

# Physiologic Stress During Baseball Pitching: A Framework for Capturing Actionable Data Beyond Mechanics

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**Disclosures:** None

**INTRODUCTION:** The baseball pitcher must exhibit a balance of precision and endurance that imparts unique injury risk at the shoulder and elbow. The goal for each pitching bout is to maximize performance and innings pitched while avoiding injury. Currently, pitcher fatigue is assessed by coaching observation, performance metrics such as velocity, and at the highest levels, by changes in quantitative mechanics. No study has investigated a pitcher's physiological stress from both a local tissue and systemic perspective. Our objective was to develop a framework to assess pitcher physiologic stress and therefore fatigue both locally and systemically during a simulated pitching bout and a 48-hour recovery period. We hypothesized that both local and systemic measurements of fatigue would be sensitive to innings pitched and recovery period.

**METHODS:** Participants threw three 20-pitch innings in a simulated pitching bout from a standard mound placed 60.5 feet from a net. IRB approval and participant consent was obtained before testing. Measurements were taken before, after each inning, and then at 30 minutes, 24 hours, and 48 hours after the bout. All pitchers were taken through standardized dynamic warm up followed by 5-minute free throw before pitching. Performance metrics included pitch velocity (mph) (Pocket Radar) and arm torque (Nm) (Pulse Sleeve) recorded on a pitch-by-pitch basis. Systemic stress was measured using reported overall fatigue (Likert scale, 0-10), hip abduction/adduction strength (N) (VALD ForceFrame), and single leg y-balance testing (cm). Local physiologic stress was tracked by ulnohumeral joint space width (JSW) and ulnar collateral ligament (UCL) thickness via ultrasound (mm) (Sonosite Edge II), flexor pronator mass (FPM) total hemoglobin (THb) (g/dL) and percent oxygenation (Moxy), FPM stiffness (N/m) (PACT sense), grip strength (N) (VALD DynamoPLUS), reported arm fatigue, reported shoulder and elbow pain, as well as shoulder internal (IR) and external rotation (ER) strength (N) (VALD ForceFrame) and total arc shoulder ROM (degrees). Repeatability of each measurement modality was assessed via ICC and Covariance by comparing measurements in the non-throwing arm before and after the bout. A repeated measures one-way ANOVA of Friedman's test for ordinal data followed by multiple comparisons were performed for each time point and measurement.

