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RESEARCH ARTICLE

Application of Sensor Technology to Reduce the Risk of Musculoskeletal Disorders in Workers through Posture Evaluation: A Study of the Effectiveness of IMUs in the Indonesian Industry

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ABSTRACT

This study aims to increase managers' and workers' understanding and awareness of IMU sensor technology for posture evaluation in Indonesia and assess the application of IMU sensors to improve workers' working posture. This study uses a quantitative research design with an experimental approach to evaluate the effectiveness of IMU sensors in reducing the risk of MSD among workers. The experiment will involve collecting posture data from workers using IMU sensors, analyzing this data to identify high-risk postures, and recommending ergonomic interventions. The results of conventional and digital REBA measurement trials with IMU technology show a difference of 1.65%, so using IMUs can improve the work system, considering that the results are faster, more precise, and more accurate. However, many researchers noted that IMU has advantages and valuables, but it still has limitations, such as the complexity of technology related to its application in work activities. Therefore, further research and development must be carried out seriously to ensure the successful implementation of IMU, promote occupational health and safety, and realize more sustainable health care.

INTRODUCTION

Musculoskeletal disorders (MSDs) are a globally significant occupational health problem, mainly affecting workers who engage in strenuous physical tasks or adopt poor posture for extended periods (Harcombe et al., 2009; Nasarudin et al., 2022). The World Health Organization (WHO) reports that MSDs can affect muscles, joints, ligaments, and nerves, causing pain, fatigue, and limited mobility, which, if left untreated, can lead to chronic conditions that require long-term medical care. This condition, in turn, results in reduced productivity and negatively impacts the quality of life of workers (Gill et al., 2023; Akbar et al., 2023).

The industry is increasingly aware of the importance of addressing and preventing MSDs in the workplace. Applying ergonomics, which optimizes workplace design to match workers' abilities, has effectively reduced this risk. Posture evaluation is a fundamental component of such efforts, ensuring that workers maintain a safe and efficient body position during their duties (Susihono et al., 2021; Oakman et al., .2023; Diantat et al., 2020; Yoon et al., 2016). However, traditional methods of posture evaluation, such as Rapid Entire Body Assessment (REBA) and Rapid Upper Limb Assessment (RULA), while helpful, often require extensive time and expertise, limiting their use in rapid industrial environments (Hignett et al., 2000; Sukapto et al., 2019; Nelfiyanti et al., 2022; Abdullah et al., 2022).

Recent technological advances have introduced sensors, especially Inertial Measurement Units (IMUs), as innovative solutions for monitoring and assessing posture in the workplace (Sabino et al., 2024). IMU sensors are based on triaxial accelerometers and gyroscopes capable of measuring 3-dimensional acceleration and angular velocity of the sensor against gravity (Luinge, 2002). These sensors, which can measure the orientation and movement of the human body, provide real-time data on posture, offering a more efficient and accurate way of evaluating posture than manual methods. IMUs are wearable devices attached to different body parts, collecting data on movement and angles, which are then analyzed to identify high-risk postures that can cause injury.

The IMU sensor is installed wearable. Wearable technology is an electronic device worn on the user's body (Stefana et al., 2021). The device can take many forms, including jewelry, accessories, medical devices, and clothing or clothing elements. With this *wearable method*, it is possible to collect data during work activities. However, there are challenges, such as its use being as much as possible without interfering with the work process. This device's capabilities can be used to measure various physiological and kinematic parameters of the human body, assess human performance, monitor human movements, conduct motion analysis in real environments, and record user kinetics (Conforti et al., 2020). By collecting data during work activities, users can review the results of ergonomic analysis to correct themselves if there are mistakes during work. Wearable technology can improve employees' work efficiency and physical well-being and reduce the risk of work-related injuries (Khakurel et al., 2018).

Using IMUs improves the efficiency of ergonomic evaluation and allows for targeted interventions. By analyzing the data collected through these sensors, companies can quickly identify body movements that pose a risk of MSD and introduce ergonomic corrections to prevent injury. Additionally, continuous monitoring through the IMU allows for tracking posture changes over time, making it possible to detect and mitigate possible long-term risks.

While there are significant advantages to using sensor technology, some challenges remain in its implementation. High investment costs and the need for specialized training to interpret and manage sensor data are significant barriers, especially for small and medium-sized enterprises (SMEs). In addition, organizations need to conduct a cost-benefit analysis to justify the initial costs of implementing this technology.

Given these potential benefits and challenges, this study aims to explore the adoption of sensor technology in Indonesian industrial workplaces, focusing on the effectiveness of IMUs in reducing MSD risks. The study also aims to address challenges related to cost, training, and worker recruitment, providing recommendations for organizations considering the adoption of sensor-based posture evaluation.

The objectives of this study are a. to increase understanding and awareness of IMU sensor technology for posture evaluation among managers and workers in Indonesia and b. to assess the application of IMU sensors in improving the working posture of workers in the workplace.

