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**ORIGINAL ARTICLE**

# Assessment of Musculoskeletal Disorders in Brick Workers Using an Ergonomic Approach

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**ABSTRACT**

**Introduction:** This study focuses on micro, small, and medium enterprises (MSMEs) engaged in the manual production of bricks. Specifically, it addresses the repetitive tasks of hoeing, mixing clay, and lifting and carrying bricks, which are performed for prolonged periods. The aim is to assess and mitigate risk factors associated with these manual tasks that may lead to musculoskeletal disorders (MSDs). **Methods:** The study involved 75 male workers with an average age of 43.52 ± 11.02 years, an average work experience of 14.18 ± 10.43 years, and an average body mass index (BMI) of 23.73 ± 2.59. The workers' manual material handling (MMH) activities were evaluated using the Workplace Ergonomic Risk Assessment (WERA) and Key Indicator Method (KIM). Additionally, the Nordic Body Map (NBM) questionnaire was used to identify areas of the body where workers experience pain related to their tasks. **Results:** The WERA assessment identified ten activities with a medium risk level, necessitating further analysis. The KIM assessment revealed six activities with a very high risk level and four with high risk. Recommendations were made for four high-risk activities, specifically suggesting the redesign of material transport carts. This intervention has the potential to reduce injury risk scores by up to 50%. **Conclusion:** The combined use of the WERA and KIM methods proves effective in assessing MMH risk in brick-production MSMEs, offering insights for targeted ergonomic interventions.

**Keywords:** brick production, KIM method, musculoskeletal disorders, SMEs, WERA method, work posture

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## INTRODUCTION

The brick-making process in Indonesia remains largely manual, involving repetitive tasks over long periods and awkward postures. Similar conditions are observed in India (Sain and Meena, 2019). Observational analysis reveals that brick production involves distinct stages: soil is first mixed with sand using a hoe, after which the mixture is fed into a milling machine to achieve a smooth consistency. The resulting dough is then pressed into bricks using a traditional, hand-controlled press. Once formed, the bricks are left to dry on racks for one week before being fired in a large furnace for 12 hours. Observations of the mixing stage indicate that workers manually trample a mixture of clay and husk, assuming a bent, rotated posture. This repeated motion increases the risk of musculoskeletal injury due to the continuous and repetitive nature of the work. Manual material handling (MMH) tasks in brick production include lifting, lowering, pushing, pulling, gripping, pinching, carrying, and holding objects by hand (Nurmianto *et al*., 2018; Hutagalung, Lawalata and Hattu, 2022). These MMH tasks often lead to symptoms of musculoskeletal disorders (MSDs), resulting in pain and impaired function in the neck, shoulders, elbows, forearms, wrists, and hands (Mikrani, Manandhar and Joshi, 2017). MSDs impact soft tissues, including muscles, tendons, ligaments, nerves, blood vessels, as well as cartilage and spinal discs (Desriani, Jayanti and Wahyuni, 2017; Aulianingrum and Hendra, 2022; Budiyanto and Pambajeng, 2022). MSDs encompass various inflammatory and degenerative conditions, often arising from prolonged work duration, improper postures, repetitive tasks, and insufficient nutrition and hydration (Mikrani, Manandhar and Joshi, 2017). Previous research on the brick-making

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process utilizing the Rapid Upper Limb Assessment (RULA) method indicates that the highest risk level occurs during the brick molding stage due to hunched postures, underscoring the need for improved ergonomic work facilities (Sugiono, Efranto and Budiprasetya, 2018).

In the present study, the workplace ergonomic risk assessment (WERA) and key indicator method (KIM) were used to assess these risks. Related studies in other industries, such as paving and vermicelli noodle manufacturing, have shown that transportation and finishing activities carry significant ergonomic risks, with some activities scoring high enough to warrant immediate improvements to work conditions (Mikrani, Manandhar and Joshi 2017; Razak and Rahman, 2017; Restuputri, Masudin and Putri, 2020). WERA is an established method used to identify physical risk factors associated with work-related musculoskeletal disorders (WMSDs) (Restuputri, Masudin and Putri, 2020), while KIM, developed by the German Federal Institute for Occupational Safety and Health, specifically evaluates musculoskeletal risks (Sukania *et al*., 2020). Currently, limited research has focused specifically on the risk of musculoskeletal injury in brick production using both WERA and KIM methods. Therefore, this study aims to assess injury risk levels among brick-making operators using these methods and to propose improvements based on calculated injury risk levels.

