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Integrated self-report and observational risk assessment for work-related musculoskeletal disorder in small and medium enterprises

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Abstract

Musculoskeletal Disorder (MSD) is a very common grievance of employees working with SMEs and large industries. The objective of this research is to examine the risk of MSD for operators in the manufacturing segment of SMEs by deploying two ergonomic approaches: self-report (SR) and observation method (OM). The project has been executed in the manufacturing SMEs in Indonesia. The SR methodology utilizes the Nordic Body Map (NBM) for assessing the comfort and grievances of the operator. Besides, the OM methodology deploys the Rapid Upper Limb Assessment (RULA) as an appraisal of the worker's work stance. A Self Report evaluation based on NBM triggered the obtained concerns in the upper body that occur on the back, neck, hips, and buttocks. OM based on RULA assessment observed that the position of the worker has a value score of 6, which requires further analysis and changes at the earliest. Based on the RULA assessment, this paper recommended the involvement of ergonomics at the place of work to decrease the MSD issues encountered by the operator and make the places of work relaxing. According to the results, the new workplace displays a value score of 3 based on RULA assessment and the final tally was noted to be a satisfactory posture. Thus, the SR method is beneficial for preliminary screening before deploying further assessment of the OM methodology. It is vital for follow-up assessment in order to offer suggestions on the basis of ergonomic risk evaluation.

Keywords: Self-report, Observational risk assessment, Ergonomic, RULA, Musculoskeletal disorder

1. Introduction

The development of small and medium enterprises (SMEs) has been taking place swiftly in Indonesia. These SMEs play a key part in augmenting the economic setup and social steadiness [1]. SMEs present rather appealing job prospects in emerging nations like Indonesia [2]. Several SMEs are growing in the country, including the food and manufacturing sectors. The majority of SMEs in Indonesia engage workers who are primarily engaged in the work process. This indicates that the role of a man or the operator is nonetheless the most vital in manufacturing a product. Human workforces play a vital part as fixers and operators in contemporary production systems and facilities. Several elements of the physical attributes of industrial jobs, primarily manual activities, involve human participation. For instance, when workers have to collect a component or fix it in the assembly posture [3]. The use of human resources in the production of certain things has few drawbacks; the deployment of manual labour cannot project the timing or target of the labour work and has certain limits in conducting that regularly. Humans require sufficient rest time to carry the work so that the level of labour output goes up [4]. SMEs have acknowledged that they need to raise output to grow revenue. One means of raising the output is by offering comfort to workforces employed with SMEs [5, 6].

An ergonomic concern that frequently encountered at the place of work, especially pertaining to human power and stamina to carry out the work, is a musculoskeletal disorder (MSD). This typically begins with a working posture that is less ergonomic. Several aspects in the work environment could trigger MSDs. Specific body parts, like the upper limb, neck, and back, face a greater risk of MSDs due to the uncomfortable posture at the place of work [7]. The painful working posture could result unproductive employees and decrease their efficiency. In worst scenarios, it could cause MSD related to injuries.

Complaints regarding MSDs are mostly about muscles like ligaments, tendons, joints, and cartilage [8]. When a muscle gets a static load recurrently and for a prolonged period, it triggers complaints about harm to the ligaments, joints, and tendons. Workers who carry our monotonous tasks in one cycle are quite vulnerable to intervention by MSDs [9, 10]. In ergonomics, stance and mobility of workers are vital information for ascertaining the risk of musculoskeletal damages at the place of work. Different approaches and tools have been formulated to evaluate exposure of risky aspects for musculoskeletal disorders related to work. For more, gauging of MSDs can be split into three: the approach to self-report (SR), direct measurement (DM), and the observational method (OM) [11].

Several research works have scrutinized by using just a single parameter measurement. This study [12-14] deploys the SR methodology. The study deliberated that the SR approach data recovery can be done through interviews and questionnaires. The drawback of this methodology that the charging procedure by respondents is not dependable every time and can drive biased construal

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[15]. The next methodology employed in many research works is DM [8, 16]. Data is gathered with the aid of sensors placed on the worker's body, allowing the results to be studied on a computer. The drawback of this methodology is the challenge of applying the DM in actual workplace scenarios as it is blocked by wires fixed to the employee's body [17]. Furthermore, due to the DM approach, employees would experience uneasiness, thus impacting their posture [18]. The OM methodology is very popular and it involves directly noticing the posture of the workers. The popular processes in this approach are REBA (Rapid Entire Body Assessment) and RULA (Rapid Upper Limb Assessment) [19].