LITERATURE REVIEW

Musculoskeletal disorders and their impact on workplace health MSD is a common occupational health problem, especially in industries that involve manual work, repetitive tasks, and unergonomic postures. Bernard (1997) identified that constant physical strain on the musculoskeletal system causes injuries that affect muscles, joints, and ligaments, often resulting in pain and decreased mobility. MSD significantly contributes to absenteeism and disability in various countries, especially in industries such as manufacturing, construction, and healthcare. Punnett and Wegman (2004) further note that risk factors for MSD include heavy weight lifting, awkward posture, and repetitive movements. Their research emphasizes the importance of a comprehensive ergonomics program to reduce MSD risks, including posture correction, risk identification, and the introduction of relevant technologies to protect workers' health (Kumar, et al., 2022; Sukapto et al., 2023; Sukapto, et al., 2019; Oliver, et al., 2021; Charles, et al., 2018).

Traditional posture evaluation methods such as REBA and RULA, developed by Karhu et al. (1977), provide a valuable tool for assessing workers' posture. This method assesses the body position, joint angle, and force applied during the task. By identifying high-risk postures, immediate intervention can be made to prevent injury (Nino et al., 2023; Tiara et al., 2017). However, as David (2005) noted, these manual methods are often time-consuming and prone to observer bias, leading to inconsistent evaluations. Developing sensor-based technologies like IMUs provides a more reliable, objective, and real-time alternative to manual assessment. Yang and Hsu (2010) showed that IMU offers more accurate and consistent data than traditional methods, allowing for the timely detection of MSD risks. In addition, Valero et al. (2016) reported that IMU has been successfully implemented in various industries, including healthcare, manufacturing, and construction, to monitor worker posture and provide valuable data for ergonomic interventions.

Challenges of sensor technology implementation while IMUs have significant potential, their adoption in the industry has not been without challenges. Chung et al. (2015) show that high initial investment costs remain a significant obstacle, especially for SMEs. In addition, Sukardi (2019) highlights that technological literacy among Indonesian managers and workers is often low, which hinders the effective implementation of such advanced tools. Widodo et al. (2020) emphasized the need for supportive policies and strategies to promote the adoption of sensor technology in Indonesia, recommending targeted training programs and government incentives to facilitate the wider use of these innovations. In summary, although IMU has shown effectiveness in improving worker health and safety, more research is needed, especially in developing countries such as Indonesia, to explore the potential benefits and challenges of applying this technology more broadly.

RESEARCH DESIGN METHODOLOGY

This study uses a quantitative research design with an experimental approach to evaluate the effectiveness of IMU sensors in reducing the risk of MSD among workers. The experiment will involve collecting posture data from workers using IMU sensors, analyzing this data to identify high-risk postures, and recommending ergonomic interventions.

Location and duration: This research has been conducted at the Laboratory of Manufacturing Process – Industrial Engineering – Parahyangan Catholic University, Bandung, and PT ASI (in the Stamping and Welding Section) in Karawang, West Java, which has a high incidence of MSD. The study is expected to last six months, during which sensors will be installed, data will be collected, and ergonomic adjustments will be applied.

Population and sample: Population For this study, the population included workers in Indonesian industries who were at high risk of MSD due to heavy physical tasks or poor ergonomic practices. The purposive sampling technique was used to select 100 workers who met the following criteria: a. Workers involved in strenuous physical tasks; b. Workers who exhibit poor posture that is at risk for MSDs; and c. Workers who are willing to participate in sensor-based posture evaluations.

The main instrument for data collection is the IMU sensor, which is placed on six critical parts: the neck, trunk, upper arm, lower arm, wrist, and leg. This sensor continuously records real-time posture and joint angle data during the workday. Although the initial investment is quite expensive, the price of this instrument can be reduced by using measurement points suitable for the working characteristics. For example, the instrument is only used for RULA measurements or on certain parts, such as the lower arm and wrist, for movements that involve only the arm. Questionnaires are also provided to gauge workers' and managers' perceptions of the technology, including ease of use, perceived benefits, and acceptance.

Procedure:

1. **Sensor installation**: The IMU sensor will be installed on the worker's body based on their work activity and risk area. There are 6 (six) IMU sensors installed, namely to calculate *neck, trunk, upper arm, lower arm, wrist,* and *legs.* The operator of the tool needs to make sure that the sensor is connected correctly, after which the operator will calibrate it by asking the worker to take the perfect posture and form a certain angle. The sensor then sends the angle measurement results to the Raspberry Pi component, which will calculate the REBA score. The angle and score data are then displayed and stored as *a spreadsheet* for further analysis.
2. **Data collection**: For one month, the IMU sensor will collect posture data from each worker. The data collected is enough in one work cycle. This data will be saved for analysis as *a spreadsheet* (extension .csv). In this data, you can see the angle of each point and the results of the calculation of the REBA score. This data can then be matched with the worker's video so that the risk of body posture for each worker's movement can be seen.
3. **Data analysis**: The data collected will be analyzed using specialized software to identify posture-related risks. The analysis will focus on detecting repetitive movements or positions that may cause MSDs, and recommendations for ergonomic adjustments will be developed.
4. **Interventions**: Based on the analysis, ergonomic interventions, such as posture corrections, workload adjustments, and training sessions, will be implemented. The effectiveness of these interventions will be assessed through follow-up evaluation using the same IMU sensors.

RESEARCH RESULTS

Systems approach in research

This study adopts a systems approach to evaluating and reducing the risk of Musculoskeletal Disorders (MSDs) in the automotive industry through IMU (Inertial Measurement Unit) technology. This systems approach integrates various interrelated elements, including data collection, risk analysis, technology development, and ergonomic interventions (Sabino et al., 2024; Sukapto et al., 2023).