## METHOD

### Object of Research

This research was conducted at a small and medium-sized enterprise (SME) specializing in brick production in Boyolali, Regency of Brick, Indonesia. The study took place from September to December 2020 and focused on the various stages of brick production, including soil preparation, mixing, grinding, pressing, drying, and firing. The primary method of data collection was direct observation, involving detailed monitoring of seven workers across ten specific tasks. Data were gathered through interviews, photography, and video recordings of each labor activity. The ten observed tasks included hoeing soil, grinding soil, cutting prepared soil, placing bricks on tables, moving bricks to the floor, loading bricks into the press machine, pressing bricks, relocating bricks, and loading bricks into the kiln. According to the Nordic Body Map (NBM) questionnaire, administered during observation, workers reported experiencing pain in their arms, wrists, shoulders, waist, back, and legs (Klussmann *et al*., 2017). This study received ethical clearance from the Ethics Committee for Health Research, Faculty of Medicine, Universitas Muhammadiyah Surakarta, under approval number 5083/B.2/KEPK-FKUMS/X/2023.

### Data Collection

The Nordic Body Map (NBM) is used to identify specific muscles experiencing discomfort. The NBM questionnaire includes questions about pain, slight pain, or absence of pain across 28 body areas, from the upper neck to the feet. Workers indicate areas of pain by marking the relevant body parts on a checklist. The body area with the highest frequency of reported pain highlights the specific regions of discomfort for the worker. For ergonomic assessment, the workplace ergonomic risk assessment (WERA) method collects data on posture, repetition (covering shoulders, wrists, back, neck, and feet), load weight, vibration, contact stress, and work duration (Engbers *et al*., 2018). WERA is applicable in any workplace setting without disrupting the workforce and requires no specialized equipment (Lakshmi and Deepika, 2020). The WERA process involves identifying and recording factors such as posture, repetition, load, vibration, contact stress, and work duration, which are then combined to produce a final risk score. Based on this score, WERA categorizes risk into three levels: low (acceptable), medium (requires further investigation), and high (unacceptable) (Sugiono, Efranto and Budiprasetya, 2018). The key indicator method (KIM) assesses work duration per day, type and frequency of exerted force, body posture during manual work, hand and arm positioning, work organization, and working conditions (Rohani *et al*., 2018). The KIM process involves assigning values for work duration, force exertion, holding conditions, hand position, working conditions, and posture. These values are then summed to produce a final risk score, which informs the evaluation of risk levels and necessary interventions.

## RESULTS

### Data Processing

The first workstation involves mixing clay with a small amount of water. This process is carried out manually using a hoe, with the aim of achieving an even consistency and a smooth dough. Figure 1 provides an image of this soil-mixing activity.

### NBM Questionnaire

The NBM Questionnaire was completed by five brick-making workers engaged in ten tasks. Workers responded by selecting items from a checklist according to their subjective perceptions of discomfort. The data revealed that the most commonly affected body parts were the left upper arm, back, right upper arm, waist, left forearm, right forearm, and right hand.

### WERA Method Assessment

The first step in the WERA assessment is identifying all ergonomic risk factors. The risk level is determined by assessing the posture and repetition involved in each work activity, particularly focusing on affected body parts. A checklist detailing the soil-mixing task using a hoe is provided in Table 1.

Figure 1 illustrates the manual mixing of clay, chaff, sand, and water into brick dough, performed repetitively by workers in a bent posture. During this process, the worker's back bends at an angle of 104.3° with a repetition rate of 15 times, while the neck bends at an angle of 26.6°, with occasional

