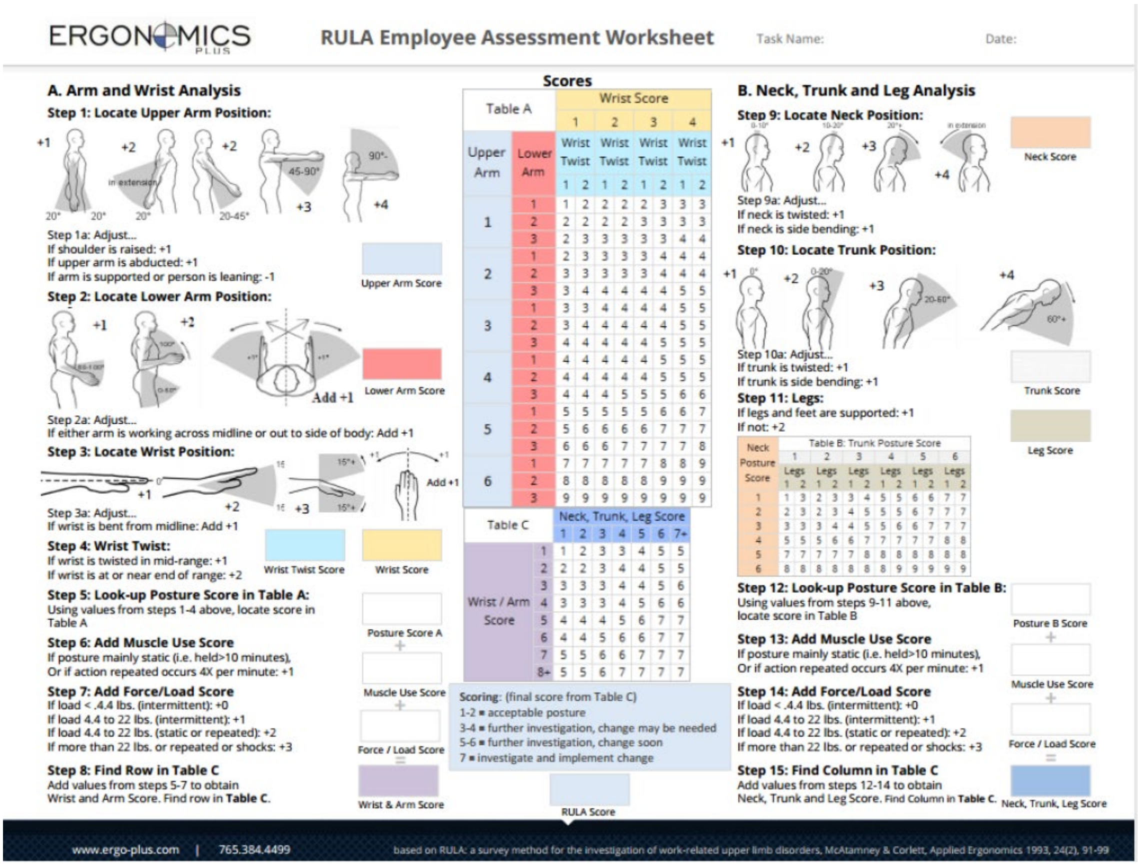


Figure 3. RULA form for measurement and assessment of complaint risk.

The RULA method is easy to use with minimum knowledge in ergonomics and without using costly tools. The evaluator will provide a score to each of the following body regions using the RULA worksheet: upper arm, lower arm, wrist, neck, trunk, and legs. Following the collection and scoring of data for each location, tables on the form compile the risk factor variables, resulting in a single score representing the level of MSD risk, as shown in Table 2 below.

Table 2. RULA score and level of MSD risk [47].

Score	Level of MSD Risk
1-2	Negligible risk, no action required
3-4	Low risk, change may be needed
5-6	Medium risk, further investigation, change soon
6+	Very high risk, implement change

Table 2 is used to determine the level of action on risk based on the final score obtained from the measurements and calculations based on the stages of the RULA method. Each level of activity determines the level of risk and corrective action recommended on the position being evaluated. The greater the value of the results obtained, the greater the risk faced for the work.

