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Construction Ergonomic Intervention to Reduce Musculoskeletal Disorders in Aluminum Formworkers

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Abstract: Manual material handling is the one of the leading causes for musculoskeletal disorders (MSDs) and lower back discomfort. According to a study, construction formworkers suffer greater rates of muscular injuries and related illness due to manual activities. However, there is still a paucity of information on MSD, preventive posture issues, and corresponding solutions for construction aluminum formworkers. As a result, MSD and disregard of worker health and safety continue to exist at construction sites. Although preventive measures and strategies have been studied in previous research, we believe it is imperative to shed light on this problem through this study. This study aims to 1) implement a simple and cost-effective elevated bench to reduce MSDs, and 2) determine the rapid upper limbs assessment (RULA) and Ovako working posture analyzing system (OWAS) action catagory of workers in different postures to assess their MSD conditions and obtain an optimal position and posture using the Jack human modeling software and simulation tool. The study findings reveal a considerable reduction in MSD discomfort and which posture is acceptable in post-intervention instances.Thus results provide inexpensive and simple ergonomic interventions with favorable RULA and OWAS ratings that can be applied at construction sites. This study demonstrates workstation ergonomic intervention cases that can aid in understanding the urgency of applying existing research strategies into practice.

Key words: musculoskeletal disorders (MSD), construction workers, muscle fatigue, aluminum formwork, simulation

1. INTRODUCTION

The construction sector is consistently ranked as one of the most dangerous occupations in the world, with various jobs that expose workers to illnesses and injuries such as musculoskeletal diseases (MSDs) and lower back discomfort. It is caused by sudden exertion or prolonged exposure to physical work involving high force, repetitive movement, awkward body posture, or vibration [1]; this includes heavy manual material handling, excessive and repetitive motions of a tool such as a screw driver, installing drywall, and difficult body postures. Aluminum formwork is a type of modular formwork.Leveling, drawing a ground sketch, brushing formwork oil, binding a steel bar, setting a steel bar to limit the width of a concrete wall, assembling panels, installing tie rods and aligners, fastening the nuts, adjusting the verticality of wall panels, and verifying and fixing panels are all part of the Aluminum type formwork system. This research, concentrated on form-worker activities such as panel lifting, assembly, and installation over time. It consists of a formwork panel that goes through the lifting box, pulls the formwork panel from the vault in a multistory structure, and installs and adjusts the beam panel.Form-workers are a common task group of persons who spend a lot of time at work in forced postures that induce muscle fatigue and musculoskeletal ailments. As a result, MSDs are a leading source of productivity loss, functional disability, and permanent injury among form-workers [1]. According to the U.S. Bureau of Labor Statistics, MSDs are the second most significant type of occupational injury, accounting for about 30 percent of all workforces' compensation expenses.However, as per literature, a study that assesses and compares MSDs and its related workstation issues has not been conducted.

MSD risks can be detected using various methods. The Ovako working posture analyzing system (OWAS) is used independently and in conjunction with other methods to detect MSD risks. Rapid upper limbs assessment (RULA) is most frequently used with other applications for better human health [2]. Based on previous findings, the RULA is the best system for estimating the postural loads and work-relatedness of MSDs [3].The National Institute for Occupational Safety and Health (NIOSH) has suggested inexpensive and ergonomic solutions for construction workers and manual laborers that require simple modifications, such as easy solutions for ground level work, overhead work, lifting, holding, and hand-intensive work [4]. However, these suggestions have been unable to provide the required effects. This study utilized the NIOSH suggestions and identified the effectiveness of using virtual simulation based on real site data.Most studies in literature have deployed questionnaires, simulations, and digital human modeling (DHM) to measure ergonomics. No studies have been conducted on formworker postures or the assessment of formworker occupational injuries. Inadequate study has been undertaken on construction professions such as welding, ironworking, and bricklaying, emphasizing the necessity for construction-related research. As a result, more research is needed to overcome the inadequacies of previous construction studies and estimate the risk of MSD among formworkers.

