PEAK RATE OF TRUNK ENERGY OUTFLOW DIFFERS BETWEEN PITCH TYPES IN SOFTBALL PITCHERS

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In softball players, it is unclear how certain pitch types may increase the risk of injury. The purpose of this study was to determine energy flow differences in the trunk and upper-arm segments between pitch types. Twenty-three softball pitchers participated. Absolute values of trunk energy inflow (IF) and outflow (OF), and upper arm IF, as well as segment energy flow when normalized to pitch speed were assessed in three pitch types. Differences between trunk energy OF were found between fastballs compared to curveballs and dropballs. When normalized to pitch speed, trunk energy OF only differed between fastballs and dropballs. For the upper arm, absolute differences were found between the fastball and curveball. Similar rates of humerus IF between the fastball and dropball and less trunk outflow in the dropball may indicate increased upper extremity demands in the dropball.

KEYWORDS: energy flow, performance, windmill pitch

INTRODUCTION: The windmill softball pitch utilizes the kinetic chain in a proximal to distal manner to transfer energy generated from the lower extremities to the upper extremities and finally to the ball for release. Energy flow analysis has recently gained popularity in baseball and softball pitching as it provides a more in-depth analysis of energy flowing through the kinetic chain (Oliver et al., 2021; Bordelon et al., 2022; Wasserberger et al., 2020; Barfield et al., 2021). Specifically, energy flowing into and out of a segment is quantified using joint force power and segment torque power parameters (Bordelon et al., 2022). Most research has investigated energy flow during the baseball pitch. However, it is important to investigate both baseball and softball research individually as the mechanisms of injury differ between the two sports. For example, biceps tendonitis and related upper extremity pain is a common injury unique to softball pitchers due to the windmill pitching motion. Recent studies have emerged analyzing energy flow during the softball pitch. One study reported drive hip external rotation isometric strength was positively associated with increased net energy flowing out of the distal trunk to the humerus when throwing fastballs (Oliver et al., 2021). Yet, no relationships were observed between upper extremity pain or shoulder kinetics and energy flow parameters for pelvis and/or trunk segments during the acceleration phase of the pitch (Bordelon et al., 2022; Oliver et al., 2022).

The lack of findings between trunk energy flow variables and upper extremity pain or shoulder kinetics is intriguing since trunk and upper extremity kinematic and kinetic parameters have been associated with pain and injury susceptibility (Oliver et al., 2018, 2019). Varying results on energy flow in softball pitching may be attributed to studies utilizing a single pitch type. Prior research has established kinematic and kinetic differences between pitch types and anecdotally increased pain has been reported when pitching specific pitches (Downs et al., 2021; Oliver et al., 2021). However, it is unknown if segment energy flow also differs between pitch types. A more in-depth analysis on segment energy flow between pitch types would help to understand the mechanical requirements for executing certain pitches and can be used to determine an appropriate time to new learn pitch types. This information may also be used from a rehab perspective on when to clear pitchers for specific pitch type when returning from an injury. Thus, the purpose of this study was to conduct an energy flow analysis to investigate if differences exist between various pitch types during the acceleration phase of the softball pitch. Specifically, the peak rates of proximal trunk energy inflow (IF) and distal trunk energy outflow (OF) and proximal humerus energy IF on the pitching arm side between the fastball, curveball, and dropball in high school softball pitchers were examined. Prior research indicated there is a significant correlation between energy transfer across the shoulder and pitch speed (Wasserberger et al., 2021). Therefore, a secondary purpose was to determine differences in energy flow parameters after normalizing to pitch speed which would allow comparisons between pitch types that are not based solely on differences in pitch speed. It was hypothesized that segment energy flow for the fastball would differ from other pitch types.

METHODS: Twenty-three (age: 14.6 ± 1.6 yrs, mass: 72.9 ± 13.9 kg, height: 1.6 ± 0.2 m) right-handed softball pitchers participated. All testing procedures were approved by the University's Institutional Review Board. All participants were injury free for at least the past six months at the time of testing. To be included in the study, participants had to be experienced throwing the fastball, curveball, and dropball in a game setting. Kinematic and kinetic data were collected using an electromagnetic tracking system (trackSTAR Ascension Technologies Inc. Burlington, VT, USA) collected at 240Hz and synced with The MotionMonitor software (Innovative Sports training Inc., Chicago, IL). Fourteen sensors were affixed to the participant's skin at various segments using previously established standards (Downs et al., 2021). Joint forces and torques were calculated using inverse dynamics methods in the MotionMonitor software (Ganon & Ganon., 1992). Force plate data were collected using a Bertec^{TM} force plate (BertecCorp., Columbus, OH, USA) sampled at 1200Hz. Following sensor attachment, participants were given an unlimited amount of time to warm-up to prepare for full effort pitching of each pitch type. Once deemed warm, participants threw three trials of each pitch type in a random order to a catcher at regulation distance (13.11 m). Participants were instructed to land on the force plate with their stride foot when performing the pitch. Pitch velocity was recorded using a calibrated radar gun (Stalker Pro II; Stalker Radar) and the fastest trial for each pitch type was used for analysis. The pitching motion was broken down into two events, top of pitch and ball release. Top of pitch was defined when the pitching-arm humerus was perpendicular to the ground and ball release was defined as one frame after maximal hand angular velocity. The motion between these two pitching events is commonly referred to as the acceleration phase (Bordelon et al., 2022). Data during the acceleration phase for each pitch type was used for analysis.

