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IMPACT OF MUSCULOSKELETAL DISORDERS IN CONSTRUCTION: ASSESSMENT AND IMPROVEMENT STRATEGIES

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Abstract

Musculoskeletal disorders (MSDs) are a significant issue in the construction industry, which continues to rely heavily on manual labor. On-site tasks involve heavy lifting, prolonged awkward postures, and long working hours—factors that heighten the risk of developing MSDs.
The workforce plays a crucial role in project progress and quality; however, worker absenteeism due to these disorders affects productivity, leads to knowledge loss, and requires additional time for training and adaptation of new workers.
Semi-continuous video recordings, task descriptions (including workload, timing, and sequencing), and postural analysis using the Rapid Upper Limb Assessment (RULA) method are utilized to evaluate the physical risks associated with these tasks.
Based on the findings, improvement proposals will be developed, addressing organizational, physical, and environmental factors to optimize working conditions while ensuring performance and worker well-being.

Keywords: construction workers, ergonomics, musculoskeletal disorders, postural analysis.

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1. Introduction

Occupational health and safety (OHS) has become a strategic priority for ensuring productivity and promoting decent working conditions, particularly in physically demanding sectors such as construction [1]. Ergonomics has emerged as a key discipline drawing from physiology, psychology, engineering, and other sciences within this framework. This interdisciplinary integration significantly prevents injuries and promotes public health [2]. Applying ergonomic principles to work system design can reduce fatigue, discomfort, chronic injuries, and biomechanical overload among workers [2].

One notable initiative in this context is Prevention through Design (PtD), promoted by the National Institute for Occupational Safety and Health (NIOSH). This strategy advocates for anticipating and eliminating ergonomic risks at the design stage, considering facilities, processes, tools, and organizational structure [3].

In the current context of rapid technological modernization, globalization, and production restructuring, occupational risks have become more diverse and harder to control [4]. Musculoskeletal disorders (MSDs) are among the most pressing global occupational health problems. Along with respiratory diseases and certain types of work-related cancers, MSDs represent a significant portion of the global work-related disease burden [5]. Conditions like carpal tunnel syndrome, low back pain, and tendinitis affect millions of workers worldwide, resulting in substantial socioeconomic costs across both industrialized and developing nations. These challenges have elevated MSDs from being viewed merely as ergonomic issues to being recognized as a global public health concern, requiring structural interventions grounded in scientific and technical evidence [2].

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The construction industry stands out due to its high incidence of injuries. Workers in this sector are particularly vulnerable to ergonomic risk factors, including heavy manual material handling, awkward and sustained postures, and the use of inappropriate tools. These factors are inherent to some of the most ergonomically hazardous occupations and are recognised as significant contributors to MSDs [6]. It is often expected that injury and poor health are part of the job, and research suggests that construction workers face a higher risk of developing musculoskeletal disorders over shorter periods compared to white-collar workers [9]. By occupation, construction labourers reported the highest number of work-related musculoskeletal disorders (WMSDs). At the same time, helpers, heating and air-conditioning mechanics, cement masons, and sheet metal workers had the highest rates of work-related musculoskeletal disorders (WMSDs). In the U.S. construction industry, from 1992 to 2014, overexertion was identified as the primary cause of work-related musculoskeletal disorders (WMSDs), with back injuries accounting for more than 40% of all such cases [7]. Although various training programs and ergonomic interventions have been developed, their implementation remains inconsistent, particularly in labour-intensive occupations such as rebar work [8]. Moreover, the practical adoption of ergonomic technologies—such as assisted transport systems, lifting mechanisms, adjustable platforms, and adapted tools—remains limited [9].

MSDs are thus a significant issue in the construction industry, which often operates with traditional, labour-intensive methods. Fieldwork typically involves lifting loads, prolonged and uncomfortable postures, and extended working hours, all of which increase the risk of MSDs. Labour is a crucial resource for both progress and quality. Worker absence due to MSDs hampers productivity, resulting in lost technical knowledge and time spent retraining new personnel. This is especially problematic when it affects older, more experienced workers, who are regarded as valuable assets due to their reliability, commitment, and trade-specific skills. Younger colleagues respect their experience and contribute meaningfully to project outcomes [9]. Although innovative technologies are being introduced in the construction industry, their practical implementation, especially in small- to medium-scale projects, remains limited. As a result, traditional manual practices still dominate many worksites, making MSDs a continuing concern despite technological advances [9].