Data collection: The data collection process begins with identifying the testing location at the Production Process Laboratory, Faculty of Engineering Technology, Parahyangan Catholic University Bandung, and PT ASI (in the Stamping and Welding Section) in Karawang. Data is collected using IMU devices installed at the 6 points mentioned in the sensor installation. During the observation period, a total of 100 data points were obtained. This data includes information about work posture, body movement, and workload, which is then processed to determine the risk level of MSDs.

Risk analysis: The data collected were analyzed using the REBA and RULA methods to assess the risk of MSDs. This systematic analysis compared data before and after implementing ergonomic interventions. The study results showed that the average value of REBA and RULA before the intervention was in the high-risk category, with an average REBA score of 10 and RULA 7. After implementing interventions, such as adjusting work positions and using ergonomic aids, there was a decrease in the REBA value to 6 and the RULA to 4. This decrease reflects a significant reduction in the risk of MSDs.

Technology development: The IMU technology used in this study was developed systematically. The development process involves hardware design and software programming for real-time data analysis. The following is a design drawing of the IMU technology that has been made (Figure 1). Six IMU sensors with the DFrobot type ICG2066 were used as the primary sensor for data from body posture. Then, the angle data measured by the IMU will be sent to the ESP32 Beetle-C3 controller to be processed and transmitted wirelessly to the Raspberry Pi. The wireless transmission data is angle data from each DFrobot DFrobot ICG2066 sensor, which is placed in 6 positions on the human body to calculate the posture score. The data is then processed and converted into REBA/RULA scores and the conclusion of posture measurements that can be accessed online. Hence, it adopts the IOT concept to reduce REBA and RULA digitally. For information, DFrobot sensors ICG2066 have high reliability and accuracy; there are low-cost versions of this kind of sensor, such as the GY 85, 87, or 91 type, which has a relatively low price. The ESP32 Beetle-C3 controller can also be chosen from more affordable manufacturing. Thus, the constraint of expensive investment prices can be overcome by choosing more afordable sensors and controllers.

Raspberry Pi is also used to communicate with cameras used to record the movements and posture of workers, so that further analysis is needed on critical postures. If the REBA and RULA scores obtained in a job produce values that indicate medium risk (4-7), high risk (8-10), or very high risk (11+), then a critical posture analysis must be carried out. This advanced analysis requires visualization of body movements that provide high values so that video recordings showing critical postures must be further analyzed to carry out ergonomic interventions such as improving the way of working, making assistive devices or other ergonomic interventions. In addition, the Raspberry Pi is useful for storing logging data from the IMU sensor, which can then be accessed online.

The IMU sensor is wearable and attached to the worker's body. It periodically sends data to the Raspberry Pi 4 server using the Message Queuing Telemetry Transport or MQTT protocol. MQTT is a transport protocol for client servers with publish*/subscribe messaging* types. The advantages of MQTT are the reduced network bandwidth and the need to transmit more reliable data. Data on MQTT can be transmitted over low bandwidth, so it is not dependent on the internet and low power consumption (Mishra et al., 2020). Because of the inflated internet access, all data contained in the IMU sensor can be accessed easily anywhere by carrying the IOT concept through desktop and mobile websites.

The tool is programmed using the C programming language and the Node-RED IoT platform. Node-RED is a flow-based software used to integrate IoT devices. Node-RED is based on *open source* developed by IBM Emerging Technology. Thus, Node-RED became the low-cost solution chosen to reduce the cost of tool development. Although *open* source, Node-RED has been widely used in industrial environments (Tabaa et al., 2018; Ferencz, 2019; Domínguez, Manuel et al., 2020).

All parts of this prototype were carried out at the Faculty of Industrial Technology, Parahyangan Catholic University. Figure 2 shows the electronic components used and the results of the sensor prototype. The dimensions of the assembled sensor are only about 40-50 cm. They are very light and carry the concept of wireless communication so that they do not interfere with workers who use them. Even after a while, the worker can forget that he is still using the prototype.

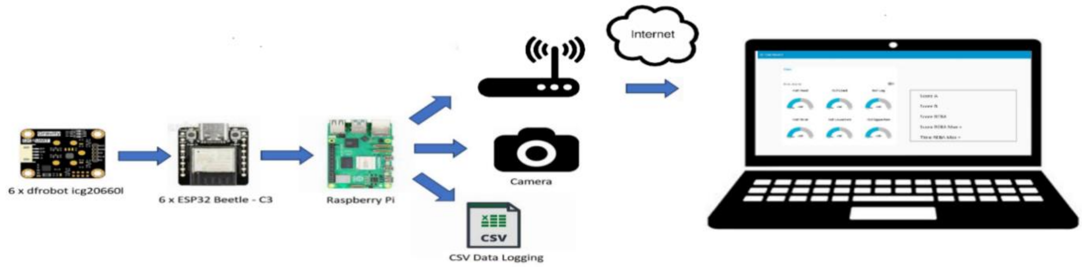


Figure 1: Conceptual design of the REBA RULA measuring instrument online.

(a) (b) (c)

Figure 2: The physical appearance of the prototype (a) sensor device, IMU, microcontroller, micro switch, and battery (b) the physical display of the sensor to be mounted on the user's limbs is photographed with a caliper as a size comparison. (c) Sensor prototypes that have been included in the 3D printing result box.