Similar to prior softball studies, a segmental power analysis was used to quantify energy flow for the trunk and pitching-side humerus during the acceleration phase of the pitch (Bordelon et al., 2021; Oliver et al., 2021). Calculations for joint force power (JFP) and segment torque power (STP) can be found below in Equations 1 and 2, respectively. Segment power was isolated at the proximal (Equation 3) and distal (Equation 4) ends using a ground-up approach to the kinetic chain. Proximal ends were defined as segments closer to the ground and distal ends were defined as further up the kinetic chain. The trunk had one proximal end (L5/S1 junction) and two distal end points (pitching and glove arm sides). For the trunk, only the distal end of the pitching arm side was analyzed. The humerus had one proximal and one distal end. The maximum positive endpoint segment power value represented peak rate of IF (work being done on the segment), while the minimum negative value represented peak rate OF (work being done by the segment) (Bordelon et al., 2022).

$$\textit{Equation 1: Joint Force Power (JFP)} = \textit{(joint reaction force)} \cdot \textit{(linear joint velocity)}$$

$$\textit{Equation 2: Segment Torque Power (STP)} = \textit{(joint torque)} \cdot \textit{(segment angular velocity)}$$

$$\textit{Equation 3: Segment Power}_{Proximal} = (JFP_{proximal} + STP_{proximal})$$

$$\textit{Equation 4: Segment Power}_{Distal} = (JFP_{Distal} + STP_{Distal})$$

Statistical analyses were performed using SPSS software (version 27; IBM Corp). Based on a Shapiro-Wilk test of normality, the data lacked normal distribution therefore nonparametric tests were performed. A Freidman test was used to determine if significant differences existed between the three pitch types for peak rate of proximal trunk IF, distal trunk OF, and proximal humerus IF. Statistical significance was set a-priori to $p < .05$. If a significant difference was found post-hoc Wilcoxon Signed Rank testing was used to determine differences between pitch types. Statistical significance was set a-priori to $p < .0167$, using a Bonferroni correction to control for type 1 error for multiple comparisons. To investigate the secondary purpose, all statistics were repeated with the variables normalized to pitch speed in mph.

RESULTS: Descriptive statistics can be found in Figure 1. The Friedman test revealed a statistically significant difference for peak rate trunk OF ($p = .001$), peak rate humerus IF ($p = .030$) and pitch speed ($p = .011$). Specifically, post-hoc testing revealed that the fastball had significantly larger peak rate distal trunk OF than the curveball ($p = .011$) and dropball ($p < .001$) and larger peak rate humerus IF than the curveball ($p =.015$). Lastly, the fastball (53.1 ± 4.6 mph) pitch speed was significantly greater than the dropball (52.2 ± 4.6 mph) ($p = .010$). No difference in pitch speed was found with the curveball (52.4 ± 4.2 mph).

