KINEMATIC AND KINETIC COMPARISON BETWEEN PRE-PROFESSIONAL DOMINICAN REPUBLIC AND AMERICAN BASEBALL PITCHERS

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The purpose of this study was to compare elbow valgus torque and shoulder distraction force in pre-professional American and Dominican Republic (DR) pitchers. Kinematics that are known to influence elbow valgus torque and shoulder distraction force were also compared. Three dimensional biomechanical analyses were performed on Dominican Republic (n = 37) and American (n = 37) baseball pitchers. Potential difference between Dominican Republic and American pitchers were assessed through analysis of covariance with 95% confidence intervals. Age, hand dominance, and pitch velocity are known to influence elbow torque and shoulder force, therefore these confounding variables were controlled for within the analyses. Pre-professional Dominican Republic pitchers were found to throw fastballs with slower ball velocity but experienced increased elbow valgus torque compared to their American counterparts. Increased elbow valgus torque and inefficient pitching mechanics among Dominican Republic pitchers should be considered when developing training programs and pitching plans for professional pitchers from the Dominican Republic.

KEYWORDS: throwing, overhead athlete, biomechanics.

INTRODUCTION: Baseball pitching is a complex series of movements that are synchronized to propel the baseball (Aguinaldo and Escamilla, 2019). Pitching mechanical inefficiency can lead to increased arm strain, increasing arm injury risk (Nicholson et al., 2021). Musculoskeletal injuries in baseball athletes are a persistent and significant problem, with the greatest incidence attributed to injuries of the pitching arm (Garrison et al., 2015). Pitching arm injuries are often contributed to excessive shoulder distraction force and elbow valgus torque (Agresta et al., 2019). Recent literature has shown that pitch velocity and kinematic variables of maximum humeral rotation velocity, shoulder abduction at foot strike, and maximum shoulder external rotation significantly influence both elbow valgus torque and shoulder distraction force in American baseball pitchers (Nicholson et al., 2021). Additionally, maximum humeral rotation velocity, among other kinematic variables, has a significant influence on pitch velocity (Nicholson et al., 2022). When considered together, these variables can help us begin to understand concepts such as pitching efficiency and ideal pitching mechanics. As such, understanding potential inefficiencies in pitching kinematics and kinetics can elucidate shoulder and elbow injury risk.

As many pre-professional DR pitchers and American collegiate Division 1 baseball pitchers are draft prospects for American Major League Baseball (MLB) clubs, there is a need to quantify pitching mechanics at time of entry into professional baseball. Shoulder distraction force and elbow valgus torque are markers of arm stress among all pitchers, but DR pitchers' mechanics and velocity producing strategies may differ from their American counterparts, resulting in differences in throwing arm kinetics. Therefore, the purpose of this study is to compare elbow valgus torque, shoulder distraction force, and kinematics that influence these arm stress variables in pre-professional pitchers from America and the DR. Age, hand dominance, and pitch velocity are known to influence elbow torque and shoulder force, therefore these confounding variables will be controlled for within the analyses. Controlling for confounding variables will give insight into how pitching mechanics influence pitching arm

kinetics. We hypothesize that American and DR pitchers will have similar pitching strategies with no significant differences in kinetics or kinematics.

METHODS: A retrospective review was performed on baseball pitchers from the DR and America who participated in biomechanical evaluations conducted by the University biomechanics laboratory personnel. This study was approved by the University Institutional Review Board.
Three dimensional biomechanical analyses were performed on DR (n = 37) and American (n = 37) baseball pitchers. All DR pitchers were prospects for the upcoming MLB draft. All American pitchers were collegiate level pitchers. Data were examined from reports generated as part of a pitching evaluation. As part of the evaluation, 3D motion data were collected using the 40 retro-reflective marker set required for PitchTrak (Aguinaldo et al., 2007), and a 12-camera motion analysis system (Qualisys AB, Göteborg, Sweden). Motion data were collected at 400 Hz. Each pitcher went through a normal pregame warm-up period, before pitching. Data were processed and variables were calculated with Visual3D (C-Motion, Inc. Germantown, Maryland). Pitching models were defined using the PitchTrak model, and segment coordinate systems were defined according to ISB recommendations (Aguinaldo et al., 2007; Wu et al., 2005). Shoulder distraction force and elbow valgus torque were normalized by body weight (N) and body weight times height (Nxm), respectively. Variables from two or more fastballs were averaged for each pitcher. Maximum hand velocity, defined as the velocity of the pitching hand segment in the laboratory's coordinate system in the direction of home plate, was used as a representation of ball velocity.
Elbow varus torque and shoulder distraction force are influenced by player height, mass, age (Fleisig et al., 1999), hand dominance (Takeuchi et al., 2019), and pitch velocity (Nicholson et al., 2020). The torque and force values are normalized by body weight times height and body weight, respectively, to account for the influence of height and mass. Age, hand dominance, and pitch velocity were confounding variables in kinetic analysis. Pitching arm kinematics and pitch velocity are influenced by age and hand dominance, therefore these were the confounding variables controlled for in kinematic analyses.
Potential difference between DR and American pitchers were assessed through analysis of covariance (ANCOVA) with 95% confidence intervals (95% CI).

RESULTS: 74 pitchers were included in this study (Table 1). ANCOVA results before and after adjusting for confounding variables can be seen in Table 2.