This study has two major objectives: (a) conduct an ergonomic intervention simulation to reduce MSDs by estimating OWAS and RULA scores for the entire body and (b) assess the efficacy of ergonomic intervention before and after using simulation. The modeling samples of this study were divided into two parts, based on the existing activity and preventive measures. Case 1: Using an elevated bench to avoid back bending. Case 2: Installing an adjustable ladder and assessing its effectiveness. This study can automatically analyze the ergonomic risks of formworkers at any task in real-time, thereby providing an integrative approach. It offers simple strategies to reduce MSD prevalence by simulating awkward postures, and estimating total ergonomic scores per frame with time. The initial layout modeling used in this study was developed using computer-aided design (CAD) and then loaded into the Tecnomatix human simulation software tool to conduct an ergonomic simulation. Thereafter, the layout was altered to explain and investigate the MSD risks of a formworker. The difference between the initial construction layout and subsequent interventions displayed the differences in productivity, duration, and worker fatigue.

2. ERGONOMIC INTERVENTION STUDIES ON CONSTRUCTION INDUSTRY

Ergonomic workstation evaluations are essential for ensuring correct working postures and workstation configurations. Ergonomic techniques have helped prevent deaths and facilitate safe and healthy practices for construction workers; however, they still have high potential for wider applications. Previous research has shown that various body parts of construction workers, such as the neck, shoulder, fingers, knee, and wrist are affected by tasks such as overhead work, ground floor level work, and intensive manual material handling [5].

In industrial sectors such as steel manufacturing, there are few notable ergonomic studies on MSDs and work environments; they cover the central workshop, steel manufacturing to transportation, and information technologies. In addition, they offered modest intervention programs that originally discovered effective answers, but did not solve work-related musculoskeletal disorders (WMSDs) due to limitations. This signals a need for prior and subsequent investigation of WMSDs among workers at an industry level.

A study that used the Nordic musculoskeletal questionnaire before and after interventions found that ergonomic intervention programs were significantly successful in a steel working environment [6]. Worker injury and stress from repetitive jobs has been confirmed by push and hold operations of diverse construction tasks [7]. Many recommendations and countermeasures have been recommended for these operations, which are performed by formworkers as well. In addition, many musculoskeletal injury prevention ideas and practical solutions have been proposed, including site-specific ergonomics programs, engineering controls, and exercise programs; this includes simple tool modifications to automated construction for lifting and pushing as part of site-specific ergonomic initiatives to lessen the strain of manual lifting hazards.However, although there are a substantial number of studies on ergonomics for industrial employees such as bricklayers and welders, as well as the workstation situation, no ergonomic intervention studies have been conducted on the postures of construction formworkers. As a result, research findings that propose practical solutions must be studied further to increase the database of studies in the construction area and produce effective ergonomic measures. Although the current study is a continuation study, it is tied to the MSD related ergonomic model simulation for formworkers using Jack software, which is a DHM approach.

3. RESEARCH METHODS

The research design had eight steps, as depicted in Figure 1. Step 1 identified issues among aluminum construction formworkers that has been used throughout the formwork installation procedure. Step 2 explained the NIOSH ergonomic preventive study regarding the existing issues of construction formworkers. Step 3 depicted awkward worker positions using a video of the construction site. Step 4 discussed the two proposed aluminum formwork layout cases: case 1 and case 2. Case 1 involved implementing an elevated bench to avoid bending posture, and case 2 involved implementing an adjustable ladder to provide a more convenient environment for the worker. The Tecnomatix simulation was run in step 5 to create a virtual environment of the formwork building site with employees in various positions, and conduct an ergonomic assessment; this includes obtaining RULA and OWAS scores. In step 6, Jack simulation, which is a human simulation tool by Siemens that helps personalize industrial activities by improving and refining ergonomic product design, was added to the process simulation model to assess injury risk, strength, strain, and task-scheduling; it was run for both ergonomic intervention instances. The software was utilized to construct a digital human using anthropometric data, and the GET, PUT, and WALK commands were applied to perform certain tasks for a specific amount of time. Frequency was repeated if necessary. Inputs such as bench height and panel market size were extracted from a real construction site for the simulation. After running the simulation, an ergonomic simulation report was obtained. Step 7 checked the efficiency of the posture. If it was satisfactory, the worker would continue to apply it, as illustrated in step 8; otherwise, the working layout would be changed and simulated again, as illustrated in step 9.

