THE RELATIONSHIP BETWEEN PITCH VELOCITY AND SHOULDER DISTRACTION FORCE AND ELBOW VALGUS TORQUE IN COLLEGIATE AND HIGH SCHOOL PITCHERS

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The purpose of this study was to 1) determine the relationship between baseball pitching velocity, shoulder distraction force, and elbow valgus torque, and 2) compare these relationships between college and high school baseball pitchers. Biomechanical pitching reports from collegiate and high school baseball pitchers were analysed with linearity not assumed. A total of 273 pitches were included in this study. Pitching velocity exhibits a positive linear relationship with both shoulder distraction force and elbow valgus torque among high school and college pitchers. However, when only examining pitches thrown above 85 mph, only high school pitches have a positive linear relationship between pitching velocity and elbow valgus torque. Despite assuming non-linearity, pitching velocity exhibited a positive linear relationship with both shoulder distraction force and elbow valgus torque. Lower powered secondary analyses should be interpreted with caution.

KEYWORDS: Baseball, Biomechanics, Pitching, Fastball, Injury, Adolescent Athlete

INTRODUCTION: Injuries among baseball players are highly prevalent, and continue to rise, with shoulder and elbow injuries attributing to the greatest incidence. Increased pitching velocity has been associated with higher risk of ulnar collateral ligament injury in professional pitchers (Chalmers, Erickson, Ball, Romeo, & Verma, 2016) and upper extremity injury in adolescent pitchers (Olsen, Fleisig, Dun, Loftice, & Andrews, 2006), with pitchers throwing at the highest velocities having the greatest risk(Bushnell, Anz, Noonan, Torry, & Hawkins, 2010; Olsen et al., 2006). However, there are conflicting studies demonstrating a lack of association between increased pitching velocity and upper extremity injury in professional pitchers(Keller et al., 2016). These discrepancies between pitching velocity and upper extremity injury risk have been previously attributed to differences in fundamental shoulder and elbow joint loading during pitching (Hurd et al., 2012; Post, Laudner, McLoda, Wong, & Meister, 2015; Slowik et al., 2019). Due to this, clinicians and scientists have sought to establish how pitching velocity relates to shoulder and elbow joint loading.
A strong association between ball velocity and joint kinetics may indicate that pitching at a higher velocity puts more stress on joints. No association between ball velocity and joint kinetics would indicate that other variables besides pitching velocity are contributing more to increases in joint kinetics. Since medial elbow injuries are linked to excessive elbow valgus torque and peak shoulder distraction force may contribute to rotator cuff injuries, understanding the relationship between pitching velocity and upper extremity kinetics can aid in better identification of pitchers at risk for upper extremity injury. Further, these data can provide a foundation for throwing and pitching loading strategies for rehabilitation and return to sport programs following upper extremity injuries. Therefore, the purpose of this study was to 1) determine the relationship between baseball pitching velocity, shoulder distraction force, and elbow valgus torque, and 2) compare these relationships between college and high school baseball pitchers and between pitcher throwing skill level.

METHODS: Data from reports generated as part of a pitching evaluation were retrospectively reviewed. A total of 70 baseball pitchers (College: n = 23; High School: n = 47) participated in a pitching evaluation. Inclusion criteria consisted of baseball players, from all competition levels, whom pitcher is their primary or secondary position.
3D motion data was collected using the 40 retro-reflective marker set required for PitchTrak (Motion Analysis Corporation, Santa Rosa, California), and a sixteen-camera motion analysis

system (Motion Analysis Corporation, Santa Rosa, California). Motion data was collected at 250 Hz. Ball velocity was recorded with a Trackman device (Trackman, Scottsdale, Arizona). Each pitcher went through a normal pregame warm-up period, before pitching to a catcher receiving throws at a regulation distance (18.4 m). Only fastball data was analysed for this study. Data was processed and variables were calculated with Visual3D (C-Motion, Inc. Germantown, Maryland). Variables extracted from the pitching reports included pitching velocity, shoulder distraction force, and elbow valgus torque. Shoulder distraction force and elbow valgus torque were normalized by body weight (N) and body weight times height (Nxm), respectively. Each pitch was considered an individual observation. Linearity was not assumed; as a result, multivariable linear regressions with fractional polynomial regressions were used to investigate the relationship between pitch velocity, shoulder distraction force, and elbow valgus torque. Subgroup analyses were then performed for college and high school pitches, and then for pitches that were thrown above 85 mph. R squared (r^2) utilized to assess model fit.