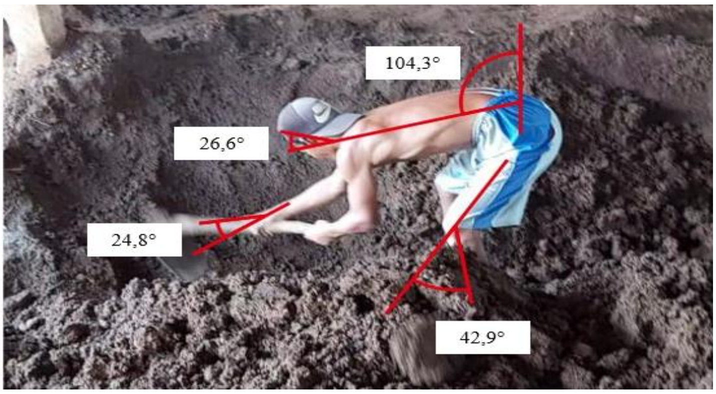


**Figure 1.** Soil Mixing Activity Using Hoe

**Table 1.** Checklist for Soil Mixing Activities Using a Hoe

| Risk Factor | | Description | Risk Level | | |
|---|---|---|---|---|---|
| | | | Low | Medium | High |
| Shoulder | 1.a. Posture | Above chest | | | √ |
| | 1.b. Repetition | A few pauses | | √ | |
| Wrist | 2.a. Posture | 24.8° | | | √ |
| | 2.b. Repetition | > 20 times | | | √ |
| Back | 3.a. Posture | 104.3° | | | √ |
| | 3.b. Repetition | > 12 times | | | √ |
| Neck | 4.a. Posture | 26.6° | | | √ |
| | 4.b. Repetition | A few pauses | | √ | |
| Foot | 5.a. Posture | 42.9° | | √ | |
| | 9.Working Duration | 7 hours | | | √ |
| Strength | 6. Strength | 2.5 kg | √ | | |
| | 3.a. Posture | > 60 degree | | | √ |
| Vibration | 7. Vibration | There is no | √ | | |
| | 2.a. Posture | 24.8° | | | √ |
| Stress Contact | 8. Stress Contact | Smooth handle | √ | | |
| | 2.a. Posture | 24.8° | | | √ |
| Working Duration | 9. Working Duration | 7 hours | | | √ |
| | 6. Strength | 2.5 kg | √ | | |

pauses. The wrist grips the hoe at an angle of 24.8°, with a repetition rate of 25 times, and the knees are bent at an angle of 42.9°. These measurements—angles, repetitions, and the weight of the hoe—were recorded in the checklist, and the overall risk level was determined based on Table 1.

Table 1 presents a checklist of nine risk factors observed in clay-mixing activities. The risk level for each factor is determined based on observed descriptions. For instance, in assessing shoulder posture, a position above chest level indicates a high-risk level, whereas repetitive motions with brief pauses suggest a medium risk level.

After determining individual risk levels, the next step is to assess overall physical risk. Table 2 provides a framework for evaluating the cumulative physical risks associated with clay-mixing activities. For example, shoulder posture is assigned a high-risk level, while shoulder repetition is categorized as medium, resulting in a physical risk score of 5. Other scores for physical risk factors include 6 for wrist posture, 6 for back posture, 5 for neck posture, 5 for foot posture, 4 for strength, 4 for vibration, 4 for stress contact, and 4 for working duration. The final score of 43 indicates that the soil-mixing task poses a medium risk level, warranting further investigation

**Table 2.** Assessment System for Soil Mixing Activities Using Hoes

| Scoring system | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Shoulder Posture | | | | | Wrist | | | | | Back Posture | | | |
| Repetition | Risk Level | L | M | H | Repetition | Risk Level | L | M | H | Repetition | Risk Level | L | M | H |
| | L | 2 | 3 | 4 | | L | 2 | 3 | 4 | | L | 2 | 3 | 4 |
| | M | 3 | 4 | 5 | | M | 3 | 4 | 5 | | M | 3 | 4 | 5 |
| | H | 4 | 5 | 6 | | H | 4 | 5 | 6 | | H | 4 | 5 | 6 |
| | Neck Posture | | | | | Foot Posture | | | | | Strength | | | |
| Repetition | Risk Level | L | M | H | Repetition | Risk Level | L | M | H | Back Posture | Risk Level | L | M | H |
| | L | 2 | 3 | 4 | | L | 2 | 3 | 4 | | L | 2 | 3 | 4 |
| | M | 3 | 4 | 5 | | M | 3 | 4 | 5 | | M | 3 | 4 | 5 |
| | H | 4 | 5 | 6 | | H | 4 | 5 | 6 | | H | 4 | 5 | 6 |
| | Vibration | | | | | Stress Contact | | | | | Working Duration | | | |
| Wrist | Risk Level | L | M | H | Wrist | Risk Level | L | M | H | Strength | Risk Level | L | M | H |
| | L | 2 | 3 | 4 | | L | 2 | 3 | 4 | | L | 2 | 3 | 4 |
| | M | 3 | 4 | 5 | | M | 3 | 4 | 5 | | M | 3 | 4 | 5 |
| | H | 4 | 5 | 7 | | H | 4 | 5 | 6 | | H | 4 | 5 | 6 |
| Final Score | | | | | | | | | | | | | 43 | |