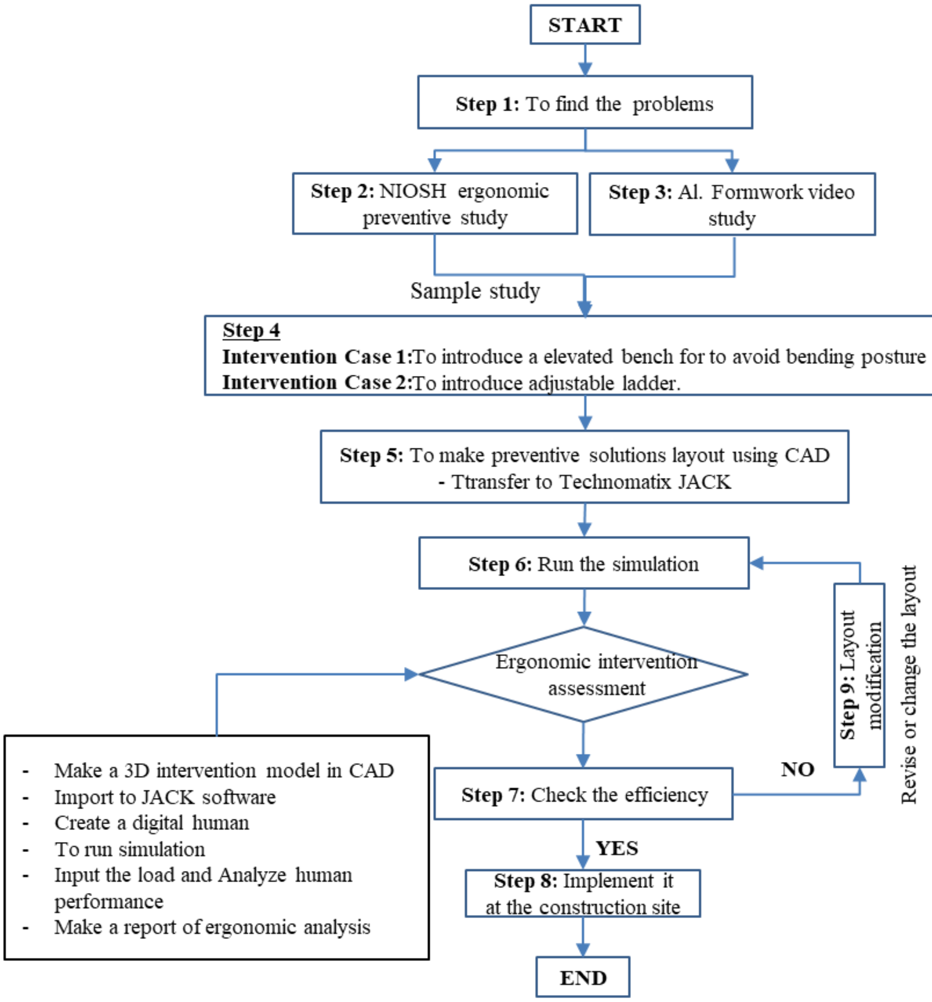


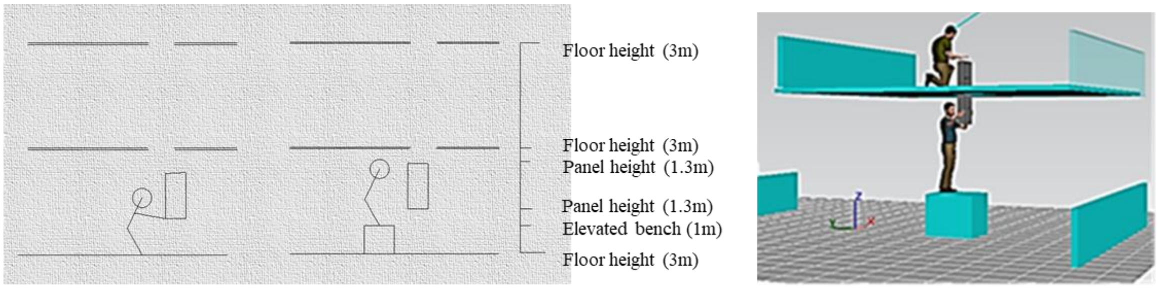
Figure 1. Research methodology

Using the proposed method, OWAS was classified into four categories. Category 1: normal postures that do not necessitate particular attention. Category 2: Postures that have harmful implications and must be corrected immediately.. Category 3: Postures that have a serious affect on the musculoskeletal system must be avoided as soon as possible.. Category 4: Postures that should be examined as soon as possible [2].

The RULA score reflected how much action is required to lower the risk of MSD. A score of 1–2 indicated an acceptable maintained position. A score of 3–4 indicated a need for changes with further research. A score of 5–6 indicated an unnatural position and an urgent need for further research. A score of 7–8 indicated a need for further research and modifications [8].

3.1. Intervention Case 1: Using an elevated bench to avoid bending

This case aimed to introduce simple and inexpensive solutions to reduce MSD prevalence by changing the layout of the construction site. Test model 1 contains an elevated bench 1 m above ground level for pulling purposes to reduce the prevalence of MSDs. Figures 2(a) and (b) display the two-dimensional elevation of a worker position before and after introducing a bench, and a three dimensional model of the changed layout where a worker standing on the elevated bench on a lower floor to avoid a