The positioning position of the six IMU sensors used to measure the posture angle can be seen in Figure 3, with detailed placement information as follows:

1. Placing the sensor above the head/on the helmet. This overhead sensor is installed to measure the angle of the *neck position* (in the picture, written *Roll Head*). In the upright head position, the sensor detects an angle of 0˚, and when looking down, a large angle will be detected, which indicates an increase in the angle value on the sensor. Likewise, the sensor will detect a negative angle value if the head is in an extended posture. The value from this angle can be measured in real-time and online through the remote internet and then processed into ***a neck score***.
2. Placement of the sensor on the chest/back. The sensor placed on the chest or back aims to measure the angle of the *trunk position* (in the image written *Roll Chest*). When the body is upright, an angle of 0 O is read, and if it is tilted forward, the sensor will detect the posture with a reading on the sensor value, which is a positive angle. The sensor will detect a negative angle if the posture is upward (in extension). The angle detected by the IMu sensor at the location of the back or chest can be measured in real-time and online via the internet and then processed by software into ***a trunk score***.
3. Placement of the sensor on the legs. The sensor placed on the foot is intended to measure the angle on the foot (in the picture written *Roll Leg*). This sensor will show the magnitude of the angle formed by the measured worker's foot so that the angle value can be converted into ***a leg score***. The three sensors above that measure neck, truck, leg, and load scores will produce a score value (*posture* score A) needed in determining the REBA score.
4. Placement of the sensor on the upper arm. The sensor placed on the upper arm aims to measure the angle on the upper arm (in the picture, written *UpperArm roll*). In a relaxed arm posture, the sensor will show the number 0^{O}. Then, when the upper arm is leaning forward, the IMU sensor will show a positive angle number according to the size of the angle formed and a negative value if the upper arm is tilted back. The amount of angle formed by the upper arm will be converted into the upper ***arm score value***.
5. Placement of the sensor on the lower arm. The sensor on the upper arm is intended to measure the angle on the forearm (in the picture, written *LowerArm roll*). In a relaxed arm posture, the sensor will show several 0^{O}, then when the lower arm is tilted forward, the IMU sensor will show a positive angle number according to the size of the angle formed for a value of 60 O-100O converted to a lower arm with a value of +1, while for an angle formed of 0 O-60O and above the angle of 100 O.will be converted to a lower arm score worth +2 The amount of angle formed by the upper arm will be converted to a lower ***arm score value***.
6. Placement of the sensor on the wrist. The IMU sensor placed on the wrist is intended to measure the angle formed by the wrist. In the horizontal position, the IMU sensor detects an angle of 0^{O}, and when the wrist is raised up or down, the angle value on the IMU sensor changes. The size of the angle will be converted into a ***wrist score***.

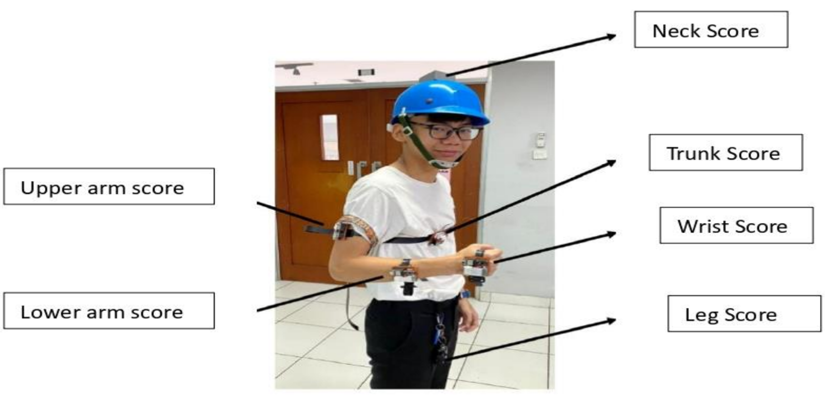


Figure 3: Placement of 6 sensors – IMU sensors

The information system needed by this prototype was also designed and made at the Faculty of Industrial Technology—Parahyangan Catholic University. The conceptual design of this information system can be seen in Figure 4 and Figure 5 below. Figure 4 shows that the auto logger process is generated with a delay of 200ms and sends data every 250ms to be stored in the dataset, thus forming the CVS data to see the maximum REBA and RULA values in a test meanwhile, Figure 5 shows the data logging process, which is the process of capturing angle data from each IMU sensor, such as the IMU sensor that is placed on the head to measure the angle and convert it into a neck score. Likewise, what happens to IMU sensors placed on other parts of the body to get chest *scores, leg scores, upper arm scores, lower arm* scores, and *wrist* scores? With the information obtained from each IMU sensor and information from the load borne by the worker, the REBA and RULA scores can be calculated.