RESULTS: A total of 273 pitches were included in this study. Of these, there were a total 28 pitchers that threw pitches above 85 mph, for a total of 101 pitches. 81 pitches thrown above 85 mph were thrown by college pitchers (n = 20) and 20 pitches thrown above 85 mph were thrown by high school pitchers (n = 8). College pitchers had greater height (p=0.006), weight (p<0.001), pitch velocity (p<0.001), elbow valgus torque (p<0.001), and shoulder distraction force (p=0.001) compared to high school pitchers.
There was a positive linear relationship between pitch velocity and shoulder distraction force (r^2 = 0.21, p<0.001) and between pitch velocity and elbow valgus torque (r^2 = 0.32, p<0.001) for the entire sample (Figure 1).

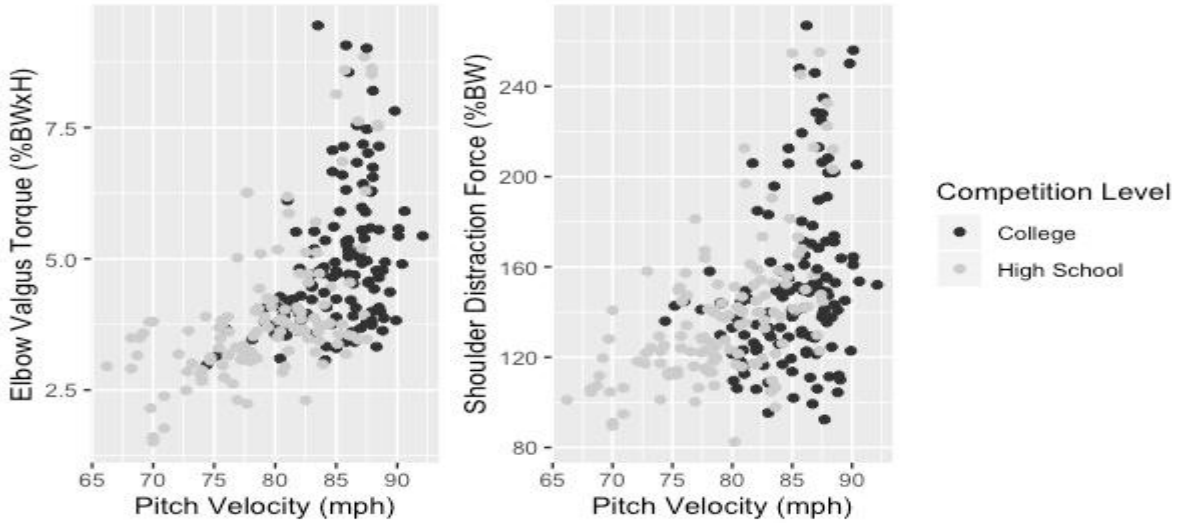

Figure 1: Elbow valgus torque vs pitch velocity and shoulder distraction force vs pitch velocity

When separated by level, college and high school pitches both exhibited a positive linear relationship between pitch velocity and shoulder distraction force (College: r^2 = 0.09, p<0.001; High School: r^2 = 0.32, p<0.001), and between pitch velocity and elbow valgus torque (College: r^2 = 0.16, p<0.001; High School: r^2 = 0.32, p<0.0001).
In pitches that were thrown above 85 mph, there was no relationship between pitch velocity and shoulder distraction force (r^2 = 0.005, p=0.500), nor between pitch velocity and elbow valgus torque. (r^2 = 0.002, p=0.712). Neither college nor high school pitches thrown above 85 mph exhibited a relationship between pitch velocity and shoulder distraction force (College: r^2= 0.004, p=0.606; High School: r^2 = 0.13, p = 0.117). College pitches thrown above 85 mph also did not exhibit a relationship between pitch velocity and elbow valgus torque r^2 = 0.007, p=0.476). However, high school pitches thrown above 85 mph exhibited a positive linear relationship between pitch velocity and elbow valgus torque (r^2 = 0.27, p = 0.020).

DISCUSSION: The main findings of the current study were that significant positive linear relationships were observed between pitching velocity and shoulder distraction force and pitching velocity and elbow valgus torque among both the high school and college pitchers. However, there was no relationship between pitching velocity and shoulder distraction force or elbow valgus torque in pitches thrown above 85 mph. When broken down further into high school and college pitches, college pitches no longer exhibited a relationship between pitching velocity and shoulder distraction force or pitching velocity and elbow valgus torque at high pitch velocities. In contrast, pitching velocity was significantly related to elbow valgus torque in high velocity high school pitches.

Despite the fact that shoulder distraction force and elbow valgus torque were normalized by body weight and body weight times height, respectively, shoulder distraction force and elbow valgus torque were still significantly greater in college pitchers than in high school pitchers. However, when considering the elite high school pitchers (those pitching over 85 mph), compared to college pitchers throwing with similar pitch velocity, the high school pitchers exhibited greater normalized shoulder distraction forces and normalized elbow valgus torques. While These results imply that high school pitchers exhibit decreased pitching efficiency compared to collegiate pitchers.

