Human-Centered Ergonomic Assessment of Concrete Block Production Workers Using The OWAS Framework

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Abstract

Background : Concrete block MSMEs rely heavily on repetitive manual material handling (MMH), forcing workers into awkward postures that trigger Work-related Musculoskeletal Disorders (WMSDs).

Purpose : This study evaluates working postures and load limits across four critical production phases to formulate low-cost ergonomic interventions.

Methodology : The Ovako Working Posture Analysis System (OWAS) was applied through a purposive single-worker case study to analyze biomechanical loads during mixing, transferring, molding, and drying.

Findings : The assessment revealed that critical phases fell into Action Category 3 and 4, indicating harmful musculoskeletal impacts driven by conventional tools and unstandardized methods. To mitigate these, feasible interventions such as mechanical tippers and extended press handles were developed.

Implications : While this study offers a practical blueprint, its single-worker design limits generalizability, meaning Future studies are recommended to involve multiple workers from different MSMEs and evaluate the effectiveness of the proposed ergonomic interventions using post-intervention OWAS assessments.

Originality : This study bridges the gap between ergonomic risk assessment and practical ergonomic interventions by providing a case study of OWAS implementation in a small-scale concrete block manufacturing enterprise. The findings may serve as a practical reference for future ergonomic improvements in similar MSMEs.

Keywords: C*oncrete block; Human-centered approach; MSMEs; OWAS.*

INTRODUCTION

Micro, small, and medium enterprises (MSMEs) in the manufacturing industry, particularly those producing building materials, continue to play a pivotal role in supporting local construction sectors and regional economic growth (Mabuting et al., 2023). A prominent example is concrete block production, which primarily utilizes sand as the main raw material mixed with cement. The production line in this sector heavily relies on manual material handling (MMH), which is repetitive, dynamic, and involves significant lifting loads (Widarman & Fikri, 2023). The working environment characteristics in such informal sectors often neglect basic ergonomic principles; the production stages are not yet comprehensively organized, forcing workers to operate in awkward postures for extended durations (Akkeesuwan et al., 2025). This constant exposure to physical workloads can no longer be overlooked as routine occupational fatigue. Instead, it serves as a strong predictor for the onset of Work-related Musculoskeletal Disorders (WMSDs), which potentially diminish long-term productivity capacity (Seo & Lee, 2021). Consequently, preventive measures centered on human-centered occupational health and safety evaluations are imperative. Utilizing measurable methods such as the Ovako Working Posture Analysis System (OWAS) is essential to map workers' biomechanical loads granularly (Diansari et al., 2023).

Although the OWAS method has been widely adopted across various global industrial sectors, most studies tend to focus on large-scale manufacturing, such as the automotive or heavy metal industries. Very little literature specifically addresses the complexities of traditional concrete block production cycles, which involve unique cross-stage processes ranging from raw material mixing and molding to material transport and manual handling of finished products (lifting/drying). OWAS assessment scores evaluate the risk of WMSDs stemming from concrete block production factors, including variations in conventional work tools, unstandardized production methods, and the dimensional variability of the concrete blocks (Setiawan et al., 2021). Empirical exploration in the literature regarding this sector remains scarce, causing existing ergonomic recommendations to be overly theoretical and challenging for local micro-entrepreneurs to adopt.

Manual material handling remains one of the major contributors to work-related musculoskeletal disorders (WMSDs), particularly in labor-intensive manufacturing sectors where repetitive lifting, bending, and awkward postures are common. Previous ergonomic studies have demonstrated that prolonged exposure to these risk factors significantly increases the likelihood of developing musculoskeletal complaints while reducing work performance and occupational well-being (Gajšek et al., 2022; Kumar & Thangavelu, 2024). Therefore, systematic ergonomic assessment methods are essential for identifying hazardous postures and prioritizing appropriate corrective actions before musculoskeletal disorders develop.