bent posture for the worker seated on the upper floor, respectively. The floor height was 3 m. Based on the distance between the object to be pulled, the sitting position of the worker on the upper floor need not be changed during a pulling task. The simulation was performed to obtain OWAS and RULA scores based on the aforementioned simulation parameters to predict the MSD risks of the worker for a particular task.



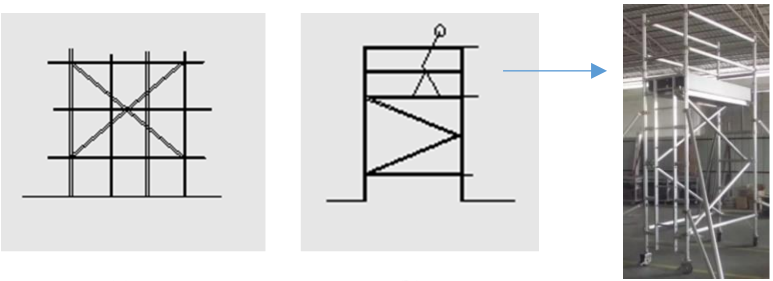
Before introducing bench After introducing bench

(a) (b)

Figure 2. Intervention CAD model for simulation: (a) two dimensional elevation and (b) three dimensional model of the changed layout

3.2. Intervention Case 2: Installing an adjustable ladder and assessing its effectiveness

Test model 2 replaced traditional scaffolding with an adjustable ladder as displayed in Figure 3 (a) and (b). Masons have to squat repeatedly to pick up and set brick, block, and mortar on a wall, which involves frequent bending and twisting. Frequent stooping induces weariness and strains the lower back. Low back discomfort and significant back injury are more likely a result of this stress. This job is required in a wide range of applications from small single-story residential work to massive multi-story structures. Since the both materials and work area were kept near the waist height with adjustable scaffolding, the brick mason required less stooping, which is more comfortable and reduces stress on the body.



