Physical Ergonomics and Human Factors, Vol. 185, 2025, 108–111
https://doi.org/10.54941/ahfe1006470

The Biomechanics and Epidemiology of Shoulder Injuries: Quantifying the Risk Accurately

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ABSTRACT

The shoulder is a very complex joint and there are many misconceptions regarding the shoulder and the risk of injury in the industrial setting. In this presentation we will break down the fundamental motions and biomechanics of the shoulder. Because of the complex nature of the shoulder, many ergonomic risk factors affecting the shoulder go undocumented. Most traditional ergonomic assessments neglect to accurately quantify the risk of shoulder injury. After discussing the biomechanics of the shoulder, we will explore epidemiology research regarding the risk of shoulder injuries. We will also discuss techniques that can be used to accurately quantify the risk of shoulder injuries in the industrial setting and ways to mitigate risk.

Keywords: Musculoskeletal, Shoulder injury, Rotator cuff, Ergonomics, MSD, Ctd, The shoulder tool, Ergonomic risk, Ergonomic analysis, Odds ratio, Epidemiology, Ergonomic, Ergonomic risk analysis, Ergonomic risk factors, Evidence based

INTRODUCTION

Shoulder injury and pain is a common problem in the general population and industry. The prevalence of shoulder pain in the general population may be as high as 6%–11% under the age of 50 years, increasing to 16%–25% as individuals get older. According to population surveys, shoulder pain affects 18–26% of adults at any point in time, making it one of the most common regional pain syndromes. Symptoms can be persistent and disabling in terms of an individual's ability to carry out daily activities both at home and in the workplace (Frost et al., 2002; Gallagher et al., 2020). There are also substantial economic costs involved, with increased demands on health care, impaired work performance, substantial sickness absence, and early retirement or job loss.

TRADITIONAL ERGONOMIC RISK ANALYSIS

Ergonomic risk is not created equal. Many traditional ergonomic risk assessment tools apply a step system. An example of such a system is seen in RULA (Rapid Upper Limb Assessment): neutral = +1, 0–20 degrees extension = +2, 20–45 degrees shoulder flexion = +2, 45–90 degrees shoulder flexion = +3, shoulder flexion greater than 90 degrees = +4. There are then adjustment values that can be used to increase or decrease the score: if shoulder is raised = +1, if upper arm is abducted = +1 and if arm is supported or person leaning = −1. There are other assessment tools that utilize a similar process. REBA (Rapid Entire Body Assessment) utilizes a similar step process: 0–20 degrees shoulder extension = +1, 20+ degrees of shoulder extension = +2, 20–45 degrees shoulder flexion = +2, 45–90 degrees shoulder flexion = +3, shoulder flexion greater than 90 degrees = +4. Similarly to RULA, there are then adjustment values that can be used to increase or decrease the score: if shoulder is raised = +1, if upper arm is abducted = +1, if arm is supported or person leaning = −1.

In 2013 NERPA (Novel Ergonomic Postural Assessment Method) was introduced as an alternative to RUAL and REBA. Similar to RULA and REBE, NERPA applies a step system based on ranges of motion: neutral position is considered 20 degrees extension to 20 degrees flexion with a multiplier of +1, 20+ degrees shoulder extension = +2, 20–60 degrees shoulder flexion = +2 and greater than 60 degrees shoulder flexion = +3. Like RULA and REBA, NERPA has adjustments that can be used to increase or decrease the score: if arm is abducted greater than 60 degrees and action is greater than 4 per minute = +1, if upper arm is abducted greater than 20 degrees and posture is static or action is greater than 4 per minute = +1 and if arm is supported or leaning = −1. Unlike RULA and REBA, NERPA does account for internal and external rotation, the primary motion subscapularis, teres minor and infraspinatus. However, internal rotation and external rotation, the primary motion of rotator cuff, is applied to the forearm, not the shoulder. The forearm is not involved with internal and external rotation, that movement is a pure rotator cuff movement.

FATIGUE FAILURE MODELS

Mounting evidence suggests that musculoskeletal disorders (MSDs) may be the result of a fatigue failure process in musculoskeletal tissues. The Fatigue Failure Shoulder Tool was released in 2020 and published in the Journal, Ergonomics. The Fatigue Failure Shoulder Tools estimates cumulative damage based on shoulder moments and loading cycles. The results of the Fatigue Failure Tools are displayed as

EPIDEMIOLOGY BASED ANALYSIS

Although many epidemiology research studies have provided odd ratios and have been available for more than thirty years, no analysis methodologies have utilized odd ratios to quantify ergonomic risks associated with the development of musculoskeletal disorders.

Shoulder injuries are not unique to manufacturing or material handling job tasks. Additionally, there are nonoccupational risk factors with associated odd ratios that allow us to now determine the predominant cause of an injury. Z-EBRA is an epidemiology-based risk analysis tool that quantifies the risk of musculoskeletal injury utilizing odds ratios. Displaying results in terms of odd ratios allows the end user to understand the odds of a musculoskeletal injury in terms of the risk above the general population. Unlike many of the older traditional ergonomic assessments that use fixed scales and arbitrary red, yellow and green zones, odd ratios have no end limit. Therefore, as risk factors increase, increased risk is reflected as a higher odd ratio.

Repetitive shoulder movements with a frequency of 1–14 shoulder flexion movements per minute have an odds ratio of 2.93 where a shoulder flexion movements with a frequency of 15–36 movements per minute have an odds ratio of 3.29. A more common way of quantifying repetition for a body part is in terms of active time and recovery time within the cycle. Shoulder flexion for <= 80% of the cycle has an odds ratio of 2.82 where shoulder flexion for > 80% of the cycle without a pause has an odds ratio of 3.33. Frost et al. (2002) reported a 2.17 odds ratio for low forceful exertions (<10% MVC) and an odds ratio of 4.21 for high forceful exertions >= 10% MVC).

CONCLUSION

Traditional ergonomic analysis tools quantify shoulder flexion and abduction in incremental multipliers of +1, +2, +3. Odds ratios clearly demonstrated that risk is not incremental. Risk gradually increases beyond 45 degrees of shoulder flexion. As shoulder flexion increases above 90 degrees, the risk of injury significantly increases. Additionally, internal and external rotation are ignored and in some instances, applied to the inappropriate body part. Where traditional ergonomic analysis processes fall short of quantifying the risk of shoulder injury, odd ratios can be used to accurately demonstrate the increased risk of injury above the normal population.

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