BIOMECHANICAL DIFFERENCES BETWEEN ONE-HANDED AND TWO-HANDED FOLLOW THROUGH TECHNIQUES AMONG PROFESSIONAL BASEBALL HITTERS

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The purpose of this study was to compare the lead shoulder joint dynamics between one-handed and two-handed follow through batting techniques. Seventeen professional baseball players underwent motion analysis while hitting a ball off a tee using one- and two-handed follow through techniques. Linear mixed regression models were used to compare the kinematic and kinetic variables between the two techniques. Shoulder horizontal abduction, elbow flexion, and lateral trunk tilt differed between the follow through types. The shoulder kinetics increased greatly during a one-handed follow through compared to a two-handed follow through, with the horizontal adduction torque increasing 23.3 Nm and the proximal force increasing 117.2 N. A one-handed follow through increases the demands on the shoulder compared to a two-handed follow through.

KEYWORDS: baseball, batting, shoulder instability, kinematics, kinetics, follow through.

INTRODUCTION: The anatomy of the glenohumeral joint allows it to be the most mobile joint in the body, and inherently the most unstable (Hess, 2000). Uncontrolled translation of the humeral head on the glenoid is defined as glenohumeral (shoulder) instability. While throwing causes most injuries in the upper extremity, the high velocities produced during the baseball swing combined with repetition can cause injury (Fleisig, Dun, & Kingsley, 2009; Monti, 2015). It is common for baseball players to release the top (lag) hand from the bat right after ball contact. This can forcefully propel the lead shoulder into extreme abduction and external rotation, increasing forces on the anterior shoulder (Lintner, Noonan, & Kibler, 2008). With forced abduction and exterior rotation of the shoulder, the anterior labrum is place under stress and may fail, resulting in subluxation. While biomechanical studies have been performed on professional players hitting a baseball (Welch, Banks, Cook, & Draovitch, 1995), age level comparison of hitting kinematics (Escamilla et al., 2009a), and effects of a choke-up grip on hitting kinematics (Escamilla et al., 2009b), swing techniques that may put batters at risk for injury have not been studied.

Research involving shoulder joint dynamics (kinematics and kinetics) while batting is severely under-represented in the literature. Due to the limited knowledge on forces and torques during batting, interventions to prevent and/or treat labral injuries remain only partially effective. The purpose of the current study was to compare the lead shoulder joint dynamics between one-handed and two-handed follow through batting techniques in professional baseball players. It was hypothesized that a one-handed follow through swing generates higher forces and torques in the lead shoulder than a two-handed technique.

METHODS: Seventeen (7 right-handed, 10 left-handed) healthy professional male baseball players (22.6 ± 2.5 years, 183.9 ± 6.1 cm, 89.9 ± 11.5 kg) were tested at an outdoor training facility. Players were included if they had no record of a moderate to severe injury within the past 12 months (requiring more than 2 weeks of rest/rehabilitation). Bats were self-selected by the players (weight: 0.90 ± 0.02 kg, length: 86.0 ± 1.5 cm). Three markers were placed on the bat: at the end of the knob, above the handle, and at the tip of the end cap. Each subject was allowed as much time as needed to perform a warm-up routine of choice. The subject was then instrumented with 42 reflective markers (14.5 mm diameter) following the model described by Badura (Badura, Raasch, Barber, & Harris, 2003). Markers were affixed to key bony anatomical landmarks using hypoallergenic skin adhesive and double sided tape and secured with an adhesive overlay. The subjects were then allowed to warm up again if