This study aims to identify and evaluate the physical risks associated with MSDs in critical construction tasks by analyzing worker postures, workload, and working conditions. The assessment will use semi-continuous video analysis and the Rapid Upper Limb Assessment (RULA) method. Based on the findings, ergonomic improvement strategies will be proposed to enhance worker health and performance without compromising productivity.

2. Methodology

To carry out this study, a combination of direct observations, audiovisual recording analysis, and standardized ergonomic methods was used to assess workers' biomechanical exposure, with emphasis on detailed video analysis of postures.

The target population was the workers of a construction company. The sample size was determined by convenience, as the company played a key role in defining the critical tasks to be analyzed within its construction processes. This approach ensured the study focused on activities that were highly relevant to productivity and posed higher ergonomic risks, making the findings applicable to the industry.

To identify critical tasks, site visits with open observations were conducted. The main tasks performed, the technical elements used, and the interaction with preceding and subsequent tasks were described during these. This characterization contextualized the risk factors present at each stage of the process.

Video recordings of the selected tasks were made, capturing the postures adopted and joint angles involved. These were analyzed to estimate the biomechanical load, identify sustained postures, and assess the risk of musculoskeletal disorder (MSD) occurrence using the Rapid Upper Limb Assessment (RULA) method.

3. Description of the case analysed

The workday extended from Monday to Friday, from 8:30 a.m. to 6:00 p.m., with a 45-minute lunch break. On Fridays, the schedule ended at 5:40 p.m., maintaining the same lunch duration. The ongoing project involved the construction of two reinforced concrete towers, each five stories high, with two underground levels and a total of 40 apartments per tower. The housing units ranged in size from 124 to 164 m² and were designed in configurations of 2, 3, and 4 bedrooms.

Tower A encompassed 30,149 m² of formwork, 4,188 m³ of concrete, and 427 tons of steel. Its structural completion was estimated for August. On the other hand, Tower D involved 18,822 m² of formwork, 2,528 m³ of concrete, and 266 tons of steel. Its structural completion is projected for the end of December.

The following section describes the activities performed by the formworker and rebar worker, focusing on one formworker and one rebar worker during the most repetitive task of the workday. Both the prescriptive and observed tasks used for ergonomic analysis are presented.

Formworker Activity

The formworker was responsible for analyzing construction plans to determine the formwork's dimensions, shapes, and technical requirements. Based on these plans, they assembled the molds using tools such as saws, hammers, and levels. The task also required installing reinforcement elements like steel bars and coordinating with the concrete foreman to supervise concrete pouring into the molds. After the concrete set, the formworker dismantled the molds and cleaned and maintained the tools and equipment, preparing them for reuse in subsequent project phases.

Field analysis focused on reinforcing formwork components for a wall approximately 1.25 meters by 2 meters. During this task, the worker maintained a forward-leaning posture most of the time. Periods of combined trunk flexion and axial neck rotation were observed, increasing biomechanical demands. The workers sometimes supported their weight on one leg to reach difficult areas. The anchoring of the formwork pieces was carried out using a hammer, involving repetitive striking motions that imposed additional mechanical loads on the upper limbs and required substantial coordination and manual force.

Rebar Worker Activity

According to professional specifications, the rebar worker was required to analyze and interpret plans or sketches to determine the required reinforcement's quantity, layout, and characteristics, per the project's technical standards. Once the planning was understood, the worker cut, bent, and assembled the steel bars using specific tools such as pliers, angle grinders, and rebar benders. The steel reinforcements were then positioned and secured within the formwork, ensuring proper alignment and readiness for the concrete pour.

The analyzed task involved installing reinforcement for a slab measuring approximately 3.20 by 4.40 meters and comprising 68 tons of steel. The specific activity observed was tying primary and secondary reinforcements. The worker sustained a forward-bending posture accompanied by lateral trunk flexion. The task was performed primarily with pliers, requiring repetitive hand movements and prolonged exposure to a forced spinal posture.