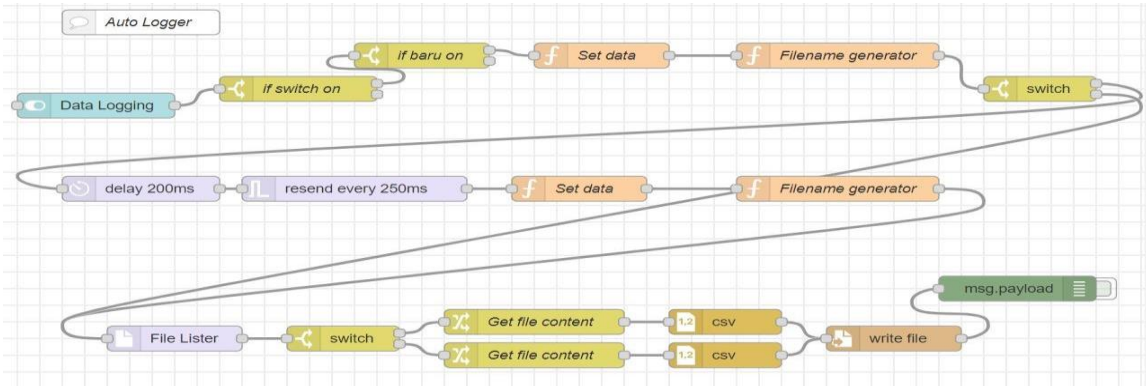


Figure 4: Part prototype information system concept for data generation process

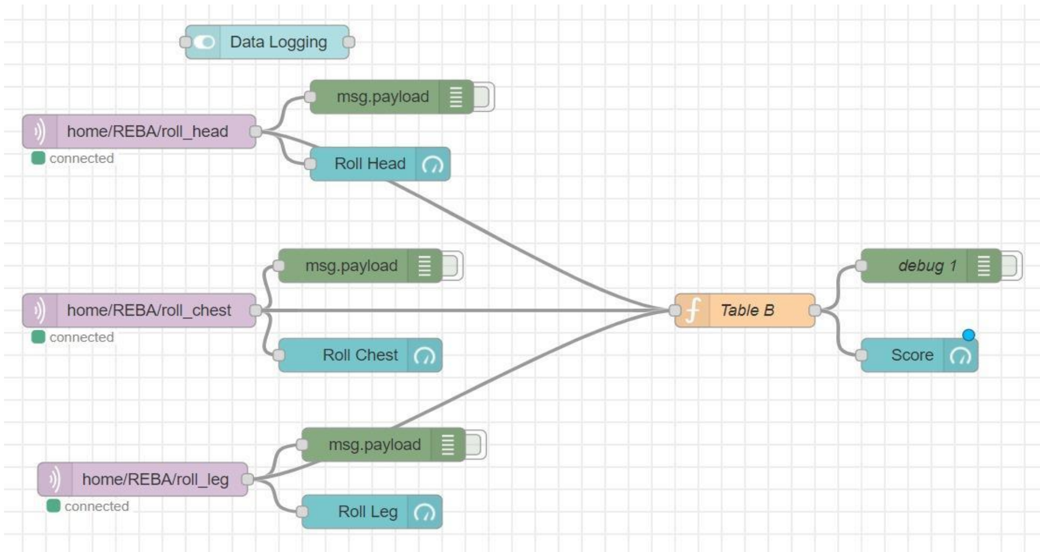
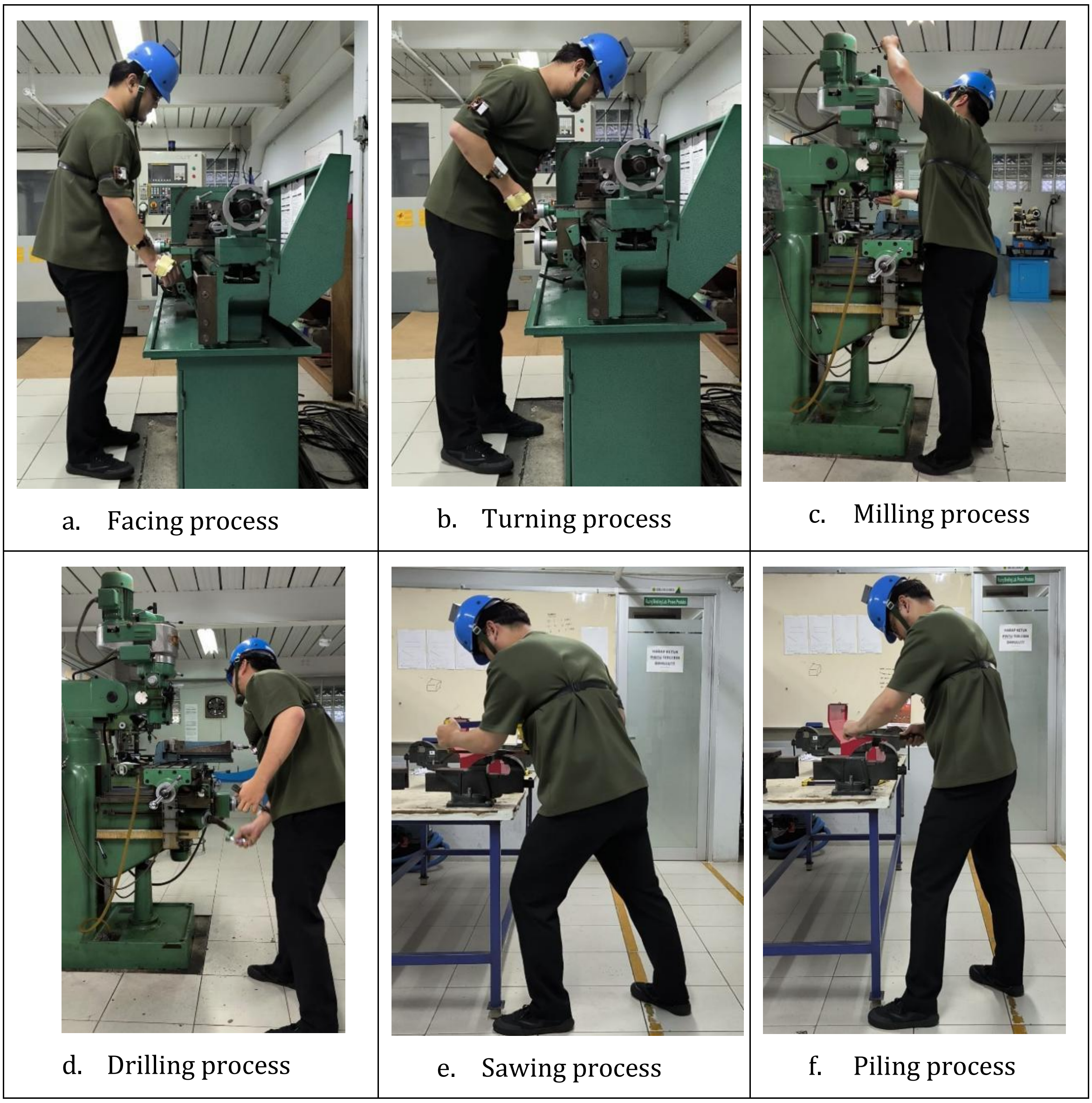