**Table 3.** Assessment of Strength Mobilization Factors for Mixing Soil Using Hoes

| Power Level | Holding (seconds/minute) | | | | Movement (times/minute) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 60-31 | 30-16 | 15-4 | 3-1 | <1 | 1-4 | 5-15 | 16-30 | 31-60 | >60 |
| Very low | 2 | 1 | 0.5 | 0 | 0 | 0 | 0.5 | 1 | 2 | 3 |
| Low | 3 | 1.5 | 1 | 0 | 0 | 0 | 1 | 1.5 | 3 | 5 |
| Currently | 5 | 2 | 1 | 0 | 0 | 0.5 | 1 | 2 | 5 | 8 |
| Tall | 8 | 4 | 2 | 0.5 | 0.5 | 1 | 2 | 4 | 8 | 13 |
| Very high | 12 | 6 | 3 | 1 | 1 | 1 | 3 | 6 | 12 | 21 |
| Peak/ Maximum | 19 | 9 | 4 | 1 | 1 | 2 | 4 | 9 | 19 | 33 |
| Hit | - | - | - | 1 | 1 | 1 | 3 | 6 | 12 | 21 |
| Strength exertion score | | | | | | | Left hand: 24 | | Right hand: 24 | |

and potential adjustments. The combined scores and calculations for soil mixing using a hoe are presented in Table 2.

The next assessment employs the key indicator method (KIM). This method starts with data on work duration, with work conducted from 8:00 a.m. to 3:00 p.m., including a one-hour break, resulting in a total work time of six hours. The strength factor—representing the physical exertion required for hoeing—is rated as very high, with a score of 24. Workers typically hold the hoe in each hand for approximately 60 seconds per minute, indicating near-continuous use, with hand movements occurring 31–60 times per minute (see Table 3).

The holding condition factor—indicating ease of grip for the hoe—scored 0, as the tool is easily handled by workers. The hand position factor, where the worker's elbow is bent while bearing weight, scored 3. For work organization, with few concurrent activities and adequate rest periods, the score was 1. The working condition factor, due to environmental noise from the milling machine, scored 1. The posture factor, which accounts for frequent bending and working above shoulder height, scored 5.

After evaluating all factors, a final risk score of 119 was calculated, indicating that the activity of mixing soil using a hoe poses a high-risk level, requiring immediate improvements or redesign. The detailed calculation for the final score of this task is presented in Table 4.

Once data collection, measurement, and assessment of each of the 11 activities were completed, final scores were determined. These scores were then categorized according to their respective action levels. The final scores and action levels for the 11 brick-making tasks, as assessed by the WERA and KIM methods, are provided in Table 5.

**Table 4.** KIM Method Final Score

| Factor | Explanation | Score |
|---|---|---|
| Deployment of Strength | Very High | 24 |
| Holding Condition | Easy to grip things | 0 |
| Hand Position | Elbows bend, bear the weight | 3 |
| Work Organization | Rarely other activities | 1 |
| Working Condition | Noisy | 1 |
| Posture | Bending often | 5 |
| Total | | 34 |
| Working Duration | 6 hours | 3.5 |
| Risk Score | Total x Duration of work | 119 |

**Table 5.** Recapitulation of WERA and KIM Methods

| Activity | WERA | | KIM | |
|---|---|---|---|---|
| | Score | Action Level | Score | Action Level |
| 1.1 Mixing the soil with a hoe | 43 | Medium | 119 | Very high |
| 2.1 Loading soil into the mill | 40 | Medium | 91 | Very High |
| 2.2 Cutting the ground that has been milled | 40 | Medium | 42 | High |
| 2.3 Laying the bricks on the table | 43 | Medium | 49 | High |
| 2.4 Moving the bricks to the floor | 39 | Medium | 73.5 | Very High |
| 3.1 Laying the bricks into the press | 31 | Medium | 33.25 | High |
| 3.2 Pressing bricks | 31 | Medium | 31.5 | High |
| 3.3 Moving the bricks to the drying rack | 35 | Medium | 42 | High |
| 4.1 Picking up bricks | 42 | Medium | 66.5 | Very High |
| 4.2 Laying bricks in the kiln | 38 | Medium | 45.5 | High |

**Table 6.** Results of Ergonomic Risk Level Recapitulation Proposed Improvements

| Activity | Final Score | | Decrease | |
|---|---|---|---|---|
| | Before | After | Score | Percentage (%) |
| 1.1 Stirring the Soil Using a Hoe | 119 | 63 | 56 | 47 |
| 2.1 Putting Soil into the Milling Machine | 91 | 45.5 | 45.5 | 50 |
| 2.3 Moving Bricks to the Floor | 73.5 | 45.5 | 28 | 38.1 |
| 4.1 Taking Bricks | 66.5 | 45.5 | 21 | 31.5 |

**Figure 2.** Comparison of Soil Mixing Activities Using Actual and Proposed Hoes
(a) Mixing Machine Design, (b) Initial Posture Condition, (c) Improved Posture and Work Tools

Table 5 shows that all 11 activities evaluated by the WERA method are associated with a medium risk level. However, in the KIM method, the action level is significantly higher for four specific activities: mixing soil with a hoe, loading soil into the mill, moving bricks to the floor, and picking up bricks. The next step involves redesigning work equipment for these four high-risk activities.