REBA method

The REBA method is an ergonomic analysis method that involves all limb movements considered harmful from workstation activities [49] [50]. This ergonomic assessment method employs a systematic approach to examine whole-body postural MSD and job-related hazards. The needed or selected body position, intense exertions, type of movement or activity, repetition, and coupling are all evaluated using a single-page worksheet [47]. The process of measuring and calculating risk analysis using the REBA method can be seen in Figure 4 below.

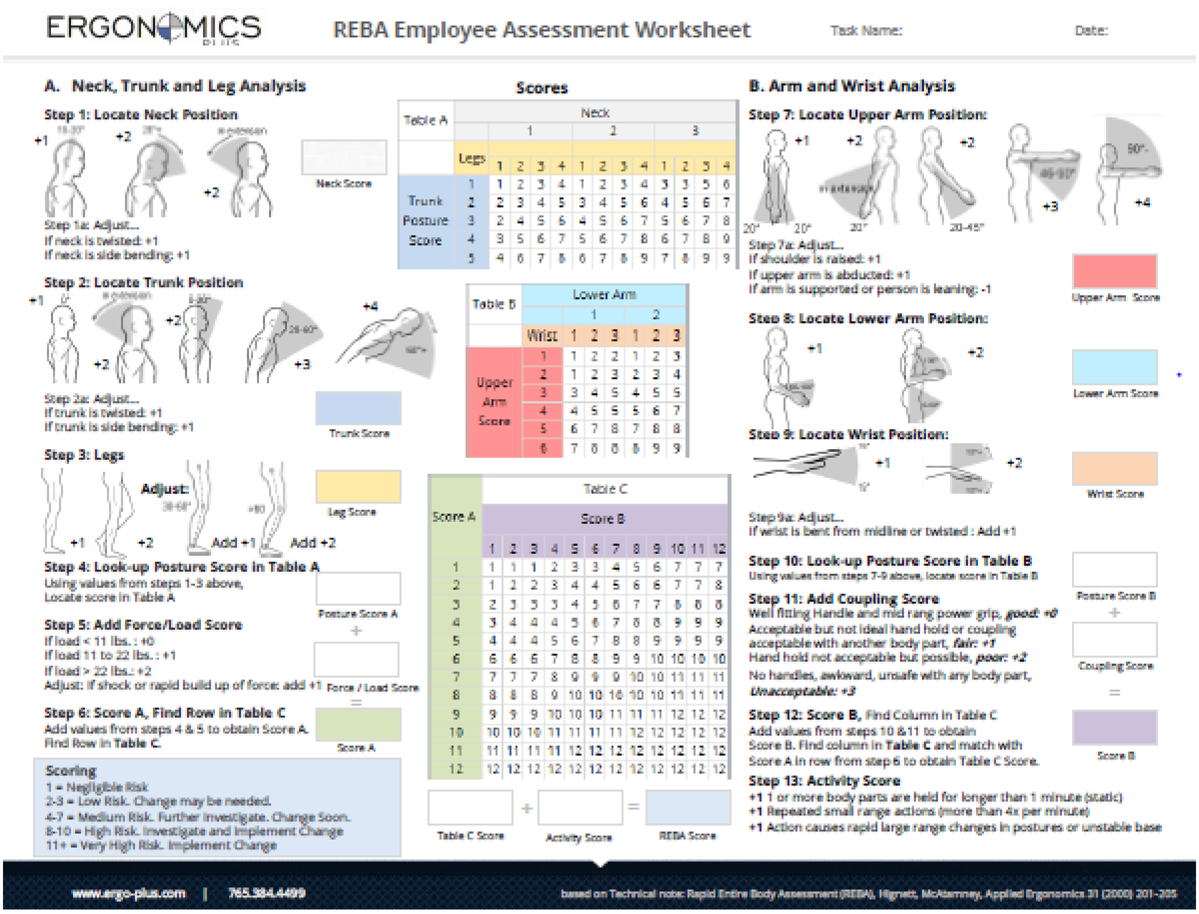


Figure 4. REBA form for measurement and assessment of complaint risk.

The REBA is also a simple method without acquiring a high level of knowledge or costly equipment. Only the worksheet and a pen are required after studying the worksheet guide. The evaluator will give a score to each of the following body regions using the REBA worksheet: wrists, forearms, elbows, shoulders, neck, trunk, back, legs, and knees. Table 3 shows the scoring of data for each location of the assembly line. Table 3 is used to determine the level of action based on the grand score obtained from the results of the calculations to decide whether improvements need to be made or otherwise to prevent injury to the musculoskeletal system. In other words, the REBA method can provide important information on any possible ergonomic risks associated with body postures during the work process.