Despite the growing application of OWAS in manufacturing industries, evidence regarding ergonomic risk assessment in traditional concrete block production remains limited, particularly in Indonesia and Southeast Asia. Existing studies have mainly focused on posture evaluation, while only a few have discussed practical ergonomic interventions that are feasible for small-scale enterprises operating with limited resources (Widarman & Fikri, 2023; Diansari et al., 2023). Consequently, empirical evidence supporting context-specific ergonomic improvements for informal concrete block production is still insufficient.

Through a human-centered framework using the OWAS approach, this study comprehensively maps the working postures of three main body segments (back, arms, and legs) along with the load weight levels across four critical phases of concrete block production. This approach integrates posture analysis with specific manual material handling (MMH) risks to formulate interventions that are not only scientifically accurate but also feasible and cost-effective for implementation in MSMEs with capital

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constraints. This research is expected to provide a practical ergonomic intervention blueprint for identifying and mitigating postural risk factors in concrete block production. The proposed interventions may serve as a reference for improving workplace ergonomics and supporting safer manual material handling practices in informal-sector concrete block MSMEs.

METHODOLOGY

This study employs a quantitative case study research design to systematically evaluate and analyze the biomechanical relationships between repetitive occupational tasks and ergonomic risk levels among workers in the informal manufacturing sector. Data collection was structured through direct field observations, structured interviews, and photographic documentation.

The sampling technique was determined based on the unique operational context of micro-enterprises. Due to the highly specialized and integrated nature of small-scale manufacturing, this study utilized a purposive single-worker case study approach at UD. Karya Batako, which is one of the MSMEs producing bricks in West Aceh Regency.



Figure 1. Work Activity

This arrangement is able to improve consistency in the execution of repetitive tasks with a stable daily output of 500 blocks, so that variations between workers can be minimized and the postural stress that arises can better represent the intrinsic characteristics of the production process itself. This approach emphasizes that harmonization between humans, tasks, technology, and work organization plays an important role in creating an effective, stable work system, and supports more objective ergonomic evaluations (Lestari et al., 2023). The research variables focused on the postural stress across four core operational phases: (1) raw material mixing, (2) transferring materials, (3) molding/shaping concrete blocks, and (4) manual lifting and drying.

Table 1. Worker Characteristics

Variable	Value
Sex	Male
Age	41 years
Height	167 cm
Weight	63 kg
Working experience	11 years
Working hours	08.00–16.00
Daily production	±500 blocks

Quantitative postural analysis was executed using the Ovako Working Posture Analysis System (OWAS) framework. Each phase was systematically broken down into distinct elements of physical

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movement. The operator's posture was coded into structured reference numbers representing four body segments: the back (4 positions), arms (3 positions), legs (7 positions), and the weight of the load handled (3 load categories, ranging up to 24 kg) (Gajšek et al., 2022).

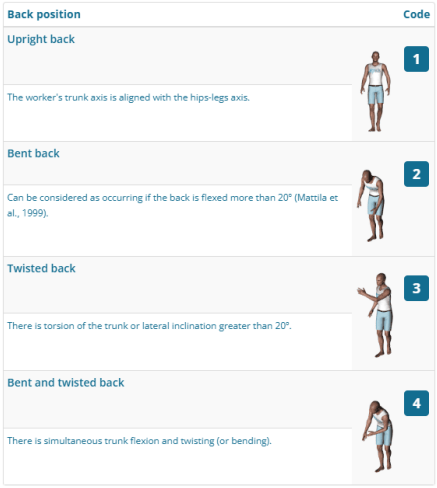


Figure 2. Coding of back position (Diego-Mas, J. A, 2015)

