INTRODUCTION

- Scalability of inertial measurement units (IMUs) allow for research to be conducted on datasets that are orders of magnitude larger than traditional motion-capture equipment.
- IMUs allow for capture of data in real-world settings rather than in a laboratory.
- Elbow injuries and revisions in pitchers have been on the rise for the last 30 years; however, there lacks evidence based criteria for rehabilitation of the throwing arm.
- Clinical and return-to-throwing programs need to better understand the effects of throwing distance on elbow torque for the purpose of program design and simulation.

METHODS

- 30 NCAA baseball players wore a motusTHROW sensor and sleeve [Figure 1] during all throwing events in the 2018 season (i.e. warm-up, long toss, bullpen, and game) [n = 238,611 throws].
- Data were tagged with real-time longtoss distance tags during longtoss activity [30-300 ft] [n = 54,701 throws] by player personnel.
- One-way ANOVA was performed to test for differences in elbow torque between throwing distances with Tukey post-hoc tests used for p-value calculation (p <0.001).
- A 3rd order polynomial regression was created to investigate the relationship between throwing distance and elbow torque.

RESULTS

- A strong relationship was found between the throwing distance and elbow torque from the 3rd order polynomial regression [p <0.01] and is seen in Equation 1.

\[
T_{valgus} = 1.18 \times 10^{-7}x^3 - 8.90 \times 10^{-5}x^2 + 2.41 \times 10^{-3}x + 0.55 \tag{1}
\]

- Elbow torque increased with throwing distance, with the most rapid increases occurring prior to 180 ft of throwing distance.
- Of the total 35 distance-distance relationships, only 7 distance combinations did not have statistical significance [80-90 ft, 210-240 ft, 210-270 ft, 210-300 ft, 240-270 ft, 240-300 ft, and 270-300 ft] [p < 0.001] and is seen in Table 1 and Figure 2.

CONCLUSION

- There was a strong cubic relationship between throwing distance and elbow torque, with the most increases in torque occurring below 180 ft of throwing distance.
- The cubic regression formula allows for clinicians to estimate peak valgus torque in the throwing arm from distance alone. This relationship can be used to better design return-to-throw programs.

CLINICAL CONNECTION

Thrower’s rehabilitation requires pitchers to progress throwing workload in an intentional fashion. However, to-date, no throwing program has undergone workload analysis. There is a strong need to understand the mechanical load and fatigue throwers are exposed to during rehabilitation. Three leading throwers rehab programs were analyzed using acute:chronic ratios from elbow torque that was converted from throwing distance.

CALCULATING WORKLOAD

Throwing programs were codified into arrays of elbow torque using the polynomial formula in Equation 1. Daily workloads were computed as the exponential sum of elbow valgus torque arrays in each day (Equation 2). Acute workloads were computed as the seven day average of daily load, and chronic workloads were computed as twenty-eight day averages of daily load (Equations 3, 4). Acute:chronic ratios for each day of rehabilitation were calculated, using dynamic divisors in the first 28 days (Equation 5).

IMPLICATIONS

Most leading rehabilitation programs expose throwers to elevated acute:chronic ratios (ACR) within the first 40 days of throwing, as well as during periodic build-up phases. Through proper workload design, these exposures can be drastically reduced, or eliminated altogether. Throwing programs can also be designed to effectively implement consecutive days of throwing.

Evaluation of Leading Thrower’s Rehabilitation Programs