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Effects of fatigue on pelvic and scapular stabilizers in overhead throwing

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The Effects of Fatigue on Pelvic and Scapular Stabilizers in Overhead Throwing

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ABSTRACT

Human movement is based on proximal to distal sequencing of the kinetic chain. Efficiency of the shoulder is dependent upon the stability and function of the pelvis and scapula. **PURPOSE:** To determine if pelvic and scapular muscle activations are altered in overhead throwing following fatigue. **METHODS:** Eleven [19.2 ± 1.0 years; 168.9 ± 6.6 cm; 68.9 + 8.7 kg] softball players volunteered. Surface electromyographic [sEMG] electrodes were placed on bilateral gluteus medius, throwing arm latissimus dorsi, lower trapezius [LT], middle trapezius [MT], and serratus anterior [SA]. Participants had to catch a simulated hit ball and perform their positional throw. Infielders caught and threw to second base and outfielders crow hopped and threw to second, simulating a game setting where a runner was trying to steal. After 5 throws, participants threw a 2 kg ball into a rebounder until maximum perceived fatigue on 0-3 scale [3 = fatigue]. Following fatigue, 5 more throws were performed. The fastest throw pre and post fatigue were selected for sEMG analysis using a paired T-test. **RESULTS:** There were no significant differences in muscle activation pre and post fatigue during the acceleration phase of throwing. It was revealed that all muscles activation was increased post-fatigue excluding LT. **CONCLUSION:** The SA and LT provide a force couple to stabilize the scapula in arm elevation. Thus, while no statistical differences were observed, the increase in SA and decrease in LT could be an indicator of possible scapular instability following fatigue. Further research is needed to understand the effects of fatigue on pelvic and scapula stabilization during overhead throwing.

Key words: softball; EMG; throwing

INTRODUCTION

An overhand throw in both baseball and softball is a complex series of movements that proceeds in a precise five-phase sequence: wind up, cocking, acceleration, deceleration, and follow through [21]. With these complex, ballistic movements, injuries due to overuse and flawed mechanics are common in throwing athletes. However, to understand specific causes of such injuries, it is necessary to grasp the concept of the body's segments acting as a kinetic chain that is maximized by the synchronous use of various muscle groups during the five throwing phases [9]. The kinetic chain utilizes the proximal segments of the legs and trunk to generate energy to transfer to the upper extremities and on to the ball [14].

When focusing on the lower extremities, the gluteus medius serves a major role as a pelvic stabilizer [18]. The coordinated activation of this muscle along with several others provides lumbopelvic stabilization and the transfer of energy throughout the dynamic movements of throwing [15]. In addition to the importance of the lower extremity musculature that supports the lumbopelvic hip complex [LPHC], shoulder musculature is dependent on having strong anchor muscles to stabilize the scapula [20, 10, 6]. The scapular stabilizers [serratus anterior, lower trapezius, middle trapezius, and latissimus dorsi] allow the scapula to act synchronously with the rotator cuff to maintain the glenohumeral center of rotation within a physiologic range during the throwing motion [18, 15].

With repeated coordinated action of these lower and upper extremity muscle groups, muscular fatigue could impair performance and increase vulnerability to injury due to a loss of proper mechanics of both the pelvic and scapular stabilizers [12]. This idea is supported by Mair's study [7] on the role of extended performance in muscular strain. This study illustrated that a muscle's capacity to absorb energy actually decreases as muscular fatigue occurs [7]. With a decrease in energy absorption from the lower to upper extremities of the kinetic chain, greater stresses would be applied to articulations and inert structures leading to possible injury [7, 3].