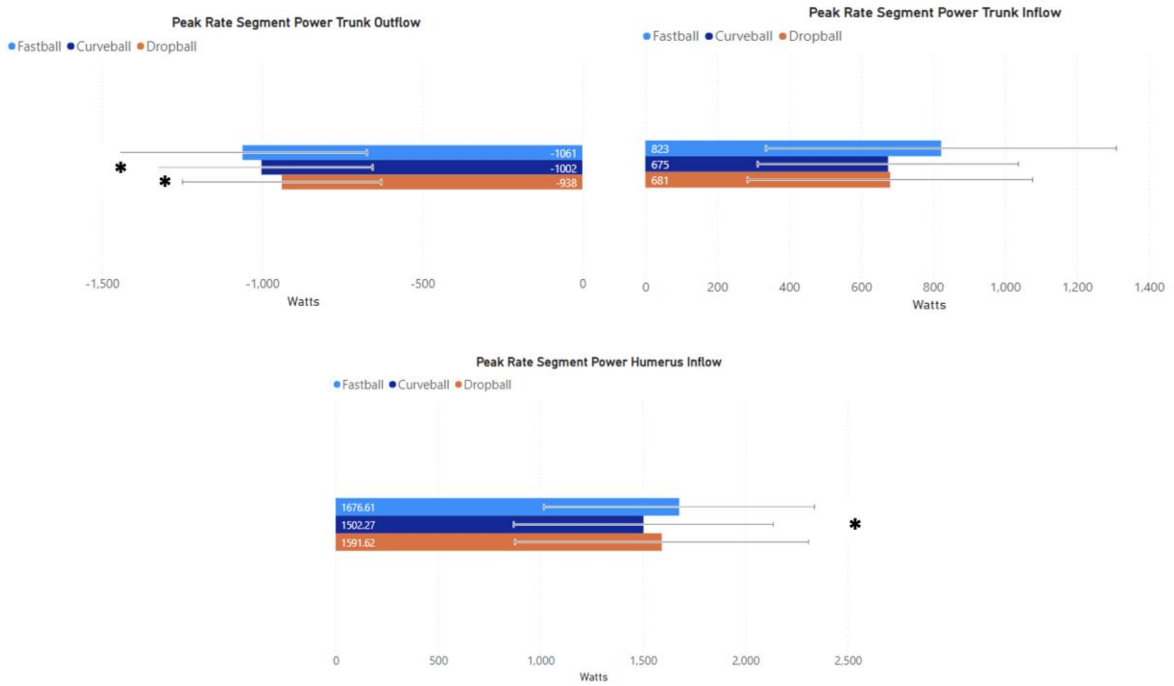

***Figure 1: Peak Rate Segment Power by Pitch Type; ****denotes statistically significant difference with fastball*

For normalized testing, the Friedman test revealed a statistically significant difference for normalized peak rate distal trunk OF (p = .004). Specifically, post-hoc testing revealed a significant difference (p = .002) between the fastball and dropball. No significant differences were observed for normalized peak rate proximal trunk IF (p = .197) or normalized proximal humerus IF (p = .072).

DISCUSSION: The main results of this study were peak rate of distal trunk energy OF on the throwing side was significantly larger when throwing the fastball than when throwing the curveball and dropball. Additionally, peak rate of humerus energy IF was also significantly greater in the fastball than in the curveball. Similar amounts of proximal trunk energy IF found between pitch types are not surprising. During the softball pitch, the lower extremity is used to generate energy to be transferred distally up the kinetic chain into the trunk (Kibler et al., 2013). Pitchers often alter the mechanics of the trunk and upper extremity to elicit different ball movements in the later phases of the pitch (Downs et al., 2021). The results of the current study may support this performance notion and prior literature, indicating that lower extremity mechanics may remain similar between pitch types while alterations occur at the more distal segments. However, future research should investigate lower extremity mechanics and energy flow to confirm this hypothesis.

A secondary purpose was to investigate differences in energy flow after normalizing to pitch speed. Normalization was done to determine if differences in energy flow could be linked to mechanical variances and not solely attributable to pitch speed associated with various pitch types (Downs et al., 2021; Wasserberger et al., 2021). When normalized to pitch speed, the fastball had a significantly larger peak rate of distal trunk energy OF on the pitching arm side than the dropball. Prior research reported trunk kinematic differences between the fastball and dropball (Downs et al., 2021). In conjunction with the results of the current study, it postulated there may be association between energy flow and kinematics.

This study found that the fastball had a significantly greater absolute peak rate of humerus energy IF than the curveball, which is an anticipated result based on the increased peak rate of distal trunk energy OF. However, in both outcomes, there was no difference in peak rate of humerus energy IF between the fastball and dropball despite the dropball having less trunk energy OF. One conceivable hypothesis is that the dropball may rely more on the upper extremity than the transfer of energy throughout the kinetic chain. This potential increased reliance on the upper extremity to produce the desired spin and break of the dropball may place pitchers at an increased risk of pain and injury. In baseball, numerous studies have reported an increased prevalence of reported pain in breaking ball type pitches (Lyman et al., 2002; Petty et al., 2004). The results of this study may allude to the etiology of the increased reported pain with breaking ball pitches, which is a preliminarily finding in softball.

This study is not without limitations. The current study only investigated the fastest trial; however, this method is in alignment with previous research methods. With the whole-body nature of the pitch, only analyzing endpoint segment power of the trunk and proximal humerus is another limitation. Future studies should analyze energy absorption, generation, and transfer and consider correlations between energy flow and kinematic variables. Investigating the relationship between pitch count and energy flow should also be considered for future work considering the lack of pitch count regulations in softball.