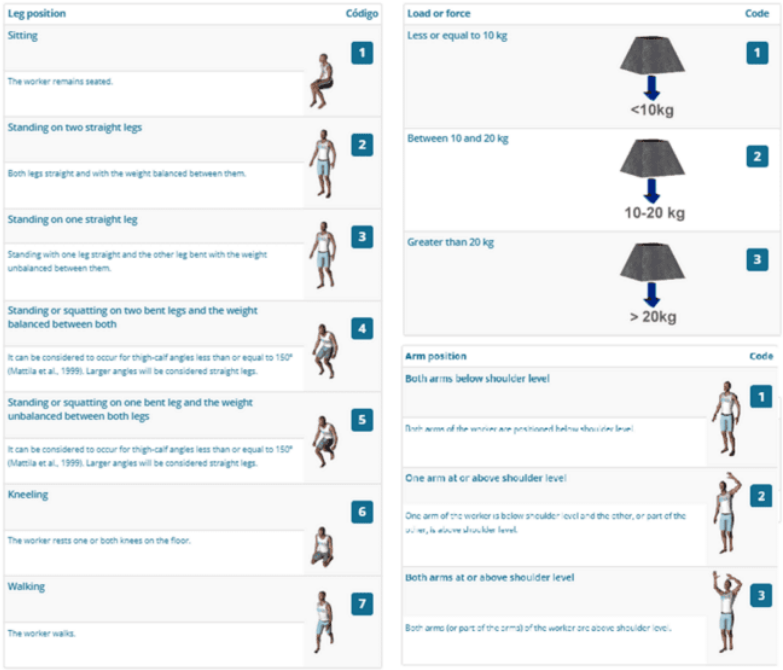


Figure 3. Coding of leg and arm position, load or force (Diego-Mas, J. A, 2015)

To ensure data reliability, repetitive observation intervals were conducted during a standard 8-hour shift, capturing the most frequent and extreme postures. The load handled during each production activity was quantified based on direct field measurements using a weighing scale and verified through repeated observations to ensure consistency across production cycles. The corresponding load category was then assigned according to the OWAS classification criteria. The combined individual codes were subsequently cross-referenced with the standard OWAS evaluation matrix to determine the final Action Category (AC). The resulting risk categories (ranging from AC 1 to AC 4) served as the quantitative basis for mapping ergonomic stress, evaluating the necessity of corrective interventions, and formulating feasible workstation redesign solutions.

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Risk Category	Effect of the Posture	Required Action
1	Normal and natural posture without harmful effects on the musculoskeletal system.	No action required.
2	Posture with the possibility of causing harm to the musculoskeletal system.	Corrective actions required in the near future.
3	Posture with harmful effects on the musculoskeletal system.	Corrective actions required as soon as possible.
4	The load caused by this posture has extremely harmful effects on the musculoskeletal system.	Immediate corrective actions required.

Figure 4. Risk Categories and Corrective Actions (Diego-Mas, J. A, 2015)

RESULT AND DISCUSSION

Ergonomic Postural Risk Assessment via OWAS Framework

The quantitative evaluation of biomechanical stress imposed on the concrete block production operator was systematically executed across four sequential operational phases. Based on direct field observations and photographic documentation, each phase was decoded using the Ovako Working Posture Analysis System (OWAS) standard criteria. The detailed breakdown of posture codes, structural variables (back, arms, legs, and load weight), and the determined Action Category (AC**)** are presented as follows:

1. Raw Material Mixing Phase

During the mixing phase, the operator manually hoisted and overturned a raw material cart to feed sand and cement into the mechanical mixer. The observed posture forced severe trunk flexion and elevated arms to handle a heavy mass. The trunk was distinctly bent forward, yielding a Back code of 2. Both upper limbs were raised above the shoulder level, resulting in an Arms code of 3. The biomechanical pivot relied on a single leg with the knee bent, giving a Legs code of 5. The combined weight of the raw materials manually handled during the tipping process was approximately 15 kg, based on direct field measurements, corresponding to a Load code of 2 according to the OWAS classification. Cross-referencing the standard code combination (2-3-5-2) into the evaluation matrix revealed a definitive Action Category 4 (AC 4). According to the OWAS evaluation matrix, this posture indicating a very high level of postural risk that requires immediate ergonomic corrective action (Kumar & Thangavelu, 2024).