Research works which have deployed the OM methodology are:[10, 19, 20]. A limitation of deploying this methodology is that the precision and substantiation of the results. It depends on the input information collected, and hence the results could be biased [21].

On the basis of the comparison of a few of these works, every study takes into account only one approach. The usage of only a single approach is because of the several ergonomic techniques which make it simple to assess; furthermore, every method has a different use [22]. The benefit of deploying two approaches is that the information would be more precise and typically the second approach would generate more wide-ranging suggestions [23].

Referring to those explanation, this current study employs self-report (SR) evaluation and Observation Method (OM) to assess an operator in manufacturing SMEs. In short, the objective of this work is also to examine the risk of MSDs faced by operators in manufacturing related SMEs. In detail, the SR method deploys Nordic Body Map (NBM) for assessing the comfort and grievances of the operator, whereas the OM methodology deploys the RULA (Rapid Upper Limb Assessment) approaches. All the data from this work might help understanding the relationship of one approach with another, particularly SR and OM. One approach would be consistent from the initial assessment to the suggestion for enhancement [24]. For instance, in case the interrelationship is in the assessment using NBM, a complaint is attained from the upper body part, and then the second methodology would seek a specific method of the upper part assessment, i.e. RULA.

2. Materials and methods

2.1 Method

This research intends to blend the SR evaluation and the OM approach. The key steps of ergonomics analysis can be noted in Figure 1.

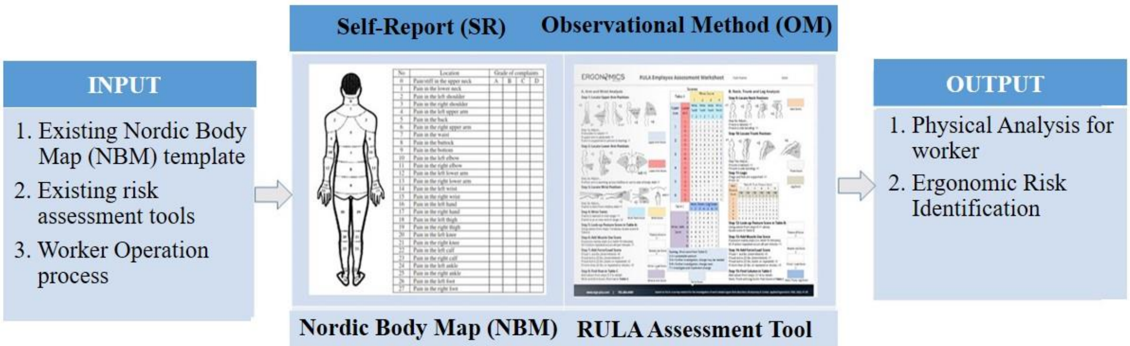


Figure 1 Main phase of ergonomics investigation

2.2 Location and participants

This study was carried out in a SME namely "WL Aluminum Yogyakarta" in Indonesia. This company is engaged in the manufacturing of aluminium home appliances like pans and pots. The firm employs approximately 76 to 100 workers and the work hours are from 8:30 am to 4:30 pm within one hour of break. Certain tasks are carried out manually, such as the installation procedure of potholders, which is repeatedly done. The operators' posture during the installation procedure is sitting on the floor with a casual working approach (bending the body and head position) as depicted in Figure 2. The activities with unbalanced work postures are handled for 7 hours to manufacture. Every worker does of almost 75 to 200 products a day.

Figure 2 Posture of the operator

2.3 SR Analysis

SR analysis aids in ascertaining a complaint by the operator through NBM questionnaire. NBM questionnaire is a kind of ergonomics specification questionnaire which is most frequently deployed for ascertaining the inconvenience of workforces. The questionnaire is generally worldwide standardized [2, 25-28]. The Nordic Body Map questionnaire intends to ascertain the employee's body parts which have painful experience prior to and after carrying out the work. There were four anatomical areas, such as the body (neck), upper limbs (forearms, shoulders, hands/wrists), lower limbs (feet, legs) and trunk (lower and upper back) [29]. The designed questionnaire used an image of the human body which was split into nine key segments: shoulders, neck, elbows, upper back, lower back, hips/buttocks, wrists/hands, knees, and ankles/feet. Individuals who answered the survey were interviewed to offer an indication whether they experienced any intervention in the parts of their body or not.

