INJURY RISK OF UPPER EXTREMITY IN BASEBALL PITCHERS: KINETICS PERCEPTION

Fajar Awang Irawan[1*], Chuang Long-Ren[2], and Peng Hsien-Te[3]

[1]Faculty of Sport Science, Universitas Negeri Semarang, Indonesia
[2,3]Faculty of Sport Coaching Science, Chinese Culture University, Taiwan (R.O.C)

[*]Email: fajarawang@mail.unnes.ac.id
(Received 23 September 2018; accepted 6 May 2019; published online 27 July 2019)

To cite this article: *Irawan, F. A., Long-Ren, C., & Hsien-Te, P. (2019). Injury risk of upper extremity in baseball pitchers: kinetics perception. Malaysian Journal of Movement, Health & Exercise, 8(2), 123-129. https://doi.org/10.15282/mohe.v8i2.319*
Link to this article: *https://doi.org/10.15282/mohe.v8i2.319*

Abstract

The upper extremity is the most important part at the time in pitching, and every pitcher has a different style. Previous studies have shown that increased pitch counts have been linked to increased complaints of shoulder and elbow pain in youth pitchers. The purpose of this study was to compare kinetic data for the upper extremity on fastball, curveball, and slider potentially injuries. Twenty-four baseball pitchers participated in this study. After signing an informed consent form and placing forty-eight reflective markers on the head, upper extremities and lower extremities, each participant threw the ball fifteen times. Each pitch type was five meters away from the pitching marker from a standing position in an indoor laboratory. Kinetic parameters were calculated using software (Motion Monitor) to compute the musculoskeletal human models using motion capture data. Parameter of torques and forces were calculated using Motion data. Repeated measurement ANOVA was used to test the effects of pitching phases. Only forearm supination torque in the arm acceleration phase was significantly different. There was no significant different in other 18 parameters in four phases base on kinetics parameters data. Ground reaction force of fastball was greater than curveball and slider. Parameters of fastball also dominated arm cocking, arm acceleration, and follow-through. Only on arm acceleration did the curveball's kinetics parameters increase compared to the fastball and slider. Overall, fastball has more injury risk than curveball and slider in pitching phases. Increased kinetic parameters have been shown to have more injury risk. Interpretation data by analysing functional anatomy can be more useful in early detection of pitching injuries.

Keywords: Kinetic, pitching, fastball, curveball, slider

Introduction

Coordination among body segments is important. The pitching motion involves coordination in motion among muscles unit in the body. Pitching is a series of activities, and every pitcher has a different style. Pitchers also have a lot of differences in terms of data collection. Some differences come from the anthropometric data, pitching styles, motion analyses data, and equipment (Irawan, Chuang, & Peng, 2017). Better information about the shoulder, elbow, forearm, and wrist in the pitching is important. Good pitching is basic to understanding how to correct movement, and which pitching technique can give the best result in the performance and predict injury risk earlier. The upper extremity is the important part at the time in pitching, while the lower extremity supports to balance the body and sustains movement when pitching. The shoulder, elbow, wrist, and fingers are the most important parts of the upper extremity to explain differences of personal pitching style (Seroyer et al., 2009).

Previous studies about kinetics and kinematics are well documented. Fleisig, Bolt, Fortenbaugh, Wilk, & Andrews, (2011) conducted the first biomechanical study about forearm and wrist action in release between fastball and curveball. The kinetic differences observed suggested greater injury risk at the higher competition levels especially in the professional level (Fleisig, 2010). Fleisig et al., (2006) studied elbow and shoulder kinetics for 26 highly skilled, healthy adult pitchers. They found in a kinetic study that the internal rotation in combination with force could produce a grinding injury factor on the labrum. Another study by Aguinaldo, Buttermore, & Chambers, 2007 also found that high rotational torques during baseball pitching were believed to be link to most overuse injuries at the shoulder. Proper biomechanics for adult pitchers was used to minimize the risk of injury and maximize performance. Irawan & Chuang, (2015) stated that the most frequent injuries reported and identified in the upper extremities were shoulder and elbow injuries. Fleisig, Bolt, Fortenbaugh, Wilk, & Andrews, (2011) found that the greater shoulder and elbow activity produced greater angles during arm cocking and arm acceleration phases. Since adult pitchers did not demonstrate different position or temporal pattern, increase in joint forces and torques were most likely due to increase strength and muscle mass in the higher level. Fleisig et al., (2006) also stated that the curveball, slider, and change-up were more dangerous than the fastball. That result found kinetics data were different between fastball and curveball especially in shoulder and elbow data, but the slider was inconclusive because of a small sample size. In the current study, these findings can be revealed in depth to complement Fleisig’s previous studies.