Table 3. REBA score and level of MSD risk [51].

Score	Level of MSD Risk
1	Negligible risk, no action required
2-3	Low risk, change may be needed
4-7	Medium risk, further investigation, change soon
8-10	High risk, investigate and implement change
11+	Very high risk, implement change

OWAS method

OWAS is a simple method used in analyzing work attitudes to a load given to the body postures [52] [53]. The OWAS approach can yield a positive effect, such as an increase in work comfort and an improvement in production quality following a change in work attitude. The OWAS system is based on observations of the worker in various positions throughout his work, and it can detect up to 252 different positions as a result of conceivable combinations of back postures (4 places), arms (3 areas), legs (7 sites), and loads (3 intervals). Table 4 provides information on the OWAS classification of risk levels in the combination of positions obtained as "Risk Level". It will determine the effects on the musculoskeletal system and recommend the corrective actions to be taken.

Table 4. OWAS work attitude level category

Risk category		Effect on the musculoskeletal system	Repair action
1	Low	Normal position without effects that can disrupt the musculoskeletal system	No need for repairs
2	Medium	The position has the potential to cause damage to the musculoskeletal system	Corrective action may be required
3	High	Positions with harmful effects on the musculoskeletal system	Corrective action is needed immediately
4	Very High	Positions with a very dangerous effect on the musculoskeletal system	Corrective action is needed as soon as possible

Table 3 describes the action of the total score obtained from the calculation of the OWAS method. Scores range from categories 1 to 4 with low to very high-risk categories with effects on the MSD system and corrective actions. The basis of application of these three methods is on results of observations made directly from various positions taken on workers during the work. It can be in the form of photo analysis, video shots and observation of activities performed by the workers. After the observation is done the next process is to analyze and assess the work postures to determine the shape of the worker's body posture when performing the activities with these three methods. Table 2, 3 and 4 are levels of action required based on the final score of the analysis of OWAS, RULA and REBA. The scored results obtained from each method used by OWAS, RULA and REBA were used to determine and analyze the level of injury risk of the most extreme MSD complaints from each workgroup.

Identification of Ergonomic Risks and Body Areas Complaint of Pain by Chassis Line Assembly Workers

After calculating the MSD risk level measurement felt and experienced by the chassis line assembly workers, further action is required to identify the risk. Identifying risk assessment in this line is expected to provide technical solutions in preventing perceived hazardous events [9]. This identification was performed based on the measurement results using the three methods used in this study, namely OWAS, RULA and REBA. This identification is expected to provide information to the automotive industry, especially the assembly section, to be able to take corrective actions that must be done to minimize MSD complaints.

RESULT AND DISCUSSION

Questionnaires

The questionnaire in the study uses a Nordic Body Map (NBM) which consists of identities and fields that workers must answer following what is felt. The essence of the average chassis line assembly worker is male due to the very, highly complex work process. The average worker on the strip is 20 to 30 years old with 3 to 7 years of working time. Differences in the characteristics of these workers can affect different work attitudes during the work process.

While the NBM questionnaire was utilized in this study to identify worker complaints while conducting work activities, the results revealed that most workers reported health complaints in the neck, shoulders, waist, back, hands, and feet. This issue stems from the workers' attitude toward their task, which includes gazing up at the head, arms extending beyond the shoulders, a back that bends forward and backwards, and legs turning to one side. In addition, there is a manual workload of 10 to 20 kg that is only supported by standard tools as sniper drills. This type of workload and job procedure causes muscular fatigue and damage. The questionnaire calculations fall into the high-risk category, and corrective action is required as soon as possible.

Measurement and Calculation of MSD Complaints Felt by Chassis Line Assembly Workers using RULA, REBA and OWAS Methods

Measurement and calculation of MSD risk complaints felt by line chassis assembly workers using a combination of three methods. The methods used are OWAS, RULA and REBA. The results of the measurement and calculation of workers' MSD risk complaints on six workgroups consisting of workgroup A (7 assembly activities), B (8 assembly activities), C (5 assembly activities), D (2 assembly activities), E (5 assembly activities) and finally F (consisting of 3 assembly activities) are:

Measurement and evaluation of working group A

Working group, A consists of 7 assembly activities: install parking brake clamp, install cable clutch, install Nepal axel, install bumper FR bracket, install stabilizer bracket, install stabilizer, and install FR Molt member. These work activities are combined because they use the same posture and working methods based on observations and interviews of employees. The measurement and evaluation of work activities can be seen in Table 5 below based on the work posture shown in Table 1.