There is currently limited research assessing and quantifying fatigue in the overhand throw. However, there have been some successful studies regarding muscular fatigue in baseball pitchers. Mullaney and colleagues [12] tested thirteen college and minor league male baseball pitchers before and after 19 games consisting of an average of approximately 99 pitches. The results demonstrated muscular fatigue within the shoulder muscles as well as marginal fatigue in the scapular and hip muscles following extended performance [12]. Another study of similar purpose by Escamilla et al. [3] analyzed ten collegiate baseball pitchers during a simulated baseball game. The main significant post fatigue differences included a decrease in ball velocity and an increase in vertical trunk position [3]. Nonetheless, this slight change in mechanics could cause a pitcher to compensate by utilizing excess shoulder musculature and reducing the involvement of the lower trunk. These compensatory measures could, in turn, lead to an increased risk of injury due to increased stress placed on the upper arm [3].

All of these studies propose the need for more fatigue data in order to fully understand the causes of increased injury. In addition to a limitation on fatigue-based research, there is also a lack of information regarding softball positional throws. With fast-pitch softball as one of the fastest growing women's sports, data are limited [17]. While there is more and more exploration into the mechanics of the windmill softball pitch, there is still a limited amount of information regarding individual positional throws including in-fielders, out-fielders, and catchers. Not only is it of extreme importance to athletic trainers and clinicians to note the weakness of stabilizing muscles that could lead to compensation and multiple injuries, but it is also significant to note any differences between the fatiguing of athletes based on the specific positional throw of that athlete. This information could assist in the understanding of preventive exercise, differing injuries from each position, and aid rehabilitative and therapeutic treatments to be more concise for athletic injuries. Therefore, the purpose of this study was to determine the muscular activation of the pelvic and scapular stabilizers [including the gluteus medius, latissimus dorsi, lower trapezius, middle trapezius, and serratus anterior] during the overhand throw in a non-fatigued state compared to a fatigued state.

METHODS

In this controlled laboratory research, eleven Division I National Collegiate Athletic Association softball players [19.2 $\pm$ 1.0 years; 68.9 $\pm$ 8.7 kg; 168.6 $\pm$ 6.6 cm] volunteered to participate. Participant inclusion criteria included coach recommendation, multiple years of playing experience prior to this study, and freedom from injury. Participants were excluded if they had suffered an injury within the past 6 months, which required medical attention, to avoid any biomechanical compensation that may have developed affecting the throwing mechanics. Testing was conducted in the University of Arkansas Health, Physical Education, Recreation, and Dance building. The University of Arkansas Institutional Review Board approved all testing protocols. Approved testing procedures were explained to each participant and proper informed consent and participant agreement were obtained before testing began.

Adhesive 3M Red-Dot [3M, St. Paul, MN] bipolar [Al/AgCl] disk surface electrodes [six centimeter in diameter] were attached bilaterally over the muscle bellies of the gluteus medius as well as latissimus dorsi, lower trapezius [LT], middle trapezius [MT], and serratus anterior [SA] of the dominant throwing arm. The electrodes were positioned parallel to muscle fibers using techniques described by Basmajian and Deluca [1]. Prior to electrode placement, the identified locations for surface electrode placement were shaved, abraded, and cleaned using standard medical alcohol swabs. An additional electrode was placed on the anterior superior iliac spine [ASIS] to serve as a ground lead for the examined muscles.

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, respectively [2].

Following the application of surface electrodes, manual muscle testing [MMT] techniques by Kendall et al. [5] were used to determine steady state contraction. Three MMT, lasting 5 seconds, were performed for each muscle and the first and last second of each contraction was removed. The MMT provided baseline data in which all surface EMG data could be compared.

Following set-up, participants were allotted an unlimited time to perform their own specified pre-competition warm-up routine. Participants spent an average of 10-12 minutes for their warm-up. Once the participants deemed themselves warm, they were instructed on the protocol. The participant 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 hopped, and threw to a positional player at second base. 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. For each throw, a position player was on the designated base to catch the ball. Only those throws where the position player on base was able to catch the ball without stepping off the base were recorded. A JUGS radar gun [OpticsPlanet, Inc., Northbrook, IL] positioned in the direction of the throw determined ball speed.

