QUANTIFYING sEMG IN PRE-FATIGUE AND FATIGUE STATES DURING THE FASTBALL BASEBALL PITCH

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Injuries to baseball pitchers typically occur as a result of constant repetitive overuse. In attempt to eventually prevent overhead throwing overuse injuries, it is important that the biomechanics and muscle activations are understood. Therefore, the purpose of this study was to describe upper and lower extremity muscle activations involved in the pitching motion while in a pre-fatigue and fatigued state. Fourteen male pitchers volunteered to participate in the study. Participants were analyzed with surface electromyography and motion analysis software. The muscle firing patterns were described during the phases of the baseball pitch while in a pre-fatigued and fatigued state.

KEYWORDS: electromyography, overhand pitching, muscle activation

INTRODUCTION: In attempt to understand baseball pitching, it is important to understand the muscle activations that allow for proper pitching mechanics. Thus the understanding of primary muscle activations involved in the pitching motion is imperative to any type of injury prevention. The repetitive nature of the baseball pitch creates great challenges for sports medicine clinicians in an attempt to reduce the incidence of injury and in particular reduce the rate of overuse injuries (Fleisig et al., 1995; Lyman et al., 2002; Fortenbaugh et al., 2009). It is not only important to understand muscle activations during the pitching motion, but it would be beneficial to understand the muscle activations during a fatigued state. It has been discussed that fatigue to the scapular stabilizers, as a result of a repetitive pitching performance, can contribute to pathomechanics of the entire glenohumeral joint (Limpisvasti et al. 2007). Improving the understanding of the pitching motion will eventually allow for measures of injury prevention to be implemented. Fatigue or overuse often leads to injury in pitchers (Mullaney et al., 2005); however, there are no data examining muscle activations while fatigued during a pitching performance. Therefore, it was the purpose of this study to examine both upper and lower extremity muscle activations during baseball pitching while in the pre-fatigue and fatigued states.

METHODS: Fourteen baseball pitchers (16.0 ± 2.28 years, 178.2 ± 8.7 cm and 78.9 ± 17.55 kg) volunteered to participate in the current study. All participants had recently finished their competitive spring high school baseball seasons, and were deemed appropriately conditioned for data collection. Throwing arm dominance was not a factor contributing to participant selection or exclusion. All data collection sessions were conducted indoors at the University's Health, Physical Education, and Recreation building and were designed to best simulate a competitive setting. All testing protocols used in the current study were approved by the University's Review Board.
Location of the bilateral gluteus maximus, bilateral gluteus medius, throwing arm biceps, triceps, deltoid and scapular stabilizers were identified through palpation. Prior to testing, the identified locations for surface electrode placement were shaved, abraded and cleaned using standard medical alcohol swabs. Subsequent to surface preparation, adhesive 3M Red-Dot bipolar surface electrodes (3M, St. Paul, MN) were attached over the muscle bellies and positioned parallel to muscle fibers using techniques described by Basmajian and Deluca (1985). Following electrode placement, manual muscle tests (MMT) were conducted using techniques described

by Kendall et al. (1993). Manual muscle tests were used to identify the participant's maximum voluntary isometric contraction (MVIC) to which all sEMG data were compared.

Surface electromyographic (sEMG) data were transmitted to The MotionMonitor™ motion capture system (Innovative Sports Training Inc, Chicago IL) via a Noraxon Myopac 1400L 8-channel amplifier. The signal was full wave rectified and smoothed based on the smoothing algorithms of root mean squared at windows of 100 ms. Throughout all testing, sEMG data were sampled at a rate 1000 Hz. All sEMG data were notch filtered at frequencies of 59.5 Hz and 60.5 Hz respectively (Blackburn and Pauda, 2009).

In addition to sEMG data, kinematic data were collected to event mark the phases of the pitching motion. Kinematic data were collected using The MotionMonitor™ motion capture system (Innovative Sports Training, Chicago IL). Participants had ten electromagnetic sensors attached at the following locations: (1) the medial aspect of the torso at C7; (2) medial aspect of the pelvis at S1; (3) the distal/posterior aspect of the throwing humerus; (4) the distal/posterior aspect of the throwing forearm; (5) the distal/posterior aspect of the non-throwing humerus; (6) the distal/posterior aspect of the non-throwing forearm; (7) distal/posterior aspect of stride lower leg; (8) distal/posterior aspect of the upper stride leg; (9) distal/posterior aspect of non stride lower leg; and (10) distal/posterior aspect of non stride upper leg (Myers et al., 2005). Following the attachment of the electromagnetic sensors, an eleventh sensor was attached to a wooden stylus and used to digitize the palpated positions of the bony landmarks.