Figure 5. Raw Material Mixing Phase

2. Raw Material Transferring Phase

This stage involved shifting the thoroughly mixed raw concrete mixture from the mixer outlet to the molding platform manually using a shovel. The frequent shoveling forced a forward trunk tilt, coded as back 2. Both upper extremities remained operational below shoulder height, coded as arms 1. The operational stance required standing on both feet with knees slightly bent, yielding a legs code of 4. The load of the wet concrete mixture on the shovel was measured at 5 kg, placing it under load code 1 the

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mapped structural code sequence (2-1-4-1) falls under Action Category 3 (AC 3). It signifies a high level of postural risk that requires corrective action in the near future to reduce exposure to ergonomic risk factors associated with work-related musculoskeletal disorders (P.S et al., 2022).



Figure 6. Raw Material Transferring Phase

3. Concrete Block Molding Phase

In the molding phase, the operator manually engaged a mechanical press handle downward to compact the raw concrete inside the mold cavity to secure product structural integrity. Pressing the lever forced the operator's trunk into deep flexion, coded as Back 2. Upper limbs were kept extended below the shoulder plane, coded as Arms 1. The posture required an identical weight-bearing stance on both legs with slightly bent knees, coded as Legs 4. The downward resistance and force required amounted to a 10 kg load equivalent, denoting a Load code of 2. According to the OWAS evaluation matrix, the posture was classified as Action Category 3 (AC 3), indicating a high level of postural risk. Repetitive downward pushing in this posture may increase exposure to ergonomic risk factors associated with muscle fatigue and work-related musculoskeletal disorders; therefore, corrective ergonomic measures are recommended in the near future (P.S. et al., 2022; Kumar & Thangavelu, 2024).



Figure 7. Concrete Block Molding Phase

4. Manual Lifting and Product Drying Phase

The operator manually extracted pairs of fresh concrete blocks resting on a single wooden pallet from the press machine and carried them to the outdoor yard for a 20-day drying process. Lifting the pallet from the floor required severe forward trunk bending, coded as back 2. The arms were extended downward below the shoulder to balance the load, coded as arms 1. Walking and pivoting to transport the load gave a legs code of 7 (moving/walking). Since a single concrete block weighed 12 kg and the

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operator consistently transported two blocks simultaneously per board, the total manual material handling load was 24 kg, yielding a load code of 3. The resulting OWAS operational code (2-1-7-3) strongly triggered Action Category 3 (AC 3). The combination of repetitive heavy manual material handling (exceeding 20 kg) and an awkward trunk posture represents a high level of postural loading that may increase exposure to ergonomic risk factors associated with work-related musculoskeletal disorders. Accordingly, this activity was classified as Action Category 3 (AC 3), indicating that corrective ergonomic measures are recommended in the near future (Erdoğan et al., 2024).



Figure 8. Manual Lifting and Product Drying Phase

Table 2 summarizes the OWAS assessment results across the four production phases. Among the observed activities, the raw material mixing phase exhibited the highest postural risk (AC 4), whereas the remaining three activities were classified as Action Category 3 (AC 3), indicating that corrective ergonomic measures should be implemented in the near future. Based on these findings, a human-centered ergonomic framework was developed to prioritize practical interventions tailored to the operational characteristics of the MSME.