Figure 5: Prototype information system concept part for IMU data logging data

The prototype of the REBA and RULA measuring instruments online has also been successfully tested at the Manufacturing Process Laboratory of the Department of Industrial Engineering – Parahyangan Catholic University. Testing this prototype includes six works as can be seen in Figure 6, with the details of the work being tested as follows:

a) Facing process using lathes
b) Turning (reduce diameter) process using lathes
c) End mill process using the milling machine
d) Drilling process using milling machines
e) The sawing process in benchwork
f) The process of miserliness in benchwork



a. Facing process
b. Turning process
c. Milling process
d. Drilling process
e. Sawing process
f. Piling process

Figure 6: The process of testing REBA and RULA measuring instruments online on six types of work

The initial prototype tested in 6 different types of work in the Manufacturing Process, Industrial Engineering laboratory, Parahyangan Catholic University will be followed by field tests at the automotive factory at PT. ASI (Adyawinsa Stamping Industries) in Karawang. This prototype is expected to work by measuring the angle between the measured position (head angle, arm angle, and others) with the reference angle value very accurately. The angular deviation between the actual and measured values in the tool is less than 1°, so this digital measuring tool is very accurate in measuring REBA and RULA values digitally and remotely/online.

This tool can be used remotely, for example, at PT. ASI and a team of experts who assess and analyze the value of REBA and RULA remotely, for example, from Parahyangan Catholic University, Bandung. The ability to measure REBA and RULA remotely using the Internet can occur because the Raspberry Pi is connected to the Router and can be accessed online through the website (desktop version and mobile version).

This technology also has a user interface that makes it easier for workers and supervisors to monitor their work posture directly.

The following Figure 7 shows the prototype's dashboard page. The left side shows the large real-time angle detected by the IMu sensor. The right part shows the value of the A, B, and REBA scores in real-time, and the three values change in real-time. Meanwhile, the maximum REBA score and time show the most significant REBA score captured by the prototype, and the time information shows the value that can be used in analyzing posture videos for the ergonomic intervention process.

Meanwhile, Figure 8 shows the application's browser file displayed. In the image, we can search for files or test results data for the analysis and ergonomic intervention process.