(a) (b)

Figure 3. Scaffolding model at workstation for simulation: a) conventional scaffolding and (b) t two dimensional drawing of adjustable scaffolding and its image

4. RESULTS

4.1. Case 1: Use an elevated bench to avoid bending

The findings of case 1 conveyed the before and after ergonomic intervention results for construction workers. Figure 4 depicts lifting postures P1, P2, P3, and P4, which have a respective before-intervention RULA score of 2, 4, 4, and 7, thereby illustrating that the position is not within permissible range and the worker is under biomechanical stress; scores were obtained for the arms, wrist, neck, chest, and leg positions. These results indicate that the workstations must be modified for enhanced ergonomic conditions. After intervention, the RULA scores of P1, P2, P3, and P4 were 2, 1, 1, and 2, respectively, which demonstrated that the position was within permitted range and did not put the worker under biomechanical stress. Figure 5 depicts an example of prior to intervention, the OWAS action category for P1 was 2 with an erect torso, both hands beneath the shoulders, standing on both feet, and a 13.5 kg weight; this position demonstrated action category 2, which is regarded to have a negative impact and demands immediate action. P2, P3, and P4 have OWAS action categories of 1, 3, and 1, respectively. P3 displayed action category 3, indicating that immediate remedial action is required. Similarly, the OWAS category for after intervention postures (P1, P2, P3, and P4) were 2, 1, 1, and 1, which is a safe working posture.

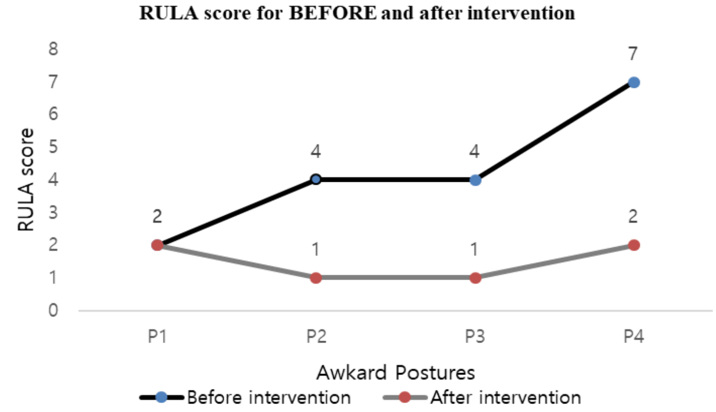


Figure 4. RULA score for case 1 (before and after intervention)

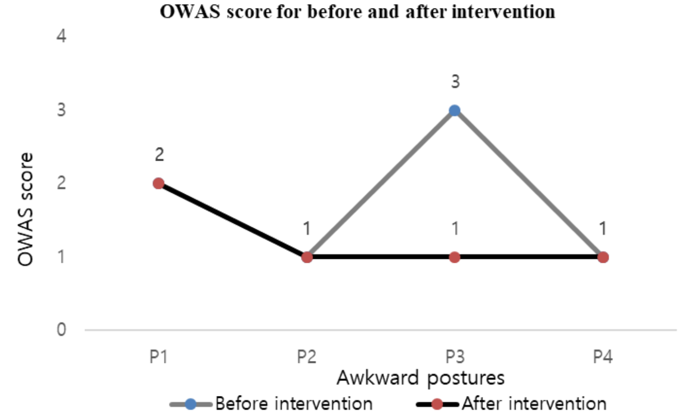


Figure 5. OWAS score for case 1 (before and after intervention)