Table 2. OWAS Assessment In Concrete Block Production

Production Phase	Back	Arms	Legs	Load	OWAS Code	Action Category	Interpretation
Raw material mixing	2	3	5	2	2352	AC4	Immediate corrective action required
Material transferring	2	1	4	1	2141	AC3	Corrective action required soon
Concrete block molding	2	1	4	2	2142	AC3	Corrective action required soon
Manual lifting & drying	2	1	7	3	2173	AC3	Corrective action required soon

Based on the OWAS assessment results summarized in Table 2, a human-centered ergonomic framework was developed to prioritize interventions aimed at reducing postural risk during concrete block production. The proposed interventions were categorized into engineering controls, manual material handling assistive devices, and administrative ergonomic practices to address the identified risk factors across the production process

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CONCLUSION

The OWAS assessment demonstrated that all observed production activities were classified as Action Categories 3 or 4, indicating that every stage of the concrete block production process involved considerable postural risk requiring ergonomic attention. Among the four observed activities, the raw material mixing phase exhibited the highest level of postural risk (AC 4), whereas the material transferring, concrete block molding, and manual lifting and drying phases were classified as Action Category 3 (AC 3). These findings indicate that manual material handling combined with awkward trunk postures remains the primary ergonomic challenge in traditional concrete block production.

The elevated postural risk identified during the raw material mixing phase was mainly associated with simultaneous trunk flexion, elevated arm positions, and manual handling of moderately heavy materials. Similarly, the remaining production phases required repetitive trunk bending, prolonged standing, and frequent manual material handling, which collectively increased exposure to ergonomic risk factors associated with work-related musculoskeletal disorders. These findings are consistent with previous studies reporting that repetitive manual material handling and awkward working postures are major contributors to elevated ergonomic risk in labor-intensive industries (Gajšek et al., 2022; Kumar & Thangavelu, 2024; Erdoğan et al., 2024).

The findings also demonstrate that ergonomic risk in small-scale concrete block production is influenced not only by manual lifting loads but also by workstation configuration and conventional production methods. Consequently, practical ergonomic improvements should prioritize feasible interventions that are compatible with the operational and financial limitations commonly encountered by informal-sector MSMEs.

Proposed Ergonomic Interventions

Based on the OWAS assessment results, several human-centered ergonomic interventions are proposed to reduce postural risk during concrete block production. These recommendations were developed according to the identified Action Categories and are intended to improve workstation compatibility with the operator's anthropometric characteristics while maintaining the operational feasibility of small-scale concrete block MSMEs. Since the proposed interventions were not implemented during the present study, their effectiveness has not yet been experimentally verified. Therefore, future studies should evaluate the proposed modifications using post-intervention ergonomic assessment, such as repeated OWAS analysis

1. Human-Centered Workstation Redesign (Engineering Controls)

The proposed engineering modifications are intended to adjust the physical dimensions of the machinery and workspace to better accommodate the operator’s anthropometric characteristics. These modifications are expected to help reduce excessive trunk flexion and overhead reaching; however, their effectiveness should be verified through post-intervention ergonomic assessment, such as a repeated OWAS analysis after implementation.

a) Remediation for AC 4 which is the raw material mixing phase, the operator to manually lift and invert a fully loaded raw material cart to feed the mechanical mixer. From a human-centered perspective, this imposes an unacceptable acute biomechanical load on the lumbar spine. The proposed solution involves installing a low-cost mechanical tipper or an inclined concrete ramp system aligned with the mixer’s inlet. By allowing the operator to dump sand and cement at waist height (approximately 80–90 cm from the standing plane), the trunk can remain neutral (reducing Back code from 2 to 1) and the need to elevate limbs above shoulder level is completely eliminated (reducing Arms code from 3 to 1).
b) Remediation for AC 3 which is the concrete block molding phase, compacting the concrete mixture via the manual press lever currently forces repetitive deep body bending. To remediate

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this, it is recommended to extend the operational length of the press handle or integrate a basic mechanical counterweight. This modification is expected to improve the operator's mechanical advantage by reducing the need for excessive trunk flexion during the compaction process. Consequently, it may promote a more neutral working posture and reduce postural risk. However, the effectiveness of this proposed intervention, including any potential reduction in the OWAS Action Category, should be verified through post-intervention ergonomic assessment.

c) Remediation for AC 3 which is material transferring phase, shoveling raw concrete aggregates from the floor can be mitigated by introducing a raised intermediate discharge bin. Keeping the raw concrete mix at a standing elbow height reduces repetitive stooping, allowing for a more natural and fluid human movement.