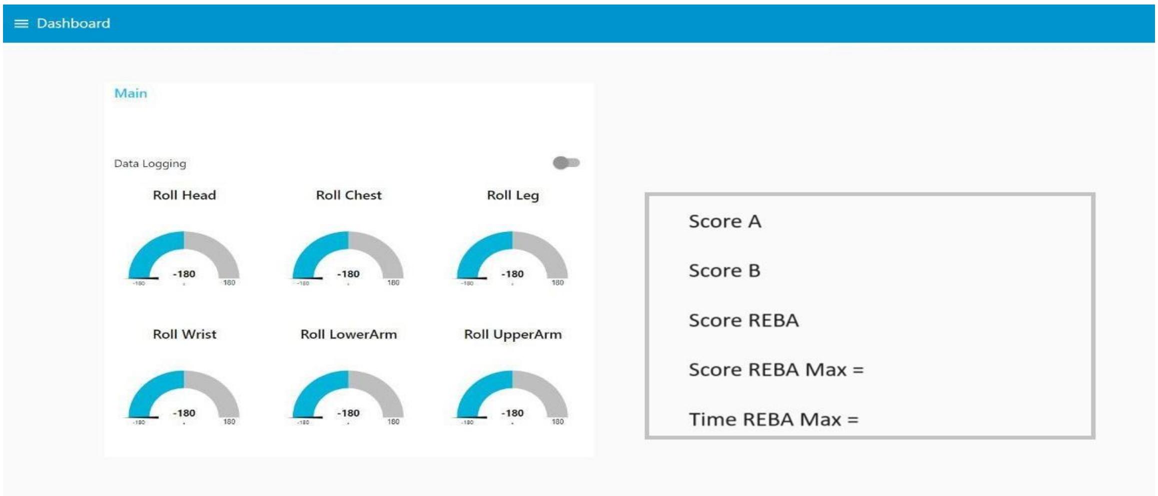


Figure 7: Dashboard view of the app

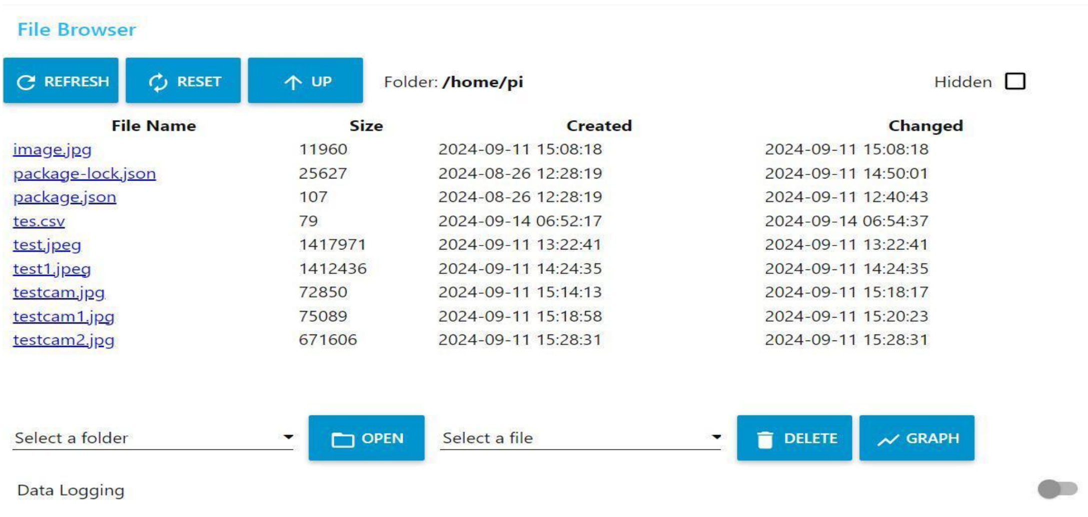


Figure 8: Browser file view of the app

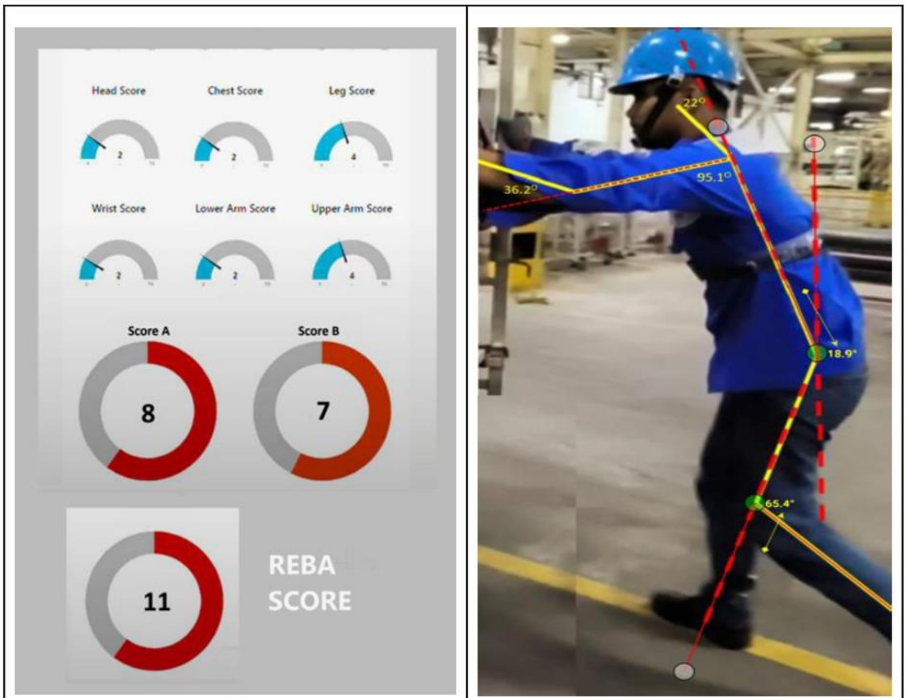
Application of Ergonomic Intervention: Based on the analysis's results, ergonomic interventions are applied in the parts that show the highest risk, namely welding and shipping goods. These interventions include changing the layout of workstations, using ergonomic chairs, and training workers on correct work techniques.

The application is carried out gradually to minimize disruption to the production process. The results of this implementation showed an improvement in worker comfort and a significant decrease in MSD complaints.

DISCUSSION

With the help of IMU, the REBA measuring instrument has succeeded in identifying the angles in the workers' posture. Testing was conducted in the Manufacturing Laboratory in Industrial Engineering – Parahyangan Catholic University. However, the results of this test still show the size of the angle and the REBA value, which is only based on the angle and does not take into account adjustment factors such as the neck score, which is an increase of +1 if the neck is twisted, and a rise of +1 if the side bending occurs. Also, at the trunk score calculation stage, if the trunk is twisted to +1, and the side bending +1, and so on, such as the amount of load in the force/load score, which is +0 when the load is <11 lbs, +1 when the load is 11 to 22 lbs, and +2 when it is above 22lbs and so on.

After repairs, it enters phase 2 testing, namely the industrial stage. This test was conducted at PT Adyawinsa Stamping Industries in Karawang, West Java. After testing, it was carried out in three parts: welding, stamping, and shipping goods. So, the posture was raised when pushing a trolly containing car components from the 2nd floor to the ground floor and then to the delivery section. This process results in the worker pushing quite firmly and in an unergonomic posture, as seen in Figure 9.