3.1. Postural Analysis

The joint position analysis of the formworker in Fig. 1a) shows that the elbow angle (blue line) exceeded the 60° risk threshold multiple times, particularly between points 5 and 11 and again at points 13 and 14. This indicates a significant risk for upper limb musculoskeletal disorders (MSDs) [8]. The neck angle (orange line) surpassed 10° during the first four measurement points and showed additional peaks at points 11 and 13–14, suggesting cervical MSD risk. The worker maintained a forward-leaning posture for most of the task, increasing the biomechanical load on the lumbar and cervical spine. Combined neck flexion and axial rotation were also observed, raising the injury risk. Additionally, periods of single-leg support were noted, which may have contributed to postural instability and increased muscular effort. Using a hammer for repetitive striking further intensified the physical demands on the upper limbs and trunk.

In contrast, the joint analysis for the rebar worker in Fig. 1b) illustrates the evolution of shoulder (red line) and trunk (green line) angles across 16 measurements relative to the 20° risk threshold for MSD prevention. The shoulder angle exceeded 20° at nearly all points, reaching values over 120°, which reflects sustained flexion (typically 40° to 80° or more) and indicates extended arm elevation. Shoulder abduction was also present, suggesting additional exertion. Regarding the trunk, the angle remained above 20° almost continuously, except at point 10 (associated with a change in task location), indicating persistent forward flexion. These factors, combined with knee extension and a slightly raised head posture, significantly increased the risk of MSDs in the lumbar, cervical, and shoulder regions. This conclusion is based on established ergonomic thresholds indicating that sustained trunk flexion above

20°, arm elevation beyond 60° [6], and cervical extension, especially when maintained throughout repetitive tasks, are key contributors to musculoskeletal strain. The posture patterns observed in the joint analysis align with these risk profiles.

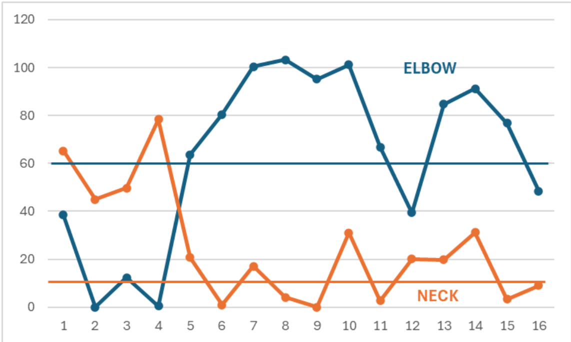

Figure 1a): Elbow and neck positioning for the formwork worker (measured in degrees)

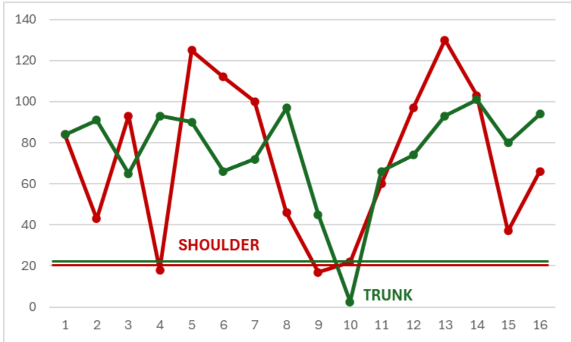

Figure 1b) - Shoulder and trunk positioning for the rebar worker (measured in degrees)

Regarding the RULA analysis, the charts in Figures 2a) and 2b) illustrate the percentage of the activity performed at different risk levels. The yellow color indicates a low risk (where changes might be necessary), orange represents a medium risk (requiring monitoring and preventive improvements), and red indicates a high risk (RULA scores above 6), where immediate action is required. The outer ring of the chart represents the shoulder and elbow joints, the middle ring corresponds to the neck and trunk, and the centre of the chart reflects the total percentage of time dedicated to the task.

