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RELATIONSHIP BETWEEN GROUND REACTION FORCES, PELVIC CONTROL, & UPPER EXTREMITY KINETICS DURING THROWING: PRE & POST FATIGUE

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SUMMARY

Dynamic human movement of the overhead throw requires sequential activation of the kinetic chain. The body is considered a kinetic chain, a series of interdependent segments that work in unison for dynamic movement. In the overhead throw, the kinetic chain functions in a proximal to distal sequence. Thus utilizing the lower extremity as the most proximal aspect of the chain to supply energy to the upper extremity or more distal end of the chain. Thus it was the purpose of this paper to determine the relationship between the lower extremity and the upper extremity in the overhead throw of softball positional players.

INTRODUCTION

Previously, movement patterns of the kinetic chain during the windmill softball pitch have been described sequentially from proximal to distal [2]. In attempt to generate energy from the proximal segments (lower extremity) to the more distal segments (upper extremity) there must be coordinated and sequential movement that encompasses not only the lower extremity but also the lumbopelvic hip complex (LPHC), scapula, and upper extremity. The gluteal muscle group plays a significant role within the LPHC, in the ability to provide the foundation to the pelvis. The gluteal muscle group acts to stabilize the pelvis over a planted leg in attempt to allow for efficient energy transfer up the kinetic chain. Therefore, the purpose of this paper was to examine the relationship between ground reaction forces, pelvic control, and upper extremity kinetics during throwing pre and post fatigue.

METHODS

Eighteen Division I National Collegiate Athletic Association softball players (19.2 $\pm$ 1.0 yrs; 68.9 $\pm$ 8.7 kg; 168.6 $\pm$ 6.6 cm) who were listed on the active playing roster volunteered. The Institutional Review Board approved all testing protocols.

Adhesive 3M Red-Dot (3M, St. Paul, MN) bipolar (Al/AgCl) disk surface electrodes (six centimeter in diameter) were attached bilaterally over the muscle belly of the gluteus medius. Electromyographic data were collected via a Noraxon Myopac 1400L 8-channel amplifier (Noraxon USA, INC, Scottsdale, AZ). The signal was full wave rectified and root mean squared at 100 ms. Surface EMG data were sampled at a rate of 1000 Hz. The surface EMG data were notch filtered at frequencies of 59.5 and 60.5 Hz [3]. Three MMT, lasting 5 seconds, were performed for each muscle and the first and last second of each contraction was removed [3]. The MMT provided baseline data in which all surface EMG data could be compared.

Ten electromagnetic sensors (Flock of Birds Ascension Technologies Inc., Burlington, VT) were attached at the following locations: (1) the medial aspect of the torso at C7; (2) medial aspect of the pelvis at S1; (3-4) bilateral distal/posterior aspect of the upper arm; (5-6) bilateral distal/posterior aspect of the forearm; (7-8) bilateral distal/posterior aspect of lower leg; and (9-10) bilateral distal/posterior aspect upper leg; [1, 3]. Following sensor placement, an 11th sensor was attached to a wooden stylus and used to digitize the palpated positions of the body landmarks [1, 3, 4]. The coordinate systems used were in accordance with the International Shoulder Group of the International Society of Biomechanics Recommendations [4]. Data describing the position and orientation of electromagnetic sensors were collected at 100 Hz. Raw data were independently filtered along each global axis using a 4th order Butterworth filter with a cutoff frequency of 13.4 Hz [3]. Two points described the longitudinal axis of each segment and the third point defined the plane of the segment. A second axis was defined perpendicular to the plane and the third axis was defined as perpendicular to the first and second axes. Neutral stance was the y-axis in the vertical direction, horizontal and to the right of y was the x-axis, and posterior was the z-axis [3]. Euler angle decompositions were used to determine humeral orientations.

Participants were allotted an unlimited time to perform their own specified pre-competition warm-up routine. Participants had to catch a simulated hit or pitched ball and perform their positional throw to a designated positional player standing on base to prevent a runner from advancing to that base. Infielders caught a simulated line drive and threw to a positional player at second base. Outfielders caught a simulated fly ball; crow hoped and threw to a positional player at second base, while catchers caught a simulated pitched ball and threw down to second base where a positional player received the ball. All three positional players (infielder, outfielder, and catcher) threw the same average distance of 25.6 m. Participants performed 3 positional throws and then threw a 2 kg ball into a rebounder until they reached maximum perceived fatigue based on a 0-3 scale (3 = max fatigue). Following fatigue, 3 more positional throws were performed. The throwing surface was constructed so that the participant's stride foot would land on top of the 40 x 60 cm Bertec force plate

(Bertec Corp, Columbus, Ohio) that was anchored into the floor. A JUGS radar gun (OpticsPlanet, Inc., Northbrook, IL) positioned in the direction of the throw determined ball speed.