Table 5. Results of measurement and evaluation of MSD complaints of working group employees A

Activity	OWAS	RULA	REBA	Description
Assembly group A (One leg forward and bent, hands above shoulders, neck bent left, back)	2	6	6	OWAS category 3: Positions with harmful effects on the musculoskeletal system and corrective action are needed immediately. RULA category 6: Medium risk, further investigation, change soon. REBA category 6: Medium risk, further investigation, change soon.

Working group A's assembly operations provide a dangerous risk to the musculoskeletal system, according to the OWAS, RULA, and REBA techniques in Table 5, necessitating further examination and corrections as soon as possible. If repairs are not made as quickly as feasible, it could lead to additional dangerous MSD concerns and stymie the assembly process. The affected parts of the body experience pain and soreness due to how the work is currently done in the neck, trunk, arms, and wrist.

Measurement and evaluation of working group B

Working group B consists of 8 assembly activities: install the fuel tank, install the propeller, fill the transmission oil, install air cleaner pipe, install the exhaust tailpipe, install the shift lever cable clamp, install the mudguard left fender and install the right mudguard fender. These eight work activities were combined into one group B using the same posture and working methods with the same level of complaints that were felt to the limbs used based on the results of interviews and observations conducted. The measurement and assessment of MSD complaints felt by workers using the three measurement methods, namely OWAS, RULA and OWAS, can be seen in Table 6 regarding the basic work posture found in Table 1.

Table 6. Results of measurement and evaluation of MSD complaints of working group employees B

Activity	OWAS	RULA	REBA	Description
Assembly group B (Body bent forward, bent sideways, neck up and tilted, wrists twisted)	3	7	11	OWAS category 4: Positions with a very dangerous effect on the musculoskeletal system and corrective action are needed as soon as possible. RULA category 7: Very high risk, implement change. REBA category 11: Very high risk, implement change.

Table 6 is the result of calculating the complaints of the assembly workers of working group B who have a hazardous risk from the OWAS, RULA and REBA methods for the MSD system. It requires investigation and improvement as soon as possible. If the repair is not done as quickly as possible, it will result in prolonged pain for workers in the trunk, neck, legs, arms, and wrist. The impact of this pain is that the smoothness of production is hampered and affects overtime in completing the capacity unit.

Measurement and evaluation of working group C

The five assembly activities in the working group care installing the house radiator, attaching the arm to the left knuckle, connecting the arm to the right knuckle, installing the socket relay block, and installing the bolt tube. Due to using the same posture and working methods with the same level of complaints that are also felt in the limbs employed, these five work activities have been classified into one workgroup C based on the findings of interviews and observations. Table 7 shows the results of measuring and assessing MSD complaints experienced by workers using the three measurement methods, namely OWAS, RULA, and REBA, concerning the primary work posture shown in Table 1.

Table 7. Results of measurement and evaluation of MSD complaints of working group employees C.

Activity	OWAS	RULA	REBA	Description
Assembly group C (The body is bent forward, the wrists are above the head, the legs are bent)	2	6	7	OWAS category 3: Positions with harmful effects on the musculoskeletal system and corrective action are needed immediately. RULA category 6: Medium risk, further investigation, change soon REBA category 7: Medium risk, further investigation, change soon

According to the OWAS, RULA, and REBA procedures in Table 5, the assembly processes of Working Group C provide a severe risk to the musculoskeletal system, prompting further assessment and modifications as soon as possible. If repairs are not addressed as quickly as possible, it could lead to more dangerous MSD issues and slow down the assembly process. Because of the way the work is now done in the neck, trunk, arms, and wrist, the afflicted regions of the body experience pain and soreness.