2. Ergonomic Assistive Devices for Manual Material Handling

The operator routinely carries a high physical load of 24 kg (two fresh concrete blocks on a single wooden board) across dynamic distances to the drying yard. This repetitive load bearing oversteps safe manual material handling thresholds. The human-centered intervention dictates eliminating direct spinal weight bearing by introducing a custom-fabricated manual multi-tiered steel trolley equipped with pneumatic, shock-absorbing wheels. Instead of lifting and walking with the load (Legs code 7), the operator can slide the block boards directly onto the trolley at waist level and smoothly push the batch. The proposed manual trolley is intended to reduce the need for workers to manually carry concrete blocks over long distances by facilitating load transport through pushing rather than lifting. This intervention is expected to reduce manual handling demands and improve working posture during material transport. However, its effectiveness, including any changes in the OWAS load classification or postural risk level, should be verified through post-intervention ergonomic assessment.

3. Administrative Controls and Ergonomic Behavioral Training

Physical workplace modifications must be complemented by human-centric administrative strategies to allow sufficient biological recovery for the muscular system:

a) Structured Micro-break Interventions: Given that a single operator manages an intensive daily output of 500 blocks, a structured administrative schedule of a 5-minute micro-break for every 60 minutes of repetitive labor must be formalized. During these brief periods, the operator should perform light dynamic stretches targeting the lower back, hamstrings, and shoulders to relieve accumulated muscle tension and promote localized blood circulation.

b) Safe Squat-Lifting Practices: To replace hazardous instinctive habits, the operator must be integrated into a basic ergonomic training program focused on transitioning from "stoop lifting" (bending the back) to "squat lifting". When retrieving blocks or pallets from lower levels, the operator must bend the knees, keep the back straight, and keep the load close to the body’s center of gravity. This simple behavioral change effectively re-routes the biomechanical compression forces away from the vulnerable lumbar discs and onto the larger, stronger muscle groups of the lower extremities.

This study applied the Ovako Working Posture Analysis System (OWAS) to evaluate ergonomic risk during four major production phases in a small-scale concrete block manufacturing enterprise. The assessment identified one activity classified as Action Category 4 (raw material mixing), indicating that immediate corrective action is required, while the remaining three activities (material transferring, concrete block molding, and manual lifting and drying) were classified as Action Category 3, indicating that corrective ergonomic measures should be implemented in the near future. These findings demonstrate that repetitive manual material handling, awkward trunk flexion, and conventional

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workstation design are the primary contributors to elevated postural risk throughout the production process.

Based on the identified ergonomic risk factors, several human-centered ergonomic interventions were proposed, including engineering modifications, manual material handling assistive devices, and administrative ergonomic practices. These recommendations are intended to provide practical guidance for improving workplace ergonomics in concrete block MSMEs. However, the proposed interventions were not implemented or validated during the present study. Therefore, future research should evaluate their effectiveness through post-intervention ergonomic assessment, such as repeated OWAS analysis, involving multiple workers and different production settings to improve the generalizability of the findings.

AUTHOR'S CONTRIBUTION

The specific roles and responsibilities of each contributor to this study are detailed as follows:
S. A. L. conceptualized the research framework, designed the human-centered ergonomic methodology, and was responsible for the final manuscript preparation and critical review.
R. S. managed field data collection, conducted structured interviews with the enterprise operator, and coordinated photographic documentation.
T. U. executed the quantitative data analysis, coded the working postures into the OWAS matrix, and drafted the results section.
Y. W. T. formulated the engineering controls and workstation redesign solutions, contributing to the development of the practical recommendations.
P. D. supported the field observations, assisted in analyzing the manual material handling loads, and formatted the manuscript according to the journal's guidelines.

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DECLARATION OF COMPETING INTEREST

The authors declare that they have no competing interests.

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