Another previous study showed that increased pitch counts have been linked to increased complaints of shoulder and elbow pain in youth pitchers. The result of Davis et al., (2009) found that 169 youth pitchers with better pitching mechanics could help to prevent shoulder and elbow injury in youth pitchers. Grantham, Iyengar, Byram, & Ahmad, (2015) also stated that overuse and poor throwing mechanics were contributor in pitcher injuries. The purpose of this study was to compare kinetics data of upper extremity on potential fastball, curveball, and slider injuries.

Methods

Twenty-four baseball pitchers (18 - 24 years old) participated in this study. All participants were familiar with pitching the fastball, curveball, and slider. All participants had no injuries and were in a healthy condition at the time of testing. Every participant signed an informed consent and was placed forty-eight markers on head, upper extremities and lower extremities. Pitching test was held in indoor laboratory with target five meters away from the pitching marker on standing position. Participants were then asked to throw fifteen pitches of fastball, curveball, and slider randomly from the pitcher's plate marker. Eleven cameras (Eagle system, Motion Analysis Corporation, Santa Rosa, CA) with a sampling rate of 200Hz and 1000Hz shutter speed were used. After tracking the data, each of the XYZ time series for the markers position data was filtered using a fourth-order Butterworth low-pass filter with a cut-off frequency of 13.4 Hz (Fleisig et al., 2011).

Kinetic parameters were calculated using software (Motion Monitor) to compute the musculoskeletal human models using motion capture data (Nakamura, Yamane, Fujita, & Suzuki, 2005), while the parameters of torques and forces were calculated using Motion data (Fleisig et al., 2006)(Fleisig, 1994). Five pitches were tested for each of three pitching types. The orders of each pitch were randomized for each participant. There was a rest interval of approximately fifteen seconds between pitch tests. A radar gun was used to recording ball velocity (Stalker Radar, Plano, Texas, USA). Descriptive data were presented as means ± standard deviation. Repeated measurement ANOVA was used to test the effects of pitching phases among the fastball, curveball, and slider. The significance level was set at $p < .05$. All data were analysed using SPSS Statistics 22 software (IBM Corporation, Chicago, IL).

Results

This study results showed one of nineteen parameters was significant difference among pitch types (Table 1). Only in terms of the forearm supination torque during the arm acceleration phase was there a significant difference. There was no significant difference in the other 18 parameters in four phases based on kinetics parameters data.

Table 1: *Kinetics data among pitchers*

Parameters	Fastball	Curveball	Slider	F Value	Compared test
Arm cocking phase					
Elbow varus torque (Nm)	23.7 ± 10.0	24.0 ± 9.8	21.6 ± 8.7	.074	-
Shoulder external rotation torque (Nm)	35.5 ± 25.7	33.3 ± 30.5	32.5 ± 31.6	.561	-
Elbow flexion torque (Nm)	7.2 ± 10.2	6.6 ± 12.6	7.1 ± 10.8	.637	-
Wrist flexion torque (Nm)	3.5 ± 3.2	1.7 ± 2.3	1.6 ± 2.8	.184	-
Arm acceleration phase					
Shoulder external rotation torque (Nm)	86.5 ± 15.2	88 ± 13.1	85.4 ± 12.1	.274	-
Wrist flexion torque (Nm)	7.6 ± 6.0	7.5 ± 4.5	7.6 ± 5.1	.987	-
Forearm supination torque (Nm)	8.0 ± 5.6	10.3 ± 6.5	9.1 ± 5.5	.001*	F<C, F<S, S<C
Elbow flexion torque (Nm)	14.9 ± 8.4	15.1 ± 9.1	13.9 ± 7.2	.590	-