Pitchers exhibited significant positive linear relationships between pitching velocity and shoulder distraction force and pitching velocity and elbow valgus torque. These results were in contrast to the results of Post et al. (2015) who reported no significant association between pitching velocity and elbow valgus torque in college baseball pitchers. Our results correspond with the results of Hurd et al. (2012) and Slowick et al. (2019) who found increased ball velocity was associated with increased varus moments at the elbow in high school and professional pitchers, and Fleisig et al. (1999) who asserted that ball velocity, elbow varus torque, shoulder internal-rotation torque, and shoulder compressive force increased with increasing level of competition.

Several authors have suggested that increased pitching velocity can result in adverse outcomes and elevated risk of upper extremity injury (Olsen et al., 2006; Petty, Andrews, Fleisig, & Cain, 2004). Based on these findings, the current study design was divided into high pitch velocity (greater than 38 m/s or 85 mph) throws and low pitch velocity (less than or equal to 85 mph) throws to elucidate further trends and relationships. After stratification, high school pitchers who threw the fastest experienced greater elbow and shoulder torques. However, this trend did not hold true among the college pitchers. The majority of the college pitches thrown above 85 mph exhibited shoulder distraction forces less than one standard deviation of the laboratory norm (<153.7%BW), and elbow valgus torque less than one standard deviation of the laboratory norm (<5.4%BWxH) and there were no significant relationships between variables. Conversely, at least half of the high school pitches above 85 mph had shoulder distraction forces and elbow valgus torques more than one standard deviation above the laboratory norms. Elbow valgus torque was significantly related to pitch velocity among the high school pitches above 85 mph. It should be noted that while these findings were statistically significant, model fit was low. These results may be influenced by decreased power due to stratification, or to certainty of only a weak correlation. Nevertheless, these findings may indicate a survival effect among the elite college pitchers compared with the elite high school pitchers. Pitchers who threw at lower velocities may not have advanced to an elite level due to ineffectiveness or an inability to increase velocities without increasing joint forces. By comparison, those who pitched at higher velocities but with increased joint stress also may not have advanced to an elite level due to increased injury risk.

Successful pitchers can optimally coordinate body segments and transfer energy up the kinetic chain. It has been shown that pitchers from higher competition levels produce greater pitching velocity and joint forces; but, also have greater pitching mechanical efficiency and skill. These competition level discrepancies between pitching velocity and biomechanical efficiency may potentially attenuate a linear increase between pitch velocity and upper extremity kinetics. It appears that older pitchers are able to generate forces in the distal extremities and more effectively transfer these forces up the kinetic chain, resulting in reduced shoulder forces and

elbow torques as compared to youth pitchers. The results of this study suggest that these age discrepancies continue to exist, and are more pronounced, among elite or highly skilled pitchers. Elite high school pitchers are experiencing significant loads on the UCL and shoulder, perhaps without the physical maturity necessary to handle such loads. Further research is needed to examine differences in mechanics between high school and college pitchers who are throwing at the same velocity. There were many successful high velocity pitches from college pitchers who were able to limit stress on the elbow and shoulder.

There are limitations to this study. Both college and high school pitchers were found to have higher shoulder distraction forces than what has been previously reported in the literature. As a result, these values were compared to a laboratory normative value rather than literature norms. Similarly, an elbow valgus torque laboratory normative value was used for comparisons. Some secondary sub group analyses reported low r^2 values. This may be due to low power or differences in number of pitches thrown between pitchers; as a result, these subgroup analyses should be interpreted with caution. Differences between forces and torques calculated in this study and previous literature can be attributed to differences in model assumptions and methods of inverse dynamics calculations. There are additional characteristics of pitching that are meaningful contributors to pitching velocity, elbow valgus torque, and shoulder distraction force that were not included. This may include parameters such as arm strength, range of motion, alterations in timing of muscle recruitment, pitching mechanics, and timing of pitching mechanics. Kinetic calculations are based on estimated body-segment masses of cadavers, which may not accurately represent the body-segment masses of the study participants. Additionally, there is an unavoidable amount of skin movement between the reflective markers and the anatomical landmarks they are representing. This effect was minimized by placing markers on bony landmarks.

CONCLUSION: Despite assuming non-linearity, pitching velocity exhibited a positive linear relationship with both shoulder distraction force and elbow valgus torque. Lower powered secondary analyses observed no relationship between pitch velocity and upper extremity forces; however, these secondary results should be interpreted with caution.

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