2.4 OM Analysis

The OM analysis was carried out to examine the operator's posture and the work which are carried out continuously to allow the occurrence of MSDs. Working position is noted as per the RULA evaluation tool (Figure 1), so as to ascertain the rigorousness of the operator's posture for analysis purposes. RULA is an observation-focused screening utility for evaluating the operator's work position [11]. RULA emphasizes on the scrutiny of stance, force and repetition applied at the workplace [10]. Evaluation is split into two segments: Part A emphasizes on the scrutiny of the wrist and arm, whereas section B emphasizes on the neck, legs and body. On the basis of this scrutiny, RULA obtained a score for ascertaining the risk of working stance. RULA inspected the risk elements to deliver a total score that falls in the range of 1 to 7 [3]. Table 1 depicts the RULA evaluation in which the score of 1-2 is termed as an acceptable working posture; a score of 3-4 is a low-risk work posture which entails more investigation. In contrast, the cores of 5 and 6 attract the risk of turning into a working posture and entail further scrutiny. Lastly, a score of 7 depicts a high risk in the working posture.

Table 1 RULA Action categorizes

Score	The level of risk	Implications and risk posture employment issues
1-2	posture accepted	acceptable posture
3-4	low risk	Needed further investigation and changes may be necessary
5-6	intermediate risk	Needs further investigation and changes are required immediately
7	Very high risk	Investigation and implement the necessary changes Soon

3. Results and discussions

3.1 SR Analysis

Information about the operators was collected through interviews as depicted in Table 2. The objective of the interviews was to ergonomically comprehend the concerns at the place of work. However, there was only one operator assessed, as he was the only one who worked and had a working posture causing MSDs. Health screening utilizing the NBM questionnaire has been presented so that the operator can cite the body parts which feel uncomfortable when carrying out the work. The operator's posture during the installation procedure is sitting on the floor and bending the body and head posture. The position lacks comfort and is in risk of causing MSDs if the work goes on daily.

Table 2 Data information about the operator

No.	Item inquiry	Result
1.	Sex	Men
2.	Age (years)	50
3.	Weight (kg)	64
4.	Height (cm)	164
5.	Experience (years)	5
6.	Marital status	Married
7.	Duration of action (hours / day)	7
8	Time of Operation	8:30 AM – 4:30 AM
9	Rest time	12:00 PM – 13:00 PM

An analysis of the body part that experienced physical complaints was conducted through the questionnaire Nordic Body Map. The NBM questionnaire data was processed for ascertaining the complaints by the operator. The results of complaints are depicted in Figure 3, marked in red, while the results of the NBM score are depicted in Figure 4. According to the NBM score, it is observed that there are 7 body points which have pain categories and 3 body parts characterise moderate pain. On the basis of the operator's complaint, the upper body had the most issues as depicted in Figure 3.

The NBM questionnaire can be used as a reference for making further observations. The NBM questionnaire is intended to find out in more detail what parts of the body experience disturbances or pain during work. NBM can identify and provide an assessment of complaints of pain experienced. The Nordic Body Map Questionnaire is the most frequently used questionnaire to determine workers' discomfort [30-32].