CONCLUSION: This is the first study to identify trunk and humerus energy flow differences between pitch types and lays an important foundation for further research to build upon. The finding of similar peak rates of trunk energy IF with differing peak rates of trunk energy OF patterns between pitch types provides a deeper understanding of the demands for executing certain pitches. Identification of pitch type differences can be used by coaches to emphasize the need for proper strength and development before introducing complex pitch types (i.e. curveball or dropball) to youth pitchers. For example, these findings suggest that increased trunk and upper extremity strength and stability may be needed to mitigate injury risk when throwing the dropball. Additionally, pitchers who report pitching related arm pain may want to consider their pitch arsenal and if they experience increased pain with a specific pitch. These additional questions may help clinicians identify the origin of pain and decide on rehabilitation strategies. Coaches can also use this information by avoiding calls for specific pitches in a game to decrease the pain and injury rates of their pitchers.

REFERENCES

Barfield, J. W., Wasserberger, K. W., & Oliver, G. D. (2021). Relationship between humeral energy flow during the baseball pitch and glenohumeral stability. *International Journal of Sports Medicine*, *42*(08), 760-765.

Bordelon, N., Friesen, K., Fava, A., Plummer, H., & Oliver, G. (2022). Peak Elbow Flexion Does Not Influence Peak Shoulder Distraction Force or Ball Velocity in NCAA Division I Softball Pitchers. *Orthopaedic Journal of Sports Medicine*, *10*(1), 23259671211067828.

Bordelon, N. M., Wasserberger, K. W., Downs-Talmage, J. L., Friesen, K. B., Dugas, J. R., & Oliver, G. D. (2022). Pelvis and Trunk Energy Flow in Collegiate Softball Pitchers With and Without Upper Extremity Pain. *American Journal of Sports Medicine*, *50*(11), 3083-3089.

Downs, J. L., Bordelon, N. M., Friesen, K. B., Shannon, D. M., & Oliver, G. D. (2021). Kinematic differences exist between the fastball, changeup, curveball, and dropball pitch types in collegiate softball pitchers. *American Journal of Sports Medicine*, *49*(4), 1065-1072

Kibler, W. B., Wilkes, T., & Sciascia, A. (2013). Mechanics and pathomechanics in the overhead athlete. *Clinics in Sports Medicine*, *32*(4), 637-651.

Lyman, S., Fleisig, G. S., Andrews, J. R., & Osinski, E. D. (2002). Effect of pitch type, pitch count, and pitching mechanics on risk of elbow and shoulder pain in youth baseball pitchers. *American Journal of Sports Medicine*, *30*(4), 463-468.

Oliver, G. D., Friesen, K., Barfield, J. W., Giordano, K., Anz, A., Dugas, J., & Andrews, J. (2019). Association of upper extremity pain with softball pitching kinematics and kinetics. *Orthopaedic Journal of Sports Medicine*, *7*(8), 2325967119865171.

Oliver, G. D., Downs Talmage, J. L., Friesen, K. B., Saper, M. G., & Dugas, J. R. (2021). Decreased Shoulder and Elbow Joint Loads During the Changeup Compared With the Fastball and Curveball in NCAA Division I Collegiate Softball Pitchers. *Orthopaedic Journal of Sports Medicine*, *9*(9),

Oliver, G. D., Wasserberger, K., de Swart, A., Friesen, K., Downs, J., & Bordelon, N. (2021). Hip Range of Motion and Strength and Energy Flow During Windmill Softball Pitching. *Journal of Athletic Training*, *56*(3), 280–285. https://doi.org/10.4085/1062-6050-145-20

Oliver, G., Bordelon, N., & Dugas, J. (2022). The Association Between Trunk Energy Flow and Peak Shoulder Distraction Force in Collegiate Softball Pitching. *ISBS Proceedings Archive*, *40*(1), 527.

Oliver, G. D., Gilmer, G. G., Anz, A. W., Friesen, K. B., Brittain, A. R., Goodlett, M. D., ... & Andrews, J. R. (2018). Upper extremity pain and pitching mechanics in National Collegiate Athletic Association (NCAA) Division I softball. *International Journal of Sports Medicine*, *39*(12), 929-935.

Petty, D. H., Andrews, J. R., Fleisig, G. S., & Cain, E. L. (2004). Ulnar collateral ligament reconstruction in high school baseball players: clinical results and injury risk factors. *American Journal ofSsports Medicine*, *32*(5), 1158-1164.

Wasserberger, K. W., Giordano, K. A., de Swart, A., Barfield, J. W., & Oliver, G. D. (2021). Energy generation, absorption, and transfer at the shoulder and elbow in youth baseball pitchers. *Sports Biomechanics*, 1-16.