necessary, with testing starting when the subject indicated readiness. This study was approved by the Medical College of Wisconsin Institutional Review Board.
An 8-camera Raptor-E system (Motion Analysis Corporation (MAC); Santa Rosa, CA, USA) was used to capture data at 270 frames per second. Prior to testing, subjects reported their preferred method of follow through style (one-handed or two-handed). The subject was randomly selected to either swing with their preferred swing style or non-preferred style first. A baseball was placed on a tee that was adjusted to the height of the players hips, with the tee placed in the middle of the capture volume. Batters were instructed to hit "up the middle". After the subject successfully hit five balls with either their preferred or non-preferred batting style, they switched batting styles and took five more swings.
Kinematic and kinetic solutions were computed using Kintools RT and Skeleton Builder modelling software (MAC, Santa Rosa, CA, USA). Joint kinematics were calculated as Euler angles, using the coordinate system of the distal segment relative to the proximal segment. Joint kinetics were derived using inverse dynamics of five segments (bat, hand, forearm, upper arm, and trunk) of the lead arm and bat. The mass and inertial properties of the body segments were calculated from anthropometric tables based on cadaver measurements as described by De Leva (de Leva, 1996). The bat-hand segment interaction was defined at the centre of the lead hand, parallel to the axis going across the hand segment. The kinetic solution of the one-handed follow through swing was solved after ball contact, when the lag hand was released from the bat and the lead shoulder supported the entire weight of the arm and bat. For two-handed swings, the kinetics solution was computed after ball contact, with a bat of half the actual mass to simulate both arms bearing the support of the bat.
The maximum values of the four kinematic parameters (shoulder horizontal abduction (HABD), shoulder abduction (ABD), elbow flexion (Flex), trunk lateral tilt (LatTilt)) and five kinetic parameters (maximum shoulder horizontal adduction torque (HADT), internal rotation torque (IRT), adduction torque (ADT), anterior force (AntF), and proximal force (ProxF)) were analysed after ball contact, during the follow through phase. Maximum bat angular velocity was also compared between the two follow through conditions. Linear mixed regression models controlling for subject random effect and follow through type preference were performed to compare the kinetic and kinematic parameters between one- and two-handed follow through techniques. To decrease the number of false discovery findings statistical significance was declared at $p < 0.01$. R software (www.r-project.org) was used for all statistical analyses.

RESULTS: Of the seventeen batters, five preferred a two-handed follow through and twelve preferred a one-handed follow through. Although follow through type preference was controlled for in all parameters, it was not statistically significant. The maximum bat angular velocity was not significantly different between the conditions (2312 ± 268 °/s and 2309 ± 354 °/s for two- and one-handed, respectively). Five of the parameters evaluated were found to have statistically significant differences between one- and two-handed follow through techniques. The percent variance attributed to the random subject effect ranged from 4.7% to 42.1%, which justified the need to control for potential dependence within person. The kinematic parameters are displayed in Table 1. Of the three kinematic parameters that were statistically significant, the lead shoulder horizontal abduction varied 67.9°, lead elbow flexion varied 69.3°, and trunk lateral tilt varied 8.3° between a one- and two-handed follow through.

TABLE 1: Comparison of Kinematics for Two-Handed and One-Handed Follow Throughs

	Two-Handed FT			One-Handed FT			
Parameter	Avg	±	SD	Avg	±	SD	*P* Value
Lead Shoulder HABD (°)	-51.3	±	21.9	16.6	±	14.4	**0.000***
Lead Shoulder ABD (°)	65.6	±	17.9	67.3	±	19.2	0.944
Lead Elbow Flex (°)	103.4	±	18.5	34.1	±	37.8	**0.000***
Trunk LatTilt (°)	-7.2	±	16.0	1.1	±	14.4	**0.000***

* Statistically significant between follow through types (P < 0.01)

The maximum lead shoulder kinetic parameters are displayed in Table 2. The lead shoulder horizontal adduction torque and proximal force were statistically significant between the follow through types. The horizontal adduction torque increased 23.3 Nm, while the proximal force increased 117.2 N, from a two-handed to a one-handed follow through.