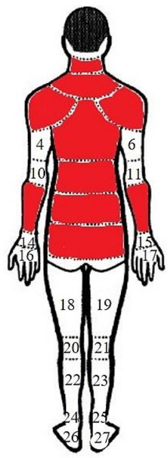


Figure 3 Results of pain levels reported by NBM questionnaire

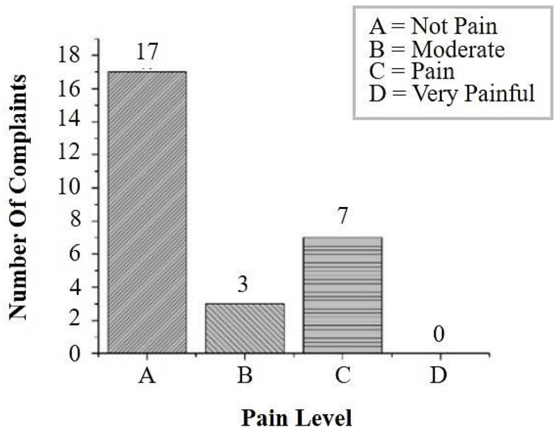


Figure 4 Results of NBM score

3.2 OM Analysis

The OM analysis was carried out by utilizing the Rapid Upper Limb Assessment (RULA). It assigned a risk score between 1 and 7. It indicates that the greater the score, the bigger being the risk of MSDs. Data on the operator's position is necessary for creating the simulation by utilizing a mannequin in CATIA. Two body parts were to be drawn: body which was visible from the left angle and the right side. Image analysis of the operator's working position is depicted in Figure 5.

In detail, the data used to determine the complaints of MSDs using RULA were the upper arm, forearm, wrist, wrist twist, neck, trunk and legs. RULA's final score determined the level of risk of a particular task [33, 34].

(a) Right Side (b) Left Side

Figure 5 Position of an operator

The design of the mannequin made using the CATIA software was as per the body dimensions or centred on anthropometric data carriers. The parameter of measurement is the 50th percentile. As an average size, this is likely to summarise the entire populace so that it can deal with the intricacy of the anthropometric measure [11]. The usage of anthropometric data for this project is based on anthropometric data of Indonesian individuals. Magnitudes for small, average, and large population are depicted as 5th percentile, 50th percentile, and 95th percentile. The data utilized are adult male population [2]. However, the percentile used in this design is 50th percentile which corresponds to the average Indonesian population [35]. On the basis of the questionnaire results, there is a complaint about the top and bottom of the neck as the worker works at an angle of 38° with the head down. The complaint about back pain is because the operator has to work in a tilted posture and at an angle of 22º. Pain in the buttocks and hips is experienced as the operator remains seated on the floor. The pain in the right and left arms is because of the absence of a table or a working tool which offers support. The operator has to hold the product at a height of less than 12-25 cm from the floor. Hence, he has to bend his head and body position. The fair pain complaints are about two parts of the body: the right and left shoulders. These complaints are triggered by the posture of the operator's head which is bent down constantly and bending the shoulders at once. The lower segment of the buttocks also experiences the pain as the operator avoids using the pedestal.

The RULA evaluation was carried out by using the CATIA software. The mannequin was adjusted as per the operator's body shape when carrying out the work. The RULA evaluation helped understanding the amount of risk for each circumstance, as undergone by the operator. Figure 6 and Figure 7 depict the observations of the analysis based on the RULA score.

