ENERGY FLOW ANALYSIS OF HIGH AND LOW VELOCITY BASEBALL PITCHERS

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INTRODUCTION

The throwing motion is characterized by the sequential motion of distal to proximal segments, which is assumed to be indicative of the transfer of energy through the kinetic chain [3]. This kinetic chain is a common focus both clinically and in research for improving performance, as well as for preventing or rehabilitating throwing injuries to the elbow [1]. While most studies investigating the kinetic chain tend to utilize correlational analysis, energy flow analysis enables us to estimate energy flowing into and out of segments, providing an estimate of the role muscles play in generating, dissipating, and transferring energy between segments [4]. This approach has been used to investigate differences between injured and uninjured elite tennis players during the overhead serve [2], but there has been little to no research investigating the role of energy flow in performance and injury risk during an overhead baseball throw. Therefore, it was the purpose of this study to explore differences in upper extremity energy transfer between high and low performing baseball pitchers.

METHODS

Thirty-two male high school baseball pitchers (height = 1.83±0.07 m, mass = 75.6±10.9 kg, hand velocity = 21.1±2.0 m/s) were recorded at 300 Hz using a 10-camera passive optical motion capture system (Vicon, Oxford, UK) while throwing 15 fastballs towards a target. An upper extremity marker set consistent with the ISB recommendations was used to define shoulder joint angles, and joint torques were calculated using standard inverse dynamics equations in Visual3D (C-Motion, Inc., Germantown, MD). The last three pitches with complete data were chosen for analysis.

The 10 pitchers with the highest and lowest average peak hand velocity were separated into high and low velocity groups for comparison. Segment power (SP) was calculated as the sum of joint force power (JFP) and segment torque power (STP) at the distal and proximal ends of each segment for the trunk, upper arm, forearm, and hand of the throwing extremity throughout the pitch cycle (Equations 1-3; Winter, 1978).

\[ JFP = \text{Joint reaction force} \cdot \text{linear joint velocity} \]
\[ STP = \text{Segment torque} \cdot \text{joint angular velocity} \]
\[ SP_{\text{segment}} = JFP_{\text{prox}} + JFP_{\text{dist}} + STP_{\text{prox}} + STP_{\text{dist}} \]

Net energy transfer was calculated as the integral of power for each segment of the arm during the arm cocking phase (stride foot contact to maximum shoulder external rotation) and arm acceleration phase (maximum shoulder external rotation to ball release), when energy is being applied to accelerate the ball.

One way ANOVA’s were performed to compare net energy flow between high and low velocity groups using height and mass as covariates. A Bonferroni-adjusted alpha level of \(p<0.00625\) was set \textit{a priori} to account for multiple comparisons.

RESULTS AND DISCUSSION

Figure 1 shows energy flow through the trunk and throwing arm during the arm cocking and arm acceleration phases for high and low velocity pitchers. Pitchers with high velocity demonstrated greater net energy flow out of the trunk (-165.9 vs. -90.9 J; \(p<0.001\)), and into the forearm (105.7 vs. 63.0 J; \(p<0.001\)) and hand (93.3 vs. 56.2 J; \(p<0.001\)) during the arm cocking phase.
Greater flow of energy out of the trunk and into the arm early in the pitch cycle increases the energy of the arm, which may aid in accelerating the ball. This finding supports the importance of the trunk musculature to generate and transfer energy into the arm to improve performance. While it may seem counter-intuitive that the upper arm, forearm and hand receive more energy during the arm cocking phase than the arm acceleration phase, this result occurs because these segments actually move forward relative to the ground during the arm cocking phase, even though they are moving backward relative to the shoulder.

This analysis gives unique insights into how energy flows through the kinetic chain, and may be an alternative method to previous kinematic analyses for assessing the kinetic chain. This analysis can also be extended further down the kinetic chain to determine the role of core and lower extremity muscles in generating and transferring energy from the ground up. Energy flow may also be a useful analysis when investigating interventions aimed at core and shoulder stability, or other interventions with a purpose of improving energy transfer between segments. Due to the exploratory nature of this study, further research is needed to corroborate these findings and determine how energy transfer relates to actual injury occurrences.

CONCLUSIONS

Performance may be improved through a greater transfer of energy out of the trunk and into the arm early in the pitch cycle. The power flow analysis used may be an effective measurement technique for better understanding the effectiveness of interventions aimed at improving the kinetic chain. Further research is needed though to understand the validity and utility of this analysis in kinetic chain tasks.

REFERENCES


Figure 1. Net segment energy flow during the a) arm cocking phase and b) arm acceleration phases. Positive values indicate net energy input to the segment, negative values indicate net energy output from the segment. * indicates $p < 0.00625$