(a) (b)

Figure 9. a. REBA Score measurement using IMU digital measuring tool
b. Manual REBA calculation

Measurements using IMUs produce measurement results, as shown in Table 1.

Table 1: Comparison of results between manual and digital REBA measurements

No.	Position	Degree	Score	Note	Adjusted Score	IMU Score	Note for IMU Score	Deviation (%)
1	Neck Score	22.00	2	Neck is not twisted, nor side bending: (+0)	2	2	22.50	2.27
2	Trunk Score	18.90	2	Trunk is not twisted nor side bending (+0)	2	2	19.80	4.76
3	Leg Score	65.40	2	Since >600 then +2	4	4	67.30	2.91
4	Posture Score A			From Table A	6	6	Calculated by software	
5	Force/Load Score		1	Load >20lbs then +2	3	3	Input manually before test started	

6	Score A			Posture score + Force/Load score	8	8	Calculated by software	
7	Upper Arm Score	95.10	4	Shoulder is not raised, and upper arm is not abducted (+0)	4	4	93.90	1,26
8	Lower Arm Score	36.20	2		2	2	35.60	1.66
9	Wrist Score	5.20	1	Wrist is twisted add +1	2	2	5.50	5.77
10	Posture Score B			From Table B	6	6	Calculated by software	
11	Coupling Score			Acceptable but not ideal hand hold or coupling	1	1	Input manually before test started	
12	Score B			Posture score + Coupling score	7	7	Calculated by software	
13	Table C Score			From table C	10	10	Calculated by software	
14	Activity Score			+1 since action causes rapid large range changes in postures	1	1	Input manually before test started	
15	REBA Score			Score C + activity score	11	11	Calculated by software	

Based on Table 1 above, it can be seen that there is a slight deviation in the angle deviation between measurements using manual measurements and measurements using digital measuring instruments using IMUs. Table 2 below is the result of measuring the deviation of the sensor used. Table 2 shows an average deviation of 1.65% from the previously calibrated arc angle.

While the deviation in Table 2 above can be seen that some deviation values exceed 1.65%, which are most likely in addition to the contribution of errors in the DFRobot ICG-20660L sensor, also contribute to errors in calculating the angle of the posture due to manual REBA calculations. So, the deviation that occurs is a deviation due to manual angle calculation coupled with a deviation due to the sensor device.

The deviation in the trunk, which reached 4.76%, quite far from the average value, was due to a problem with the fastening system on the sensor in the trunk, which turned out to be not tightly attached to the user's body. So due to high work activity and the sensor strap that is not tight enough, the sensor moves slightly from its initial position. Therefore, the next research will focus on improving the place where the sensor and the strap tie it to the user's body so that it does not shift and remains comfortable for the user.

Table 2: Comparison between measurements using IMU sensors and angle measuring instruments

DFRobot ICG-20660L Sensor Angle Testing		
Arc angle (deg)	**The readable angle at the sensor (deg)**	**Deviation (%)**
0	0.5	N/a
30	30.7	2.33
45	46.4	3.11
60	60.8	1.33
90	90.9	1.00
135	137.6	1.93
180	179.7	0.17
Average of deviation (%) =		1.65

Digital REBA measurement will greatly impact the improvement of the work system because the measurement results can be obtained quickly, accurately, and accurately. The next step is to improve the work system more quickly and accurately so that safer and more comfortable working conditions will be realized sustainably for workers. This is in line with some of the results of previous research. IMU devices are reported to be more suitable for the presentation of assessment studies on an operator's gestures by combining information from several sensors (e.g., accelerometers, gyroscopes, and magnetometers) to allow for more accurate and faster assessments than conventional methods (Lim & D'Souza, 2020).

The challenges of implementing IMU are as follows: a. IMU is a compassionate type of technology. Positioning the measurement and calibration of the sensor takes a certain amount of time; b. At the time of data collection, a trained professional is always required, although the reality is that it is sometimes not easy to provide the person due to the various tasks given; c. It is necessary to simplify the process of sensor technology, allowing ergonomic and health service professionals to be able to make their own acquisitions to achieve better results; d. In addition, various efforts have been made to increase workers' acceptance. Another concern is the difficulty of guaranteeing the immobilization of IMU sensors when workers are moving; f. A sterile environment must be well maintained. Material handling on this device may increase the transmission risk to others. For this reason, workers need training to maintain the sterility of roars (Sabino et al., 2024). Other research suggests that sensors are more expensive and more complex for MSD risk assessment performance than conventional methods (such as questionnaires and observational methods). In addition to the considerable initial investment, it is necessary to maintain it and ensure that the tool can be used effectively and efficiently, which requires technically trained staff (David, 2005).

CONCLUSION

1. The results of conventional and digital REBA measurement trials with IMU technology show a difference of 1.65%, so the use of IMUs can be used to improve work systems, considering that the results are faster, more precise, and more accurate.
2. However, many researchers noted that IMU has advantages and valuables, but it still has limitations, such as the complexity of technology related to its application in work activities. Therefore, further research and development must be carried out seriously to ensure the successful implementation of IMU in an effort to promote occupational health and safety so that it can realize more sustainable health care.

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