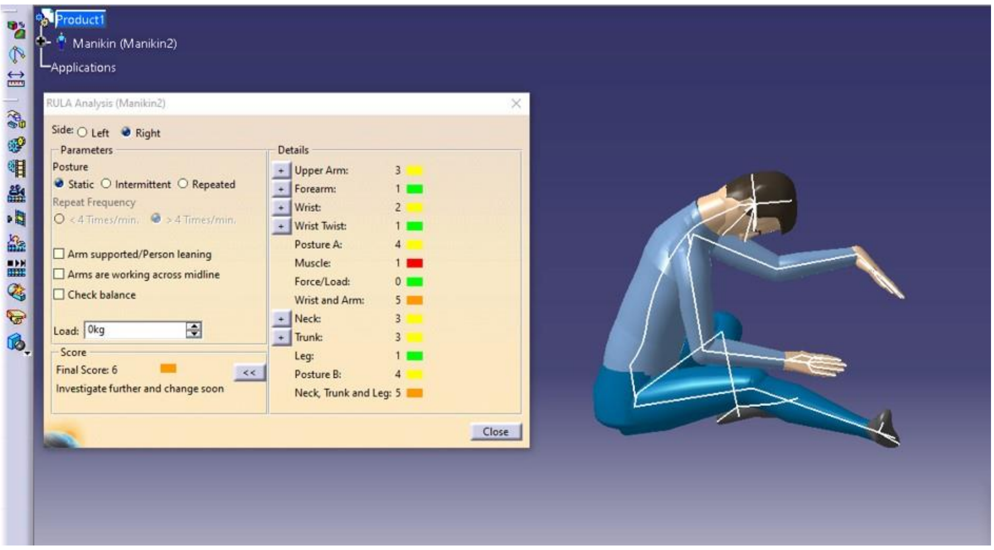


Figure 6 RULA Score right side

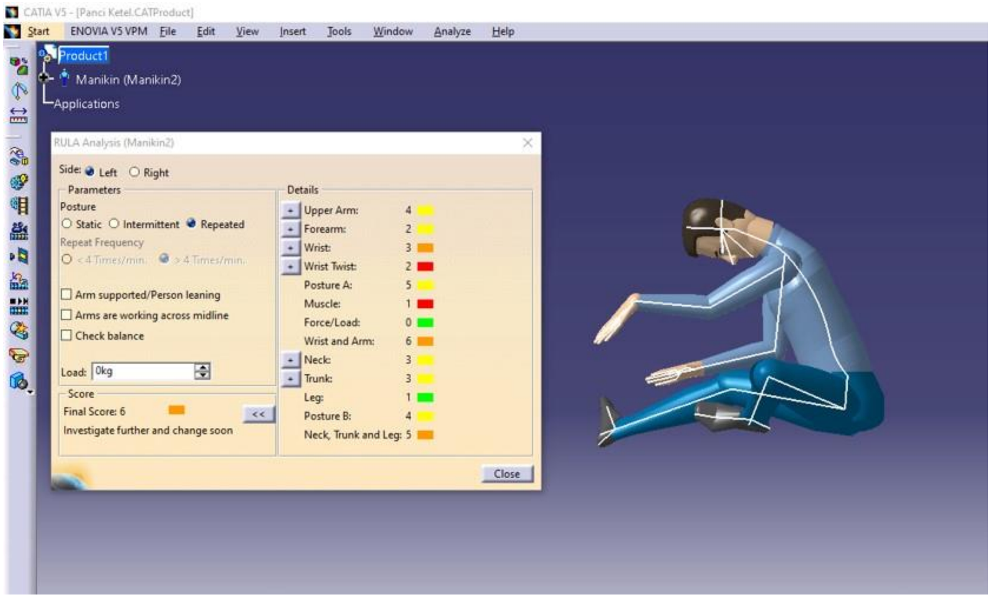


Figure 7 RULA Score left side

The RULA evaluation score observed from the left and right side is 6. It implies if a worker works and remains at a seated position on the floor, the RULA score is 6 as depicted in Table 3 RULA Final score more investigation and changes are needed straightaway.

Table 3 RULA Final score

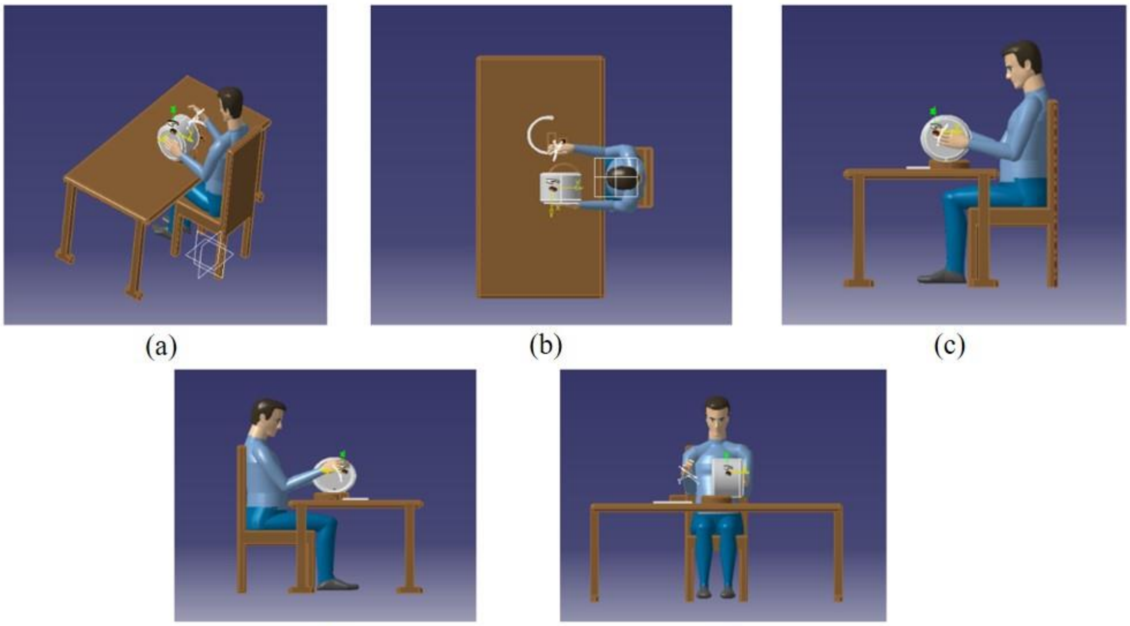
Tool	Color code	RULA Score	Action
RULA		6	Needs further investigation and changes are required immediately