Measurement and evaluation of working group D

Two installation activities in the working group, namely install pedalling machine and adjust hand brake. The combination of these two assembly activities into working group D is due to the similarity of work posture used during the work process and based on the results of complaints from interviews conducted based on direct observations conducted. Table 8 shows the results of measurements and assessments performed based on work posture and observations performed directly using the methods of OWAS, RULA and REBA based on Table 1 for working group D.

Table 8. Results of measurement and evaluation of MSD complaints of working group employees D

Activity	OWAS	RULA	REBA	Description
Assembly group D (The body is bent forward, the wrists are above the head, the legs are bent)	2	5	5	OWAS category 3: Positions with harmful effects on the musculoskeletal system and corrective action are needed immediately. RULA category 5: Medium risk, further investigation, change soon REBA category 5: Medium risk, further investigation, change soon

The calculation of MSD complaints of working group D assembly workers based on the OWAS, RULA and REBA methods falls into the category of moderate and dangerous risks that need improvement as soon as possible to avoid continuing complaints that have a fatal impact. If this complaint is not corrected, it will affect pain and soreness in the trunk, wrist, and arms, affecting the smooth production process of car assembly.

Measurement and evaluation of working group E

Working group E consists of five assembly activities: carpet installation, hose canister installation, brake oil filling, LLC filling, and Freon AC filling. Job complaints about the limbs employed throughout the work process are identical in these five assemblies. These problems are caused by poor postures that do not follow ergonomic guidelines. Table 9 shows the measurement and computation of MSD complaints experienced by workers in working group E, based on the work posture depicted in Table 1 and observations made.

Table 9. Results of measurement and evaluation of MSD complaints of working group employees E.

Activity	OWAS	RULA	REBA	Description
Assembly group E (The body is bent forward, the wrists are above the head, the legs are bent)	2	6	5	OWAS category 3: Positions with harmful effects on the musculoskeletal system and corrective action are needed immediately. RULA category 6: Medium risk, further investigation, change soon REBA category 5: Medium risk, further investigation, change soon

Based on the calculation results performed on the MSD complaints felt by the workers of working group E, which are found in Table 9 by using the OWAS, RULA and REBA methods, they are included in the category of moderate and dangerous risk. This risk will require corrective action as soon as possible to avoid worsening pain for workers, especially in the neck, trunk and legs. So to keep the production process running smoothly, it must be considered to make improvements following the existing work situation in workgroup E.

Measurement and evaluation of working group F

Install the left front and rear left tires, the right front and rear tires, and the FR RH tires are the three assembly activities in Working Group F. These three assembly activities are grouped in workgroup F because they all require the same body posture complete. This classification is also based on the findings of observations and interviews using the NBM questionnaire as a supplement to identify the level of worker dissatisfaction. Table 10 shows the investigation results of the computation of MSD complaints experienced by workers in working group B based on the work posture depicted in Table 1.

Table 10. Results of measurement and evaluation of MSD complaints of working group employees F.

Activity	OWAS	RULA	REBA	Description
Assembly group F (The body is bent forward, the wrists are above the head, the legs are bent)	2	5	5	OWAS category 3: Positions with harmful effects on the musculoskeletal system and corrective action are needed immediately. RULA category 5: Medium risk, further investigation, change soon REBA category 5: Medium risk, further investigation, change soon

Table 10 shows that MSD complaints of working group F assembly employees calculated using the OWAS, RULA, and REBA methodologies fall into the moderate and dangerous risk categories, requiring immediate modification to avoid continued complaints with fatal consequences. If this problem is not resolved, it will cause pain and soreness in the trunk, wrists, and arms, interfering with the smooth manufacturing of automobiles.

Comparison of Ergonomic Risk Assessment Results for Chassis Assembly Workers based on OWAS, RULA and REBA Methods

The methodologies utilized in this study to assess the level of danger perceived by chassis line assembly employees were OWAS, RULA, and REBA. These three ways can describe the movement of all sections of a worker's body and improve overall body mobility, providing a sense of comfort and safety while executing work activities. Based on the findings, it can be seen that all three methodologies give the same results for all operations of the chassis line assembly. The risk analysis results are divided into moderate or dangerous categories and extremely high or very dangerous. The working group A, C, D, E, and F, which falls into the medium and dangerous category, comprises five groups. This working group needs to take corrective measures as quickly as possible to avoid more discomfort that could jeopardize the seamless production of automobiles. The usual worker's pain is felt in the trunk, legs, wrists, and arms.