Elbow proximal force (N)	311.7 ± 129.9	305.7 ± 134.2	321.6 ± 122.9	.722	-
Shoulder horizontal adduction torque (Nm)	41.5 ± 44.9	41.3 ± 41.1	40.7 ± 47.1	.956	-
Shoulder proximal force (N)	644.2 ± 214.9	690.3 ± 255.4	685.4 ± 227.9	.170	-
Arm deceleration phase					
Shoulder external rotation torque (Nm)	21.3 ± 9.8	20.7 ± 7.4	20.2 ± 7.5	.763	-
Elbow flexion torque (Nm)	7 ± 6.3	6 ± 6.1	5 ± 6.1	.725	-
Wrist flexion torque (Nm)	5.8 ± 4.1	2.5 ± 3.8	3.1 ± 3.2	.165	-
Shoulder adduction torque (Nm)	44.5 ± 26.0	49.8 ± 24.1	46.4 ± 23.3	.277	-
Follow-through					
Shoulder external rotation torque (Nm)	6.5 ± 5.4	4.3 ± 3.7	5.2 ± 5.1	.174	-
Elbow extension torque (Nm)	4 ± 4.3	3 ± 3.8	3 ± 3.5	.561	-
Wrist flexion torque (Nm)	1.8 ± 1.3	1.1 ± 2.1	1.3 ± 1.2	.875	-
Ground Reaction Force (N)	1062 ± 194.92	1047.33±239.76	1057.17±206.04	.017*	F<C, F<S, S<C

Data are means ± SDs.
F= Fastball, C= Curveball, S= Slider, n= total subject.
*Significant difference at $p < .05$

Discussion

The first inspection of the kinetic data suggested that the slider might have the lowest potential of injury risk to the shoulder and elbow compared to the fastball and curveball (table 1). The current study’s results for the fastball and curveball had similar data result with a previous study by Fleisig et al., (2006) which found that those pitch types had similar injury risk potential due to similar joint load. The ground reaction force in this study for the fastball was greater than that of the curveball and slider. This study had been supported by Stodden, Fleisig, McLean, & Andrews, (2005) that Ground Reaction Force pushed the power back to the main body of the pitcher and gave feed-back to increase power of the leg in pitching. Even though, the current study had no significant difference, the force for the fastball was still greater than other pitch types.

Kinetic data in the elbow varus torque in the arm cocking phase at fastball was 23.7 ± 10.0 Nm, curveball was 24.0 ± 9.8 Nm, and slider was 21.6 ± 8.7 Nm. Fleisig et al., (2006) found similar results as the fastball (82 ± 13) was greater than curveball and slider (79 ± 14 and ± 81 5). The shoulder external rotation torque for the fastball was 35.5 ± 25.7 Nm; the curveball was 33.3 ± 30.5 Nm; and the slider was 32.5 ± 31.6 Nm. Elbow flexion torque for the fastball was 7.2 ± 10.2 Nm, curveball was 6.6 ± 12.6 Nm, and slider was 7.1 ± 10.8 Nm. Wrist flexion torque showed in a small value at fastball 3.5 ± 3.2 Nm, curveball 1.7 ± 2.3 Nm, and slider 1.6 ± 2.8 Nm. There were no significant differences data in the arm cocking phase.

The acceleration phase is a transformation which continues the motion before the deceleration phase has been reached. Shoulder external rotation torque had similar data among pitches. Fastball showed 86.5 ± 15.2 Nm, the curveball 88 ± 13.1 Nm, and the slider 85.4 ± 12.1 Nm. The result of wrist flexion torque in arm acceleration phase at fastball was 7.6 ± 6.0 Nm, curveball was 7.5 ± 4.5 Nm, and slider was 7.6 ± 5.1 Nm. Compared to other parameters in the slider and curve, the forearm supination torque showed significant differences, as the fastball was 8.0 ± 5.6 Nm, curveball was 10.3 ± 6.5

Nm, and slider was 9.1 ± 5.5 Nm. Previous study showed that fastball was 5 ± 4, curveball 5 ± 3, and slider 3 ± 1, and there were no significant differences in each pitch type (Fleisig et al., 2006). Fleisig et al., (2006) also stated that there was indication of elbow and shoulder injuries related to forearm activities. Elbow flexion torque for the fastball was 14.9 ± 8.4 Nm, while the curveball was 15.1 ± 9.1 Nm, and the slider was 13.9 ± 7.2 Nm. The elbow proximal force for the fastball was 311.7 ± 129.9 N, while the curveball was 305.7 ± 134.2 N, and the slider was 321.6 ± 122.9 N. Shoulder proximal force for the fastball was 644.2 ± 214.9 N, curveball was 690.3 ± 255.4 N, and slider was 685.4 ± 227.9 N. Shoulder horizontal adduction torque results for the fastball was 41.5 ± 44.9 Nm, while the curveball was 41.3 ± 41.1 Nm, and the slider was 40.7 ± 47.1 Nm.