3.3 Proposed solution

The design is executed after understanding the operator's body size with a range of 50th percentiles for anthropometric data carriers. The size of the body measurements was ascertained before carrying out the designed task for tables and chairs. It was suggested that the chair’s height has to be in accordance to the body size of the operator. For the chair’s height, the design utilizes a popliteal height aspect such that the chair’s height is 43 cm. The width of the chair’s back is 41 cm. The back’s height is 59 cm. The design of the seat’s width is based on the hip-width dimension of 40 cm, and the seat length is 45 cm as per the popliteal buttocks features. The observations suggest that additional modification of the chair should also provide an ergonomic worktable. The dimensions of the table match the elbow height in a seated posture. The table’s height is 64 cm. The width of the worktable is set as per the hand span, which results in the dimensions being 163 cm. The length of the table is adjusted as per the hands, and the length set at 78 cm.

3.4 Effectiveness modifications

A simulation test was carried out to note whether the size of the working device has been able to decrease the risk faced by the operator on the basis of the observations from the RULA analysis. Simulations were conducted using mannequins and by creating a work tool. The tools used during the simulations were those that are commensurate with the design size determined using anthropometric measurement data carriers. Figure 8 depicts a mannequin operating the tools on the worktable.



(a) (b) (c) (d) (e)

Figure 8 Mannequins of the operator

The results of the image analysis, based on the RULA evaluation, can be observed through Figure 9 and Figure **10**. Both kinds of operator postures, i.e. posture when holding the hammer and when it hits the pin, have the same RULA analysis outcomes when seen from the right and left of the operator's body. RULA analysis suggests that the right upper arm, wrist twist, forearm, neck, trunk, and legs are classified as green. The colour indicates that the operator has a comfortable posture that is acceptable for work. In the wrist segment, arm and wrist, yellow colour code means that the position of the operator working on the table classified as the less risky position. The parts indicated in red colour are understood to be in a dangerous position and these gain muscle. The regions represented in red have a low value of 1.

On the left side, the right upper arm, wrist twist, forearm, neck, trunk, and legs are classified as green. The colour indicates that the operator has a comfortable posture that is acceptable for work. The muscle growth segment indicated in red colour indicates a dangerous position. The regions represented in red have a low value of 1. The RULA analysis of the left and right sections of the body yields a final score of 3, which falls in the yellow category. This indicates that the operator is working in comfort with the media and the posture is not too risky.

The RULA posture considers static postures and cannot be utilised to compute dynamic postures [11]. The RULA computations entail substantiation by deploying some software like Kinect so that the computations can be considered valid [11]. The usage of a single approach in ergonomic risk evaluation is not applicable to all MSD issues. It is only useable on particular parts of the body. For these reasons, a combination of methods is required so that the ergonomic assessment may be performed objectively [29]. The results of the studies collated to have information of self-reporting on material combinations in order to assess operator posture. Furthermore, the assessment can be blended with OR. SR measurement exhibits reliability and legitimacy and hence can be utilized for decision-making [36, 37]. On the other sides, the SR approach can be utilised for managerial decision making as well, so that workers can feel at ease and MSDs can be decreased. Furthermore, SMEs should have a well understanding regarding ergonomics as well. Unfortunately, the majority of SMEs ignore comfort and ergonomic execution at the workplace, thus impacting the symptoms of MSDs [9].