Participants were allotted an unlimited time to perform their own specified pre-competition warm-up routine. Participants were asked to spend a small portion of their warm-up throwing from the indoor pitching mound to be used during the test trials. After completing their warm-up and gaining familiarity with the pitching surface, each participant threw a series of maximal effort fastballs for strikes toward a catcher located the regulation distance (18.44 m). The mound was positioned so that the participant's stride foot would land on top of the 40 x 60 cm Bertec force plate (Bertec Corp, Columbus, Ohio) which was anchored into the floor. After five fastballs for strikes were thrown, the participants then threw a 2kg ball into a rebounder until they reported max perceived fatigue. A scale of 0-3 (Kimura et al., 2007), with three being only able to make 15 more throws, was used to quantify fatigue. Once a fatigue of 3 was reported, participants completed 10 more throws with the 2kg ball before returning to the mound to throw five maximum effort fastballs while in the fatigued state. Those data from the fastest pitch passing through the strike-zone for the pre-fatigue and fatigue deliveries were selected for analysis.

Data were analyzed in the current study using the statistical analysis package SPSS 15.0 for Windows. Data for the fastest strike mean and standard deviation for all sEMG and kinematic parameters were calculated for both pre-fatigue and post fatigue states. Once measures of central tendency were calculated, a series of descriptive statistics were conducted. A MANOVA was run for each of the four phases comparing pre-fatigue to fatigue with an adjusted alpha level using Bonferroni correction to allow for multiple tests ($p \leq 0.01$).

RESULTS: The pitching motion has previously been described into five phases (DiGiavine et al, 1992), however for the case of this study only stride through deceleration phases were analyzed. Stride phase was described as the beginning of motion to stride foot contact (SFC). The cocking phase was from SFC to maximum external rotation (MER) of the throwing shoulder. Next, was the acceleration phase that was from MER to ball release (BR), and finally phase 4, the deceleration phase, was described from BR to maximal internal rotation (MIR) of the throwing shoulder. There were no significant differences between pre-fatigue and fatigued states by phases ($p \leq 0.01$). Means of muscle activations are graphically summarized in Figures 1-2.

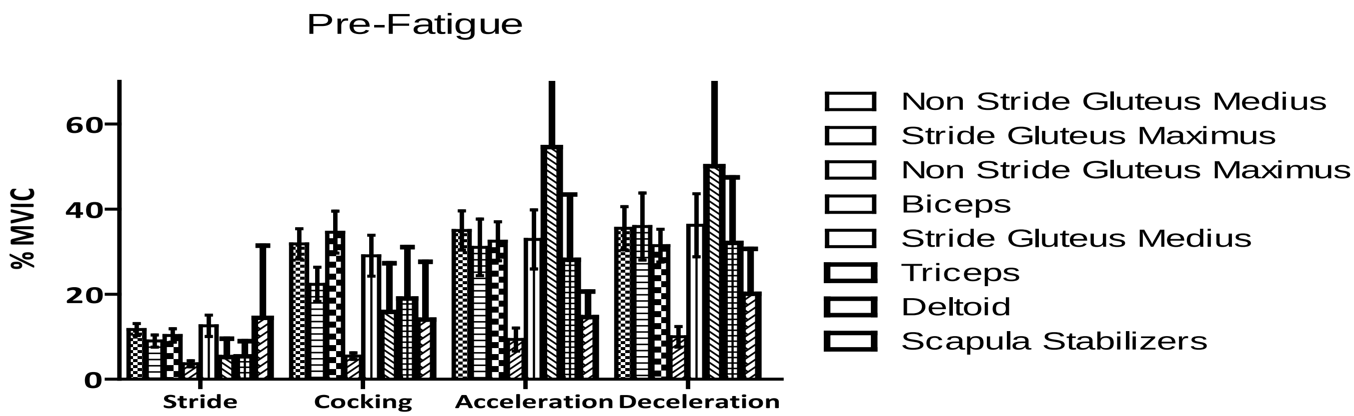

Figure 1. Muscle Activation as a %MVIC during the pre-fatigued state of the Baseball Pitch