Table 1: Participant Descriptives

Variable	**All Participants (n = 74)**	**United States (n = 37)**	**Dominican Republic (n = 37)**
Age (years)	19.2 (1.7)	20.1 (1.6)	18.2 (1.2)
Height (cm)	186.8 (6.3)	187.2 (7.1)	186.4 (5.6)
Weight (kg)	86.4 (11.2)	93.2 (10.7)	79.5 (6.4)
Hand Dominance (%Left)	28%	35%	22%
Maximum Elbow Valgus Torque (%BWxH)	6.7 (1.3)	5.9 (1.1)	7.5 (1.1)
Maximum Shoulder Distraction Force (%BW)	145.9 (26.2)	155.0 (25.7)	136.8 (23.8)
Shoulder Abduction at Foot Strike (°)	85.9 (10.8)	86.2 (10.6)	85.6 (11.1)
Maximum Shoulder External Rotation (°)	172.2 (12.7)	168.2 (11.9)	176.0 (12.5)
Maximum Humeral Rotation Velocity (°/s)	5,545.9 (485.3)	5,423.3 (502.4)	5,668.5 (440.9)
Maximum Hand Velocity (°/s)	4,538.1 (975.4)	5,109.1 (613.8)	3,967.1 (939.4)

Results are reported as mean (standard deviation) or percentage for count data.
BW = Body Weight; H = Height

Table 2: ANCOVA Results

Variable	Difference with no confounding variables	Difference with confounding variables
Maximum Elbow Valgus Torque (%BWxH)	-1.5 (-2.0,1.0)*	-2.0 (-2.7, -1.2)*
Maximum Shoulder Distraction Force (%BW)	18.2 (6.9, 29.4)*	0.4 (-1.2, 19.7)
Shoulder Abduction at Foot Strike (°)	0.6 (-4.3, 5.6)	-0.7 (-6.9, 5.5)
Maximum Shoulder External Rotation (°)	-7.8 (-13.4, -2.3)*	-4.3 (-10.9, 2.9)
Maximum Humeral Rotation Velocity (°/s)	-245.2 (-460.5, -29.8)*	-230.2 (-498.6, 38.1)
Maximum Hand Velocity (°/s)	1142.1 (780.5, 1503.6)*	1129.5 (677.5, 1581.4)*

Results are reported as the difference between American pitchers and Dominican Republic pitchers (95% Confidence Interval)
*p<0.05; BW = Body Weight; H = Height

American pitchers demonstrated 1.5% BWxH less elbow valgus torque, an increased shoulder distraction force, a decreased maximum shoulder external rotation, a decreased maximum humeral rotation velocity, and an increased maximum hand velocity (pitch velocity) compared to DR pitchers. When controlling for confounding variables, American pitchers demonstrated a further reduction in elbow valgus torque compared to DR pitchers with 2% BWxH less torque, but the difference in shoulder distraction force was diminished. Further, when controlling for age and hand dominance, American pitchers maintained an increased pitch velocity compared to DR pitchers.

DISCUSSION: Pre-professional DR pitchers throw fastballs with slower ball velocity but experience increased elbow valgus torque compared to their American counterparts. Reducing elbow valgus torque and shoulder distraction force may be key to limiting upper extremity injuries in professional pitchers (Bullock et al., n.d.). Pitch velocity has been shown to be a primary contributor to both elbow valgus torque and shoulder distraction force (Nicholson et al., 2021, 2020), supporting the importance of pitch counts at all levels of play. However, pitching mechanics have also been shown to influence elbow valgus torque and shoulder distraction force (Nicholson et al., 2022, 2021), suggesting there are ideal or efficient mechanics that can help reduce pitching arm stress without sacrificing pitch velocity. Pre-professional DR pitchers throw fastballs with slower ball velocity, while experiencing decreased shoulder distraction force, but increased elbow valgus torque compared to their American counterparts. Since ball velocity is the primary contributor to both elbow valgus torque and shoulder distraction force, controlling for ball velocity eliminated the significant difference in shoulder distraction force, but further increased the elbow valgus torque discrepancy between American and DR pre-professional pitchers. Maximum humeral rotation velocity and maximum shoulder external rotation have been shown to influence elbow torque (Nicholson et al., 2021), but also influence ball velocity (Naito et al., 2017). DR pitchers demonstrated increased humeral rotation velocity and maximum shoulder external rotation despite their decreased ball velocity. When controlling for confounding variables, significant differences in maximum shoulder external rotation and maximum humeral rotation velocity were eliminated. This is most likely due to the increased percentage of left handed pitchers in the American cohort. Left handed pitchers have decreased humeral torsion and less passive external rotation, limiting the time they have to generate humeral rotation velocity (Takeuchi et al., 2019). However, left handed pitchers also tend to have decreased pitch velocity, which only furthers the pitch velocity differences between American and DR pre-professional pitchers. These results suggest that Dominican Republic pitchers utilize a less efficient pitching pattern with decreased

ability to generate and transfer energy through the kinetic chain. Additionally, pre-professional American pitchers have improved access to strength and conditioning resources and plans. This is reflected in the increased mass among American pitchers. Increased mass and strength may allow American pitchers to limit elbow torque and transfer energy more successfully.
Future research should explore other pitching kinematic differences between DR and American baseball pitchers. Additional research should also evaluate whether increased elbow valgus torque among pre-professional DR pitchers predisposes professional DR pitchers to elbow injury.

CONCLUSION: Pre-professional DR pitchers demonstrated increased elbow valgus torque and decreased pitch velocity compared to American pitchers. When controlling for confounders, DR pitchers demonstrated a greater divergence in elbow valgus torque compared to United States pitchers. Increased elbow valgus torque and inefficient pitching mechanics among DR pitchers should be considered when developing training programs and pitching plans for professional pitchers from the Dominican Republic.

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