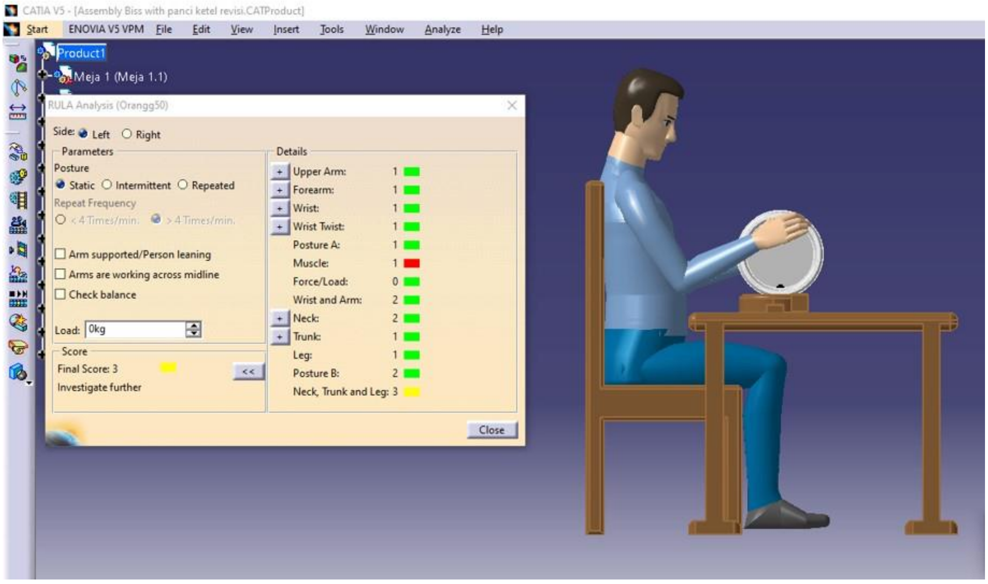


Figure 9 Posture analysis by RULA when operators do their jobs and viewed from left side

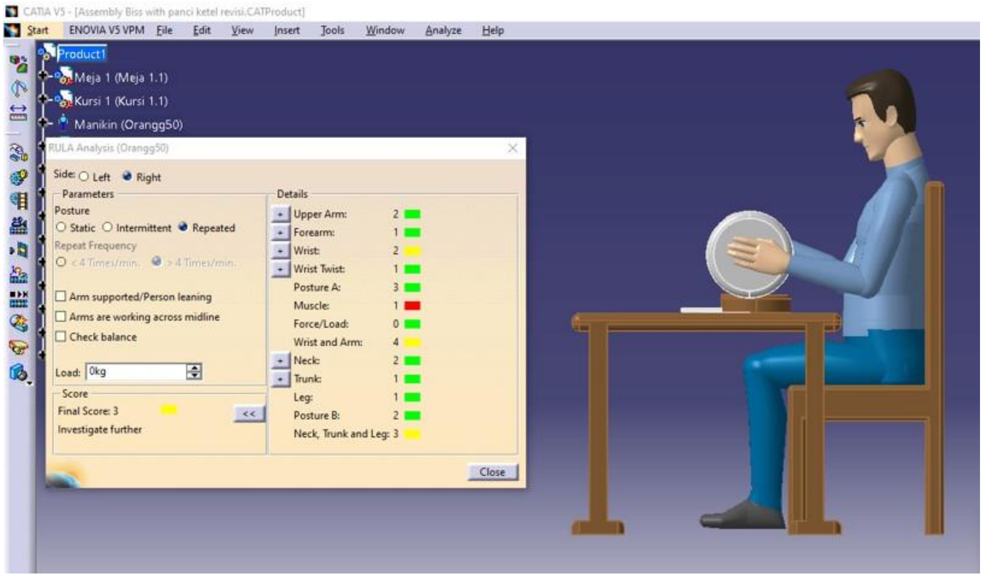


Figure 10 Posture analysis by RULA when operators do their jobs and viewed from right side

4. Conclusions

OM and SR are interconnected methodologies which render a broad ergonomic assessment. The Nordic Body Map may be used for SR and RULA analysis using the OM approach. The results report complaints in the upper body when the Nordic Body Map is used. In specific, the complaints are about the back, neck, hips, and buttocks. Additional related studies through the OM approach may be conducted by using the RULA method. The RULA method evaluates the worker’s position score as 6, which suggests more analysis to be performed and changes are immediately done. This necessitates a difference in the working posture by creating working tools to assist the workers. If the work tools are modified to increase operator comfort, the RULA score the change with a score of 3.

5. Acknowledgements

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