4.2. Case 2: Installing an adjustable ladder and assessing its effectiveness

The findings of case 2, which involves installing an adjustable ladder, demonstrated the consequences of MSDs for aluminum construction formworkers before and after ergonomic intervention. Figure 6 displays the RULA scores of lifting postures P1, P2, P3, P4, and P5; scores were obtained for the positions of arms, wrists, neck, chest, and legs. Before intervention, the respective scores were 3, 5, 4, 6, and 4, which were not within the permitted range, thereby indicating that the worker was experiencing biomechanical stress. Therefore, the workstation must be redesigned for enhanced ergonomic conditions. After intervention, the RULA scores of P1, P2, P3, P4, and P5 were 1, 1, 1, 2, and 2, respectively, indicating that the position was within acceptable range and did not place the worker under biomechanical stress. The acceptable ranges have been discussed in section 3. Figure 7, the OWAS action category for P1 was 3, with an erect body, both hands beneath the shoulders, standing on both feet, and a 27.5 kg load; this is seen as having a negative impact and necessitating quick corrective actions. P2, P3, P4, and P5 OWAS action categories were 2, 3, 4, and 3. All postures had a high action category, indicating that corrective actions are needed immediately away. Furthermore, the OWAS category for post-invention postures (P1, P2, P3, P4, and P5) was less than 2, indicating that construction workers were safe.

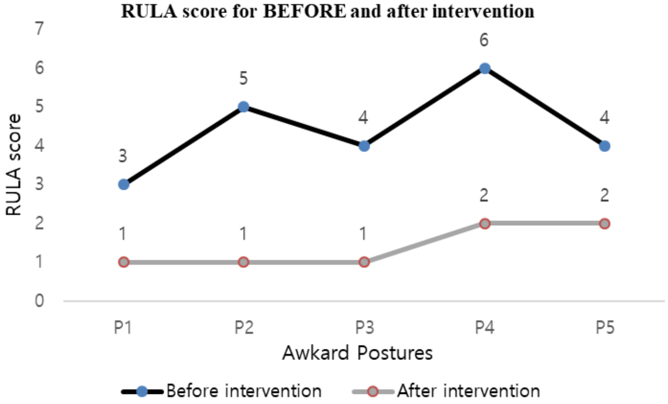


Figure 6. RULA score for case 2 (before and after intervention)

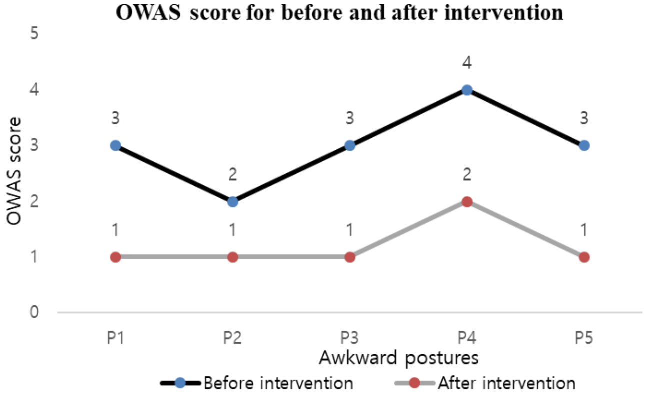


Figure 7. OWAS score for case 2 (before and after intervention)

5. CONCLUSION

This study provides an ergonomic risk assessment of MSDs and subsequent preventive techniques for aluminum construction formworkers by transferring real-world events to simulated environments. Ergonomic examination of muscular strain due to repetitive postures was evaluated by calculating OWAS action category and RULA scores. According to the results, both RULA and OWAS demonstrated unsafe and undesirable human postures in two antecedent formworker test instances before intervention; thereafter, based on the revised scores, adjustments were recommended in the workstation architecture. The simulation demonstrated safe postures with no harmful effects using a simple elevated bench arrangement and adjustable scaffolding, which can contribute to the drop in MSD occurrences. These analogies can aid the correction of specific postural flaws and help predict how long job designs will last in terms of job preparedness. These comparisons can be utilized to aid in the development of a certain postural feature. The research will be enhanced in the future to simulate and quantify semi-automated and fully automated equipment used by form-workers throughout installation procedures.

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