**RESULTS SECTION:** 17 pitchers were included in the study. Highest level of play was reported as follows: 2 college, 1 professional, 9 college club, 3 high school, and 2 little league. No participants had previous shoulder or elbow injury or surgery. Average time for data collection between innings was 363s +/-53s. Average pitch velocity for the 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> inning was 69.7 +/- 7.9, 68.6 +/- 7.6, and 68.3 +/- 7.5mph, respectively; arm torque was 53.4 +/- 9.3, 53.1 +/- 8.5, and 53.4 +/-8.1 Nm, respectively. Grip strength (CoV=0.05) and FPM THb (CoV=0.01) demonstrated excellent repeatability (ICC>0.9), shoulder ER strength (CoV=0.08), UH JSW (CoV=0.15), and UCL thickness (CoV=0.09) demonstrated good repeatability (ICC>0.75), shoulder ROM (CoV=0.03), FPM stiffness (CoV=0.05), and FPM %oxygenation (CoV=0.09) demonstrated moderate repeatability (ICC>0.5), and shoulder IR strength (CoV=0.09) demonstrated poor repeatability (ICC<0.5). There was a significant increase in reported overall fatigue between pregame, 1.2 +/- 1.7, and post second inning, 3.6 +/- 1.8 (p<0.0001), and post third inning, 4.6 +/- 1.7 (p=0.009) but a decrease during the recovery period at 24, 2.0 +/- 2.5 and 48 hours, 2.0 +/- 2.3 (p=0.001) (Figure 1). Hip abduction strength in the drive leg decreased significantly throughout pitching bout 378.9 +/- 68.9 vs 359.3 +/- 73.4N (p=0.017) and recovered by 48 hours, 387.0 +/- 66.8N (p=0.005). Hip abduction strength in the lead leg did not decrease during the bout but demonstrated a significant increase during the recovery period 348.6 +/- 82 vs 393.7 +/- 66.5N (p=0.002). Similarly lead leg hip adduction demonstrated significant recovery at 48 hours 364.4 +/- 115.64 vs 400.3 +/- 112.7N (p=0.017). No significant changes were seen for drive leg adduction strength. Y-balance testing demonstrated only significant increase in the pitchers drive leg reach when reaching lead leg back, pregame 107.7 +/- 9.6 vs post game 116 +/- 11.1cm (p=0.006). There was a significant change in UH JSW from pregame to post-game 1.81 +/- 0.78 vs 2.13 +/- 0.67mm (p=0.015) as well as post-game and during the 24-hour time point 1.81 +/- 0.64mm (p=0.027) (Figure2). Baseline UCL thickness was 2.04 +/- 0.58mm and did not change significantly. FPM % oxygenation increased during the bout, 47.9 +/- 5.5 vs 58.7 +/- 7.4% (p<0.0001) and decreased during the recovery period, 46.97 +/- 6.43% (p<0.0001). FPM THb demonstrated significant increase during the recovery period 12.82 +/- 0.39 vs 13.01 +/- 0.2g/dL. Reported arm fatigue and elbow pain demonstrated significant increase during the pitching bout, 0.76 +/- 1.15 vs 5.59 +/- 1.94 (p<0.0001) and 0 +/- 0 vs 2.82 +/- 2.79 (p=0.002), respectively, but only arm fatigue decreased during the recovery period 1.65 +/- 2.03 (p<0.0001). No significant change was found in shoulder pain or grip strength. Both IR and ER Shoulder strength increased during the recovery period 125.5 +/- 34.7 vs 136.12 +/- 35.8N (p=0.014) and 138 +/- 33.6 vs 162.6 +/- 41.7N (p=0.017) (Figure 3). Total arc shoulder ROM increased during the recovery period 199.4 +/- 15.89 vs 208.3 +/- 19.0 degrees (p=0.019).

**DISCUSSION:** This study introduces a framework for measuring the local and systemic physiologic stress a pitcher undergoes during a simulated bout in a timely manner between innings and after a 48-hour recovery period and establishes repeatability for the chosen measurement modalities. Local and systemic measures of physiologic stress both increased during the pitching bout and decreased during recovery period. The increase in UH JSW observed in this study is consistent with prior ultrasound studies. Limitations include small sample size, moderate pitcher stress (60 pitches), and imperfect testing modalities. Other considerations include heart rate, respiratory rate, saliva or blood lactate, strike percentage, and other performance metrics. Next steps include optimizing the testing protocol and implementing in an actual in-game scenario with the goal of establishing pitchers' baseline physiologic stress curves.

**SIGNIFICANCE/CLINICAL RELEVANCE:** This study is the first to employ a broad range of physiologic and metabolic measurements to assess pitcher fatigue between innings, during a simulated game and subsequent recovery period. By establishing a method to assess pitcher physiologic stress real-time, our understanding of the early events that lead shoulder and elbow injury in this population may allow us to better prevent injury in this vulnerable population.

## IMAGES AND TABLES:

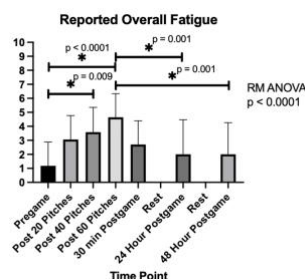


Figure 1

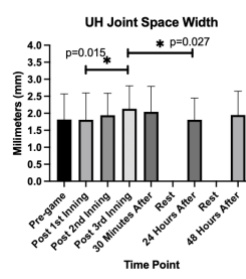


Figure 2

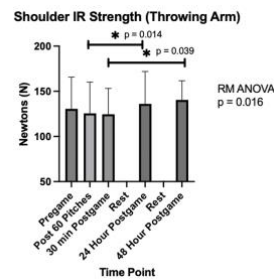


Figure 3