TABLE 2: Comparison of Kinetics for Two-Handed and One-Handed Follow Throughs

Parameter	Two-Handed FT Avg	±	SD	One-Handed FT Avg	±	SD	*P* Value
Max HADT (Nm)	28.2	±	9.6	51.5	±	26.3	**0.007***
Max IRT (Nm)	22.3	±	8.1	29.2	±	11.8	0.149
Max ADT (Nm)	-6.0	±	8.2	-12.5	±	19.2	0.496
Max AntF (N)	90.0	±	28.7	101.3	±	32.0	0.226
Max ProxF (N)	34.9	±	24.7	152.1	±	63.8	**0.000***

* Statistically significant between follow through types (P < 0.01)

DISCUSSION: Hitters generate bat speed by passing momentum up the kinetic chain from their hips, trunk, shoulders, and finally the bat. With high rotational velocities, combined with the weight of the bat and the repetitive exposure of swings, the batter's lead shoulder is at risk for injury (Fleisig et al., 2009; Monti, 2015). The limited research on baseball hitting, especially during the follow through phase, provides incomplete knowledge of the forces and torques that occur during batting. Due to the inherent instability of the shoulder joint and the range of motion that occurs at the shoulder while batting, certain swing techniques may put batters at risk for injury. This was the first study to quantify the shoulder joint dynamics during two common follow through swing techniques, which have not been previously characterized. Defining the joint dynamics associated with different swing types allows for injury potential to be determined with far greater precision than is currently available. Five variables were found to be statistically different between one-handed and two-handed follow through techniques.

The hypothesis that a one-handed follow through swing technique generates higher forces and torques in the lead shoulder than a two-handed follow through was found to be partially true. By releasing the top lag hand off the bat, the lead arm is free to extend at the elbow and stay more horizontally adducted. This was reflected in the results (Table 2) with the shoulder horizontal abduction and elbow flexion being significantly different, along with less trunk lateral tilt involved in the one-handed technique. A two-handed follow through had the shoulder positioned in horizontal adduction with the elbow flexed greater than 90°. In a one-handed follow through, the position transitioned to shoulder horizontal abduction with the elbow flexed much less than 90°. These kinematic differences lead to differences in the kinetics as well. The maximum lead shoulder horizontal adduction torque increased from 28.2 ± 9.6 Nm in a two-handed follow through to 51.5 ± 26.3 Nm during a one-handed follow through (Table 3). This significantly increases the amount of torque occurring at the anterior aspect of the shoulder joint. The maximum lead shoulder proximal force also significantly increased from a two-handed (34.9 ± 24.7 N) to one-handed (152.1 ± 63.8 N) follow through. The labrum is primarily responsible for resisting this large increase in distractive force applied to the lead shoulder, which may leave it susceptible for injury during a one-handed follow through.

There were some limitations to this study. The assumption of independent motion of each arm in the two-handed kinetic model may have increased the lead shoulder forces more than a closed-loop constraint may have. The assumption of half the bat mass in each hand is another limitation. Although shoulder external rotation is increased during a one-handed follow through, it was not calculated in this study. With the players hitting the ball off a tee, it eliminated the need to adjust for pitch location. While this provided a safe capture volume for data collection, live batting may be a better indicator of the forces occurring at the shoulder during outside pitches, or when the player misses the ball. The sample size was also small, limiting the power of the study. The current study focused primarily on the shoulder biomechanics during the follow through of two swing types. Additional insight into batting injuries may be explored during other phases of the swing.

CONCLUSION: The results of the study suggest that a one-handed follow through significantly increases the lead shoulder horizontal adduction torque and proximal force compared to a two-handed follow through. With the goal being to compare two follow through swing types, hitting off a tee eliminated other factors (pitch location, missed pitch) that may affect the biomechanics differently than the follow through style used. These results will impact baseball coaches and players alike by providing new information on potentially unsafe swing techniques and characteristics. Further research to identify shoulder joint dynamics during live pitching, involving missed and outside pitches, is needed.

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