Data were analyzed using statistical package of IBM SPSS version 21 (SPSS, Chicago IL). Pearson product moment correlation coefficients were calculated to identify possible relationships pre and post fatigue between ground reaction forces, gluteal muscle activation, and upper extremity kinetics during two phases of the throwing motion: foot contact (FC) to maximum shoulder external rotation (MER), and MER to maximum shoulder internal rotation (MIR).

RESULTS AND DISCUSSION

Means of ground reaction forces, bilateral gluteus medius activation and upper extremity kinetics are presented (Table 1). Pearson correlation revealed significant relationships both pre and post fatigue from FC to MER. Prior to fatigue there was a significant negative relationship of the throwing side gluteus medius and shoulder anterior/posterior force ($r = -0.69$), and a positive relationship between ground reaction forces and elbow distraction forces ($r = 0.615$). Post fatigue there was a positive relationship between non-throwing gluteus medius and shoulder anterior/posterior force ($r = 0.851$). There were no significant relationships between ground reaction forces, gluteal muscle activation and upper extremity kinetics during the phase of throwing from MER to MIR either pre or post fatigue.

To position for the phase from FC-MER, the body is temporarily in a position of single leg support in attempt to propel the body forward. From FC to MER bilateral gluteus medius displayed over 60% MVIC indicating activation while maintaining pelvic support. From MER to MIR, bilateral gluteal musculature exhibited more than 100% MVIC in providing pelvic support as well as transfer energy up the kinetic chain from the proximal lower extremity to the more distal upper extremity and on to ball release.

Greater throwing side gluteus medius activation revealed decreased anterior/posterior shoulder forces exhibited from FC - MER. When transferring weight from throwing side to glove side, the throwing side gluteus medius has to exhibit greater activation in attempt to stabilize the pelvis and LPHC. This efficient activation was exhibited pre fatigue. However post fatigue the opposite tend occurred. The glove side gluteus medius displayed a positive relationship with anterior/posterior shoulder force. Hence, as the throwing side gluteus medius was not able to stabilize the pelvis on single leg support, the non-throwing side gluteus medius exhibited greater activation and thus resulted in greater shoulder forces.

CONCLUSIONS

The results supported the hypothesis that there was a relationship between the lower extremity and the kinetics of the upper extremity in softball players performing their positional throws pre and post fatigue. If the gluteal musculature is unable to maintain pelvic stability then the energy transfer is interrupted and the shoulder and elbow have to generate energy versus transfer it. Previously, it has been reported that the pelvis positions the torso in overhand throwing motions [3]. The current study accounted for the relationship between the lower extremity and the upper extremity during overhead throwing. It indicated that there could be additional kinetic chain segments such as the pelvis and/or shoulder that preclude the elbow relationship with the gluteal muscle group.

REFERENCES

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Table 1: Means and standard deviations for the two throwing phases, pre and post fatigue.

	FC to MER		MER to MIR	
	Pre Fatigue	**Post Fatigue**	**Pre Fatigue**	**Post Fatigue**
Ground Reaction Force	803.3±152.6 N	723.2±174.9 N	720.7±171.2 N	714.4±218.1 N
Shoulder Anterior Force	19.4±32.1 N	65.3±38.2 N	201.6±92.0 N	58.3±76.7 N
Elbow Valgus Force	46.9±25.5 N	50.3±28.0 N	112.9±105.4 N	115.7±92.6 N
Elbow Distraction Force	32.1±47.8 N	25.9±33.1 N	107.2±146.5 N	77.1±159.1 N
^R Glut Medius Activity	75.7±41.5	113±72.5	120.1±51.1	139±82.8
^L Glut Medius Activity	82.6±96.3	63.4±59.4	87.9±81.7	75.2±70.1

^Expressed as % of maximum voluntary isometric contraction.