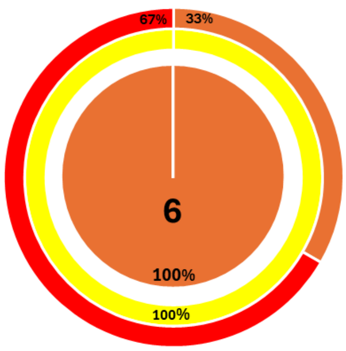

Figure 2a: Score RULA for the formwork

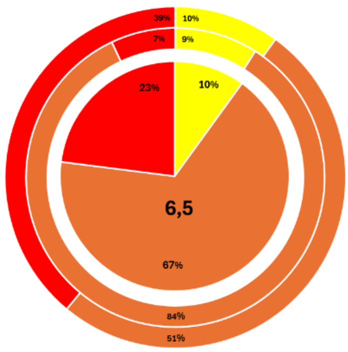

Figure 2b: Score RULA for the reinforcement worker

Both tasks presented a medium risk of developing musculoskeletal disorders (MSDs): the formworker was exposed for 100% of their working time, while the reinforcement worker was exposed for 67%. Therefore, paying attention to these results and implementing preventive measures is essential.
In the case of the formworker, there are no significant demands on the shoulder and elbow joints except during the hammering action to secure the formwork pieces. However, in the neck and trunk area, 67% of the time is spent in a high-risk condition, primarily due to the inclined posture adopted when inspecting pieces at low heights.

The RULA value for the formworker is slightly above 6.5. During 67% of the task time, they are at medium risk, while 23% are at high risk. Specifically, in the outer ring (neck and trunk), 39% of the time, the joints are in a high-risk position (due to the trunk and neck inclination), and 51% of the time in medium risk. Regarding the shoulder and elbow (central ring), 84% of the time, the operator maintains a medium-risk posture, mainly due to arm extension.

3.2. Improvement proposals

Based on the ergonomic analysis of formwork and rebar installation tasks, a set of improvement strategies is proposed to reduce the risk of Musculoskeletal Disorders (MSDs). These proposals are structured across three main categories: organizational, physical, and environmental.

For the organizational measures, implementing task rotation is recommended to reduce physical strain. Alternating tasks with different biomechanical demands helps prevent prolonged exposure to awkward postures and balance loads throughout the day. Active breaks and stretching before and during shifts enhance recovery and promote a preventive health culture. Rest periods should be managed to avoid cumulative fatigue.

Retaining experienced workers is essential, as their knowledge and skill transfer are key to training younger personnel, highlighting the strategic importance of ergonomic studies in maintaining workforce continuity. Physical conditioning programs tailored to specific tasks are proposed: for formwork workers, strengthening upper limbs and core; for rebar workers, focusing on trunk stability and lower body strength due to crouched positions.

Technical and organizational training should be strengthened. Rebar workers need support to interpret construction drawings better, minimizing errors and rework. For formwork tasks, coordination with crane operators must improve. Activities should be categorized as individual or collective. Promoting on-site digital tools like BIM can help reduce inefficiencies.

Tasks can be redesigned to reduce **biomechanical demands**. In rebar work, pre-marking reinforcement positions on formwork cuts time in harmful postures. Introducing adjustable stools or benches enables more neutral body positioning. Prefabricated assemblies shift demanding work off-site to more controlled settings.

For formwork operations, ergonomic tools like anti-vibration hammers and support systems to hold components in place help reduce repetitive movements. Supervised use of weightlifting belts may assist in load handling, though care is needed to avoid weakening core muscles.

Mobile carts and adjustable tables are recommended to reduce manual handling. Protective equipment such as gel-padded knee pads and foam wedges helps mitigate strain during squatting tasks. All gear should be individually adjusted for proper anatomical fit.

To reduce **environmental stressors**, installing shade structures in outdoor areas, especially for rebar work, helps mitigate heat exposure and the risk of heat-related illness. Accessible water stations should promote continuous hydration, and proper clothing should buffer temperature extremes.

Improving lighting in work zones reduces visual strain and related postural issues. Noise levels must also be assessed and controlled to foster focus and lower physiological stress.