While one working group, namely working group B, is in a very high-risk category and very dangerous that requires corrective action as soon as possible. These complaints are very reasonable and can impact the smoothness of the work. Usual complaints of pain the average worker feel are in the trunk, neck, legs, arms, and wrist. Figure 5 below shows a summary of the assessment obtained from the measurement results of the analysis of MSD complaints felt by chassis line assembly workers based on the three methods used, namely OWAS, RULA, and REBA. The highest MSD complaints relate to the lower back, accounting for 50.9% of 78.4% of workers who complained [54]. The most common complaints are neck, shoulders, arms, hands, back, waist, legs and ankles [13].

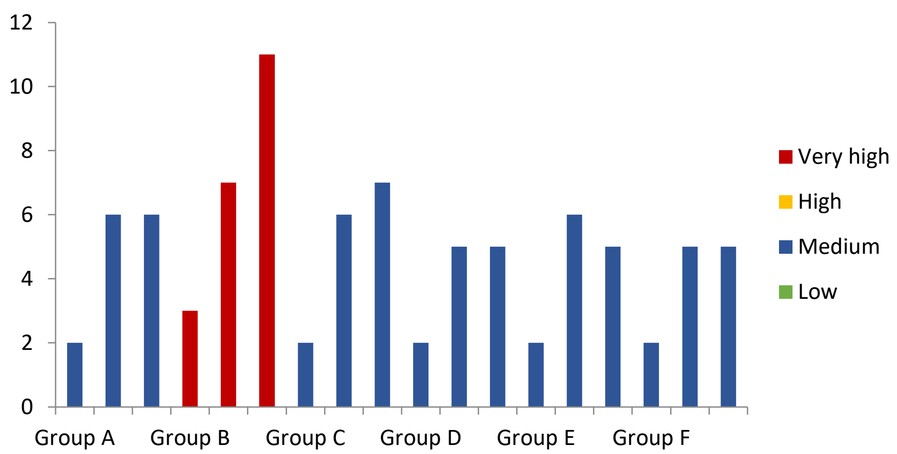


Figure 5. Final recap of scores with risk categories from each workgroup based on OWAS, RULA, and REBA methods.

Figure 5 shows the results of the calculation and risk categories of MSD complaints felt by chassis line assembly workers in sequence based on the three tools used for each workgroup starting from OWAS, RULA and REBA. The working group's A, C, D, E and F are categorized in the medium category, which requires corrective action. While working group B is very high with a red symbol, it needs corrective action immediately or as soon as possible. The results of calculating workers' MSD complaints with the three methods used, namely OWAS, RULA and REBA, are at the same risk of complaints about each assembly activity. Groups A, C, D, E and F belong to the medium and dangerous risk categories. While group B has a very high-risk level and is very dangerous. The three ergonomic measuring instruments used have similar results for each workgroup measured and analyzed. However, the REBA ergonomic measuring tool is the most suitable for the situation and condition of the workers in the chassis assembly line because it considers all the limbs used in this study, namely the trunk, neck, legs, upper arm and lower arms. The percentage of MSD complaints felt by chassis line assembly workers was 83.33% in the medium and hazardous categories, while 16.67% were categorized included in the very high and very dangerous categories. Therefore, what must be a priority in minimizing MSD complaints felt by chassis line assembly workers is working group B with a percentage of 16.67%. Improvements to minimize MSD complaints felt by workers are making the design of aids such as ergonomic work chairs that reduce pain in the neck, arms, back, waist and legs while working.

CONCLUSION

The chassis assembly line assembles components manually with an average weight of more than 8 kg under the car body. This process has an impact on MSD's complaints against workers. This line has 30 assembly activities divided into six major groups, namely A, B, C, D, E and F, based on the work posture used. REBA, RULA and OWAS were used in this study to measure and analyze MSD complaints felt by workers. Of the three existing methods, REBA is the most appropriate method because it considers all aspects of the limbs used in work. Groups A, C, D, E, and F, showed that 83.33% of the complaints were classified as moderate, detrimental, and required corrective action. While group B measured 16.67%, the complaints are very high and very dangerous that need to take corrective action as soon as possible. Among corrective actions suitable for the improvement is to design an ergonomic work chair and standardize work procedures by considering the aspects of the right and left hand to minimize the complaints of MSD workers.

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