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Analysis of Lower Back Compression Forces During Lifting Tasks While Standing on the Ground and on a Scaffold

David Imuetinyan, Vamsi Pusapati, and Fereydoun Aghazadeh*

Department of Mechanical and Industrial Engineering, Louisiana State University, Baton Rouge, LA, USA,70803.

*Corresponding Author's Email: aghazadeh@lsu.edu

Author Note: David Imuetinyan is a Ph.D. student in the Department of Mechanical and Industrial Engineering, Louisiana State University. **Vamsi Pusapati** is a Ph.D. candidate in the Department of Mechanical and Industrial Engineering, Louisiana State University. **Fereydoun Aghazadeh** is a Professor in the Department of Mechanical and Industrial Engineering, Louisiana State University.

Abstract: Background/Objective: The construction industry is a labor-intensive one where construction workers perform many manual material handling activities, which exposes workers to a high risk of musculoskeletal disorders. Occupational injuries in the construction industry in the United States accounted for 10.1%, with Work-related Musculoskeletal disorder (WMSD) accounts for 35% of occupational injury and illness leading to loss of work. It has been reported that workers on high elevation such as scaffolds encounter difficulties in physiological adjustment when performing heavy-duty or delicate tasks. This study aims to evaluate the biomechanical stresses on the lower-back compression using the same weight at two levels – the ground level and scaffold height level.

Methods: Four males participated in this experiment. Each participant was fitted with IMU sensors and lifted a box from the floor to the reach height. This task was carried out on the ground level and on the scaffold level. The scaffold level is at the height of 7.5 feet measured from the base of the scaffold tower. The IMUs were calibrated, and YEI MOCAP software was used to record the motions of the participants. The posture data at the elbow height was inputted into 3DSSPP, and the low-back compression forces at L4/L5 intervertebral disc were calculated.

Results: The statistical analysis was done using a paired t-test. The t-test shows a significant difference between the low-back compression forces at the ground and the scaffold height levels. The low-back compression forces at the scaffold level were 45.5% higher than the ground-level forces.

Conclusion: The data suggest that workers experience increased lower back compression forces when working on scaffolds. This increase can be attributed to the participants maintaining a low center of gravity on the scaffold, thereby lifting in an awkward posture.

Keywords: Scaffolds, Lifting, Low-back pain

1. Background and Objective

The construction industry is a labor-intensive one where construction workers perform many manual material handling activities involving physical strength, repetitive work, and awkward postures, which exposes workers to a high risk of musculoskeletal disorders. Occupational injuries in the construction industry in the United States account for 10.1%, with Work-related Musculoskeletal disorder (WMSD) accounting for 35% of occupational injury and illness leading to loss of work (Bureau of Labor Statistics 2016). Working on scaffolds is one of the construction's highest hazardous jobs (Hsiao & Stanevich, 1996). Workers on high elevation have encountered difficulties in physiological adjustment when performing heavy-duty or delicate tasks (F.-W. Hsu et al., 2016). The effects of extreme weather conditions, such as heat or cold stresses and strong winds, on high-rise building construction workers' work performance and safety are greater than those of ground-level workers (D. Hsu et al., 2008).

Min et al. (2011) experimented to determine if the level of worker experience and the floor level affects postural stability, rotational spinal stability, and the availability of safety handrails (with and without a handrail) while conducting manual work on scaffolds. Min et al. (2012) examined cardiovascular stress and postural stability in construction workers as a follow-up study. The resulting analysis indicated that stability was compromised at higher scaffold height and absence of handrails, but the effects of these variables on major body segment forces were not examined. For our study, we used IMU sensors and 3DSSPP to perform a biomechanical analysis of lifting tasks. The objective of this study was to investigate the low-back compression forces while performing lifting tasks on the ground and scaffold levels.

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2. Materials and Methods

Four males between the ages of 24 and 43 years voluntarily participated in the experiment. The mean height and weight values are 181.45 ± 8.31 cm and 80 ± 16.17 kg, respectively. All participants were healthy, had no musculoskeletal disorders, and were fully kitted with Personal Protective Equipment (PPEs). The participants had no prior experience working on scaffolds. The instructions on the proper lifting procedures were provided before the start of the experiment. The apparatus used for this experiment were IMU sensors, scaffold, wooden box, weighing scale, and weights. A wooden box (46"x30.5"x20") weighing 8lbs was used to hold the weights. The weight used for lifting was18.6lbs, while the overall weight was 26.6lbs.

This experiment was carried out in a controlled lab environment. Each participant was fitted with IMU sensors and lifted a box from the floor to the reach height. The reach height was an overhead platform, while the posture modeled by 3DSSPP was when the lift was at elbow height. This task was carried out on the ground level and the scaffold level. The scaffold level is at the height of 7.5 feet measured from the base of the scaffold tower. The IMUs were calibrated, and YEI MOCAP software was used to record the motion of subjects. The lift posture at the elbow height was inputted into 3DSSPP, and the compression forces at L4/L5 intervertebral disc were calculated. The scaffold, lift at elbow height, 3D Mannequin, and 3DSSPP simulations are shown in the figures below.