4. Discussion

The high incidence of Musculoskeletal Disorders (MSDs) in the construction industry reflects a structural issue that extends beyond physical strain, highlighting the need for changes in job design and work management [1] The ergonomic assessment through RULA and video analysis revealed that tasks such as formwork and rebar installation expose workers to high-risk postures, particularly affecting the trunk, neck, and upper limbs. However, these findings must not be viewed in isolation: MSDs result from a combination of factors, including postures, work pace, organizational processes, and environmental conditions.

Cultural factors within construction sites also play a critical role. It has been found that this culture fosters poor working practices, such as high levels of physical exertion and an aversion to the use of personal protective equipment (PPE), which may contribute to a higher prevalence of musculoskeletal symptoms among younger workers [9]. The fact that younger workers report more acute MSD symptoms suggests that neither chronological age nor years of experience alone are reliable predictors of risk and that workplace culture and task allocation may also be significant contributing factors.

Recognizing and retaining experienced workers is essential. Older workers are valuable assets due to their reliability, dedication, and high-quality work [10]. They also command the respect of younger colleagues, who benefit from their advanced craft skills and training [11]. However, prolonged exposure to physical risk factors and age-related decline often accelerate premature workforce exit, even among skilled individuals.

Despite growing awareness of ergonomic risks, barriers to adopting ergonomic innovations remain. When the short-term benefits of new tools are unclear, employers are less inclined to invest in them [8]. Moreover, different stakeholders within construction firms must go through distinct behavioral stages, such as 'becoming aware' or 'having the ability to use'—before ergonomic tools are implemented [8]. This highlights the need for targeted strategies that go beyond simply introducing tools, focusing instead on behavioural change and capacity building within organisations.

The study highlights the effectiveness of organizational and physical interventions in mitigating ergonomic risks. Some construction firms adopt active breaks and warm-up routines at the start of the workday as preventive protocols [12]. These practices help prevent injuries and mitigate the effects of physical ageing on performance. Still, broader systemic adoption of such practices remains inconsistent, often limited by management priorities, production pressures, and lack of evidence-based ergonomic awareness at the site level.

Finally, the study has some limitations. A purposive sampling strategy was used, where site managers selected workers to be assessed. Given the itinerant nature of construction work and the time constraints of workers, this approach may introduce selection bias and limit the generalizability of findings. Future studies could benefit from randomized sampling and broader participation across diverse construction roles and settings.

Ultimately, transitioning from traditional methods to more ergonomic and efficient construction models is feasible and urgent. Evidence-based improvements show that worker well-being and operational performance are not mutually exclusive but reinforcing objectives.

5. Conclusions

The ergonomic analysis demonstrates that both form and rebar workers are exposed to medium and high risks of developing musculoskeletal disorders (MSDs), particularly in areas such as the trunk, neck, shoulders, and elbows. In the case of formwork, sustained trunk inclination and neck flexion postures, combined with repetitive hammer use, significantly increase the biomechanical load and the risk of cervical and lumbar injuries. Similarly, the reinforcement worker maintains prolonged postures of high shoulder flexion and abduction, as well as constant trunk inclination, reinforcing the need for preventive interventions to minimize physical strain and protect worker health.

These findings provide relevant evidence in an underexplored area within the construction sector, highlighting the importance of applying scientific ergonomic methodologies directly on-site. Based on the results obtained, control measures must be implemented to correct forced postures, introduce ergonomic tools, and promote work practices that reduce the risk of musculoskeletal disorders (MSDs). In this way, the goal is not only to protect the physical integrity of workers but also to contribute to the sustainability and efficiency of construction projects.

It is important to note that this study represents an initial phase of a broader research project. Only two types of job roles were analyzed here—formwork and rebar, serving as illustrative examples of wider trends in the sector.

Future stages will expand this analysis to include additional construction tasks and a more diverse group of workers, allowing for greater generalizability of findings.

In addition, the project aims to incorporate psychosocial risk assessment tools, recognizing that physical strain is only one component of an individual's overall well-being. A comprehensive understanding of construction site health must integrate both biomechanical and psychosocial dimensions, particularly in light of evolving work demands and workforce demographics.

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