Data for the arm deceleration phase showed no significant differences foreach parameter. Shoulder external rotation torque for the fastball was 21.3 ± 9.8 Nm, curveball was 20.7 ± 7.4 Nm, and slider was 20.2 ± 7.5 Nm. Elbow flexion torque among pitches were 7 ± 6.3 Nm at fastball, 6 ± 6.1 Nm at curveball, and 5 ± 6.1 Nm at slider. Wrist flexion torque in arm deceleration at fastball was 5.8 ± 4.1 Nm, 2.5 ± 3.8 Nm at curveball, and 3.1 ± 3.2 Nm at slider. Shoulder adduction torque for the curveball was higher (49.8 ± 24.1 Nm) than fastball and slider (44.5 ± 26.0 Nm and 46.4 ± 23.3 Nm). Difference result might have been caused by different types of equipment and the procedures.

Follow-through in this pitching phase was the end of all pattern. This study result showed shoulder external rotation torque for the fastball was 6.5 ± 5.4 Nm, while the curveball was 4.3 ± 3.7 Nm, and the slider was 5.2 ± 5.1 Nm. Elbow extension torque was 4 ± 4.3 Nm at fastball, 3 ± 3.8 Nm at curveball, and 3 ± 3.5 Nm at slider. Wrist flexion torque for the fastball was 1.8 ± 1.3 Nm, curveball and slider were 1.1 ± 2.1 Nm and 1.3 ± 1.2 Nm. All kinetics parameter data in follow-through had no significant difference. However, no specific comparison could be made with the current study.

Several limitations of this study, such as short distance to pitch in an indoor laboratory and flat ground, might have affected the results. Any differences in terms of equipment, design, and procedures may also have caused different results. Kinetic data results in this study had been used to support previous research about kinematic comparison of upper extremity among fastball, curveball, and slider (Irawan et al., 2017). Kinetic and kinematic data are vital in determining the correct movement and detect any potential injuries in pitching motion. Previous data in the wrist was so minimum, comparison between the latest research and current study might not be found to solve the issues especially in the wrist analysis because of limitation data.

Relation between each segment would elevate intermuscular contraction. Greater shoulder external rotation and elbow extension torque can be factors in increased pain and injury. Increase in the number of pitch counts have been linked to increased complaints of shoulder and elbow pain in pitchers. Pitchers with better pitching mechanics can help to prevent shoulder and elbow injuries in young pitchers (Davis et al., 2009). Matsuo, Fleisig, Zheng, & Andrews, (2006) mentioned that increased potential for elbow problems with a curveball pitch might be related to the position of the forearm at peak loads. This supports the current study which found that the curveball had higher torque in forearm supination compared to the fastball and slider. Ebben, Fotsch, & Hartz, (2006) found during curveball pitch, rapid ulnar deviation occurred simultaneously with wrist flexion and the forearm activity was in a more supinated position. The greater amount of supination during pitching might influence the ability of the elbow to accommodate a repetitive load.

A common problem in unsuccessful pitching technique is having different pitcher's mechanic among pitch types. Preparation in a good pitching when facing batter can minimize prediction of batter to detect pitch type of pitcher. Pitcher have to know the capabilities he has. Pitcher should immediately improve his performance in a short time. The basis for improving appearance in pitching performance is correct movements, especially in the upper extremity. If a pitcher can take control of basic motion, the pitcher can elevate his or her skills to the next level. Future research is needed to quantify both kinetics and kinematics of various pitch types in youth, high school, and professional baseball pitchers. The current study's results and implications may be specific to collegiate pitchers.

Conclusion

The conclusion of this study indicate that the ground reaction force for the fastball was greater than that of the curveball and slider. The parameters of the fastball also take into consideration the domination of arm cocking, arm acceleration, and follow-through. Only on arm acceleration did the curveball's kinetics parameters increase compared to the fastball and slider. Overall, the fastball had more injury risk than curveball and slider in the pitching phases.

Increased kinetics parameters may lead to increased injury risk. Interpreting data by analysing functional anatomy can be more useful in the early detection of pitching injuries.

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