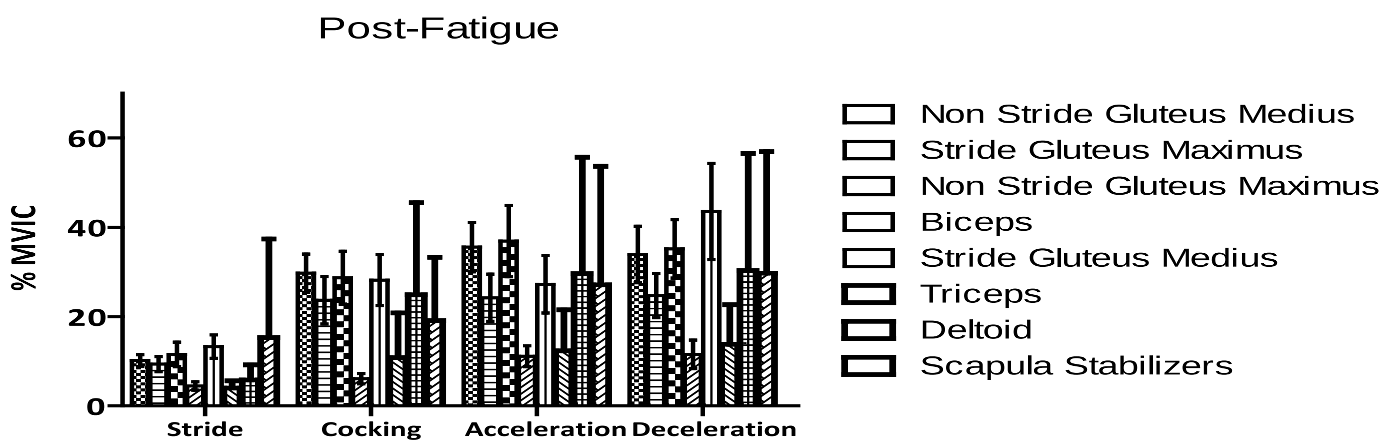

Figure 2. Muscle Activation as a %MVIC during the fatigued state of the Baseball Pitch

DISCUSSION: Previous sEMG studies of baseball pitching have focused on the upper extremity in a non-fatigued state. The current study was able to quantify muscle activations, of both the upper and lower extremities, while the participants were deemed free from fatigue and then in a fatigued state while throwing the fastball baseball pitch.

During pre-fatigue the stride leg and non stride leg had similar gluteal activations during pre-fatigue in attempt to stabilize the pelvis during the stride phase. The non stride gluteal group demonstrated greater activation as the participants were preparing for single leg support during pre-fatigue. Once fatigued, the stride leg gluteus medius had the greatest activation of the lower extremity muscles.

Pre-fatigue the gluteal muscle group increased in activation as did upper extremity muscle activations during cocking. The triceps displayed the greatest activation, eccentric in nature, during the cocking phase. Once fatigued, the triceps greatly reduced their activation; while the biceps, deltoid, and scapula stabilizers increased in activation. During the cocking phase the humerus was abducted and scapular movement during this phase allows for elevation of the acromion.

Pre-fatigued displayed a continual increase in gluteal muscle activation with the highest muscle activation being generated by the scapular stabilizers during acceleration. During cocking and acceleration the scapula must rotate in order for the rotator cuff to clear the acromion. In attempt to gain maximum external rotation, the scapula must retract and then protract to achieve acceleration for ball release. Once fatigued, the stride gluteus medius remained consistent in attempt to counter balance the non stride gluteal activation as well as the decreases activation of the stride leg gluteus maximus in attempt to keep the pelvis level while the body was shifting weight over to the stride leg for BR. Additionally, the deltoid and scapula stabilizers remained active.

Deceleration, pre-fatigue, revealed great activation of the gluteal muscle group with decreases in stride leg gluteal muscle activation during the fatigued state. The scapula stabilizers continued to stay active with slight decreases during fatigue. The scapula is the common point of attachment for the biceps, triceps, and deltoid. Therefore, the scapula stabilizers direct the efficiency of the musculature attached to the scapula. If the scapula is unstable, then alterations in all musculature that attaches to the scapula will occur.

CONCLUSIONS: We were able to identify muscle activation for the upper and lower extremities during the baseball pitch. We were also able to identify muscle activation during a fatigued state. Those muscles that had increased activation during the fatigued state could be a result of having to recruit more muscle fibers to perform the precision task of throwing a strike. To date there are no data available examining sEMG of the upper and lower extremity during the pitching motion in a pre-fatigued and fatigued state. More studies need to be conducted in attempt to validate our results with higher level of evidence of muscle activations during dynamic muscle fatigue. Studies examining kinematics and sEMG during the fatigue state are warranted. Findings from these types of fatiguing studies could direct practitioners in appropriate strength and conditioning regimens that would aid in pitching performance.

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