Figure 2 illustrates the redesigned setup for the clay-mixing activity, which received the highest risk score of 119. The current process (Figure 2(b)) involves manual mixing with a hoe, while the redesigned approach (Figure 2(a)) utilizes a semi-automatic mixing machine with a circular drum. Workers now place the clay mixture into the drum, which processes it into a smooth dough before moving on to the molding stage. Figure 2(c) depicts improvements in posture and tool use following these ergonomic adjustments. Post-redesign, risk factors and scores were reassessed according to the WERA and KIM criteria.

Based on data analysis, the risk levels for each activity were recalculated. Table 6 shows a decrease in final scores for the four targeted activities. The most significant reduction occurred in the task of loading clay into the milling machine, with a 50% decrease from 91 to 45.5. A full summary of these ergonomic improvements is presented in Table 5.

## DISCUSSION

Brick kiln workers commonly experience musculoskeletal issues, particularly in the shoulders, lower back, knees, and neck (Klussmann *et al*., 2017). Analysis using the WERA method revealed that none of the assessed activities reached a high-risk level, with all activities categorized as moderate risk. Similar findings were reported by Widodo, Daywin and Nadya (2019), where all tasks were rated as medium risk, indicating that further investigation and potential modifications are necessary. For example, in their study, activities involving iron plates scored 35, 31, and 29, while those involving wood plates scored 33, 32, and 29. In contrast, the KIM method identified four high-risk activities: stirring soil with a hoe, loading soil into the mill, moving bricks to the floor, and picking up bricks. Six additional activities were rated as increased risk, including tasks such as cutting milled soil, placing bricks on tables and presses, pressing bricks, transferring bricks to drying racks, and arranging bricks in the kiln. In related research on tea leaf harvesting by Widodo, Daywin and Nadya (2019), tasks involving loads exceeding 5 kg significantly increased the risk of low back pain, particularly affecting the shoulders and upper arms. Given the high-risk levels determined by the KIM method, proposed improvements include mechanizing soil-stirring tasks to reduce manual exertion and movement frequency. Additionally, ergonomic adjustments to hoeing posture, such as limiting reach distance and minimizing bending, may further reduce musculoskeletal strain. Figure 2(a) depicts a proposed design for a semi-automatic clay mixer, offering an ergonomic alternative to manual hoeing. Figure 2(b) and (c) compare traditional hoeing with the proposed mechanized solution. Table 6 illustrates the effectiveness of these ergonomic interventions, showing decreased risk scores across four high-risk activities. Notably, the task of loading soil into the milling machine saw the highest reduction in ergonomic risk (50%), while the task of picking up bricks showed a 31.5% reduction. A study by Rejeki *et al*. (2022) using WERA and QEC methods similarly found prevalent musculoskeletal issues in the back, shoulders, neck, and wrists, with 88.9% of tasks rated medium risk and 11.1% rated high risk using WERA. Research by Shoja *et al*. (2019) on female weavers using the WERA method identified high-risk levels in tasks such as warp yarn preparation, pay folding, tying, and weaving on various loom types. Furthermore, Lakshmi and Deepika (2020) applied the KIM and EAWS methods in the barcode industry, finding that tasks like woodcutting and shaving yielded the highest KIM scores. Re-evaluation of these high-risk stations with the EAWS method resulted in scores of 54.4, 81.3, and 91, which subsequently dropped to 47.4, 50.8, and 56.5 following workstation redesigns. Finally, Klussmann *et al*. (2017) reported that KIM risk values showed significant correlations with MSD prevalence in body regions such as the shoulder, elbow, and wrist. This reinforces the utility of ergonomic interventions to mitigate risk in tasks with high physical demands.

## CONCLUSION

The WERA method's assessment of the risk levels associated with the ten evaluated work activities reveals that each activity posed a moderate risk (medium level), suggesting the need for further investigation. In contrast, the KIM method's assessment indicates that six of the ten observed work activities carry an elevated risk of injury, warranting additional review for possible repairs or redesigns. Moreover, four of these activities were identified as having a high risk of injury, highlighting an urgent need for immediate repair or redesign. The initial recommendation for improvement includes replacing manual stirring of dirt with a hoe. Further enhancement suggestions involve incorporating a mixer machine, conveyor machine, brick table, and an improved brick cart design.

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