Figure 1(a): front view of the scaffold; (b): lift at elbow height on the scaffold and ground levels

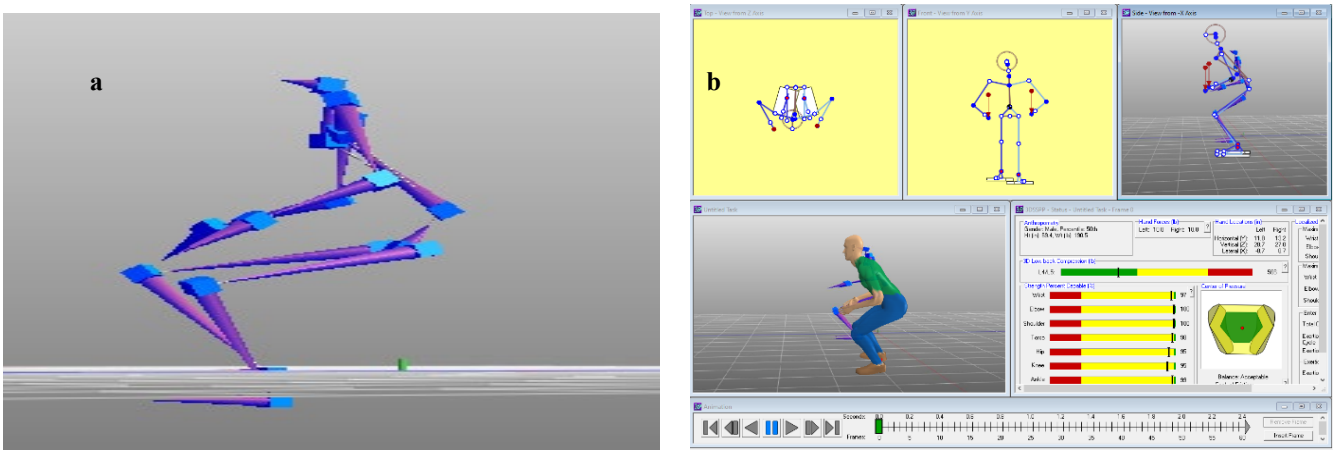

Figure 2 (a): YEI MOCAP 3D Mannequin; (b): 3DSSPP Simulation

3. Results and Conclusions

A paired t-test was performed to identify if there was a difference in the average of the low-back compression forces between the ground and scaffold level, with the null hypothesis stating that the difference between average low-back compression force

of the ground and scaffold level equals zero, and the alternative hypothesis stating otherwise. The alternative hypothesis makes it a two-sample t-test. The P-Value (Pr > 0.0004) was less than the alpha level of 0.05, so the null hypothesis was rejected. Next, the percentage increase between the ground and scaffold was computed. The computation showed a significant increase as the low-back compression forces at the scaffold level were 45.5% higher than ground-level forces. The 45.5% difference in compressive force is excessive. The average lower back compression forces for the ground and scaffold level participants were 476.5lb and 693lb. The participant low back compression forces are shown in figure 3. This increase can be attributed to the participants trying to maintain a low center of gravity on the scaffold, thereby lifting in an awkward posture. In addition, the experience level of the participants working on scaffolds was also a contributing factor to this increase. The resulting analysis shows that the low-back compression forces increased when working on the scaffold (greater) height as observed in the participants' L4/L5 spinal region.

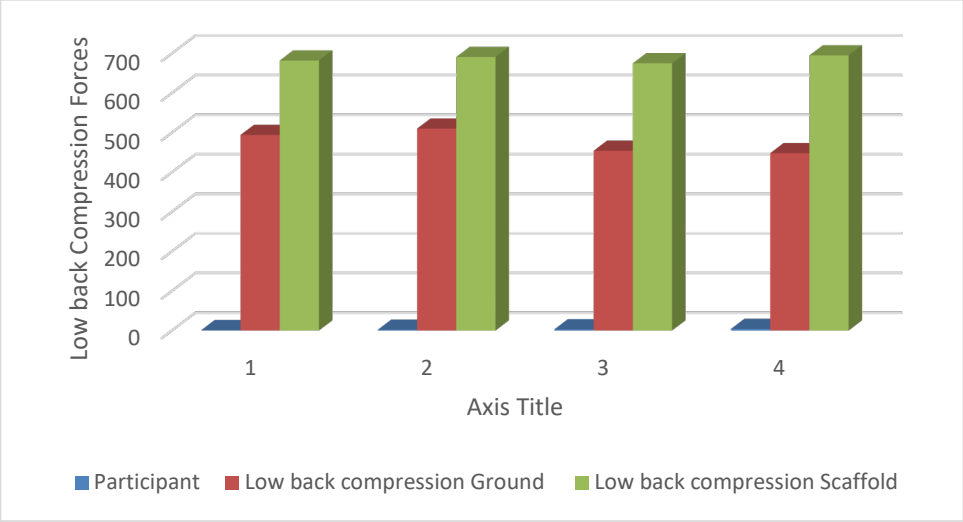

Figure 3: Participant Low Back Compression

Elders and Burdorf (2001) studied the effect of working on scaffolding and concluded that scaffold workers are more susceptible to low back injuries. Bangaru et al. (2019) studied the low back compression forces on two scaffold levels and concluded that workers on higher levels were prone to having low back pain. This result agrees with these studies.

Based on the results of this study, we recommend that construction workers use a back belt while lifting on scaffolds. This will help maintain a straight posture while lifting, thereby reducing the lower back compressive force. Also, construction materials to be handled on a scaffold can be transported to workers via lifts. This allows them to retrieve the material at elbow heights rather than from the scaffold floor level. Further study can be expanded to include participants with experience of working on scaffolds and female participants working in the construction industries, especially working on scaffold height. Also, multiple postures should be considered for analysis. In addition to adopting different postures while lifting on scaffolds, further studies should be carried out to include EMG data to explore different muscle activity usage while maintaining balance.

4. References

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