Following five successful positional throws, the participants utilized a 2 kg weighted ball to perform overhead throws into a rebounder. These weighted throws continued until the participant reported maximum perceived fatigue. A scale of 0-3, with three being maximal fatigue, was used. Once a fatigue of three was reported, participants threw five more maximum effort positional throws. The trials with the fastest and most accurate throw, one in a pre fatigue state and one in a post fatigue state, were selected for detailed analysis [14, 17].Data were analysed using PASW 19 for Windows [SPSS, Chicago, IL].

RESULTS

Based on a paired T-test analysis, each muscle [gluteus medius, latissimus dorsi, lower trapezius, middle trapezius, and serratus anterior] illustrated no significant changes in pre and post fatigue measurements during the throwing motion. However, there was, overall, an increase in muscular activation within the gluteus medius, latissimus dorsi, middle trapezius, and serratus anterior during post fatigue analysis. The serratus anterior experienced the greatest increase in activation based on maximum voluntary isometric contraction [MVIC] measurements. An exception to this increase in muscular activation was observed in the lower trapezius, which had a decrease in post fatigue activation. The results are summarized in Figure 2.

Please insert Figure 2 here.

DISCUSSION

This study aimed to determine if pelvic and scapular muscle activations, specifically the gluteus medius, latissimus dorsi, lower trapezius, middle trapezius, and serratus anterior, would be altered in overhand softball positional throws following fatigue. While the results did not illustrate a statistically significant variation in the activation of the muscles from pre to post fatigue measurements, there was a post fatigue increase in serratus anterior activation along with a post fatigue decrease in lower trapezius activation that could be an indicator of scapular instability following fatigue. This may be explained by the joint functioning of the lower trapezius and serratus anterior as an imperative force couple to allow scapular rotation.

A force couple has been defined as two divergent forces working together to create a rotary effect about an axis [4]. With the lower trapezius performing downward rotation of the scapula and the serratus anterior performing upward rotation of the scapula, these two muscles form a significant force couple that plays a vital role in maintaining scapulohumeral rhythm, or the intricate, smooth pattern of movement within the shoulder complex [4, 20]. Research has demonstrated that a weakness or imbalance in this force couple would lead to scapular instability and a disruption of scapulohumeral rhythm. In turn, shoulder dysfunction could occur, eventually leading to muscular strain and impingement [16, 19, 20].

The changes in lower trapezius and serratus anterior activation found within our study were comparable with the findings of Mithun and colleagues [11], who noted a decrease in lower trapezius activity and no change in serratus anterior activity in overhead athletes following fatigue. Mithun's study [11] utilized surface electromyography to measure muscle activation of 25 overhead athletes including baseball players, tennis players, volleyball players, and swimmers. The subjects were required to follow a diagonal movement pattern, using a specific hand held weight, which was guided by an apparatus built from foam padding and polyvinyl chloride pipe. The movement simulated a similar movement pattern that these athletes would actually perform in their respective sport. This motion involved flexion, abduction, and external rotation at the shoulder during the ascending phase and extension, adduction, and internal rotation at the shoulder during the descending phase. The participants completed five trials utilizing the apparatus before the fatigue protocol and five trials following the fatigue protocol [11].

The major findings of the Mithun study involved a decrease in lower trapezius activation, an increase in infraspinatus activity, and no changes in serratus anterior and upper trapezius activity [11]. While both our study and Mithun's study did find a decrease in lower trapezius activation, other discrepancies regarding the results from this study compared to our study could be contributed to the fatigue protocol. Mithun et al [11] attempted to achieve fatigue through abduction of the shoulder using a weighted dumbbell with the participant lying in a prone position. The subject continued shoulder abduction until he or she could no longer lift the weight or was unable to keep pace with the metronome. In contrast, our study required participants to continue with the overhead throwing motion using a weighted ball while standing, and measured fatigue based on a 0-3 maximum perceived fatigue scale. These differences in the methods utilized to achieve and measure fatigue could provide a possible explanation for the variations in the results. The use of varying methods and fatigue protocol limits the comparisons that can be made regarding fatigue in overhead athletes. Therefore, it may be useful for future investigations to address these discrepancies in protocol in order to produce results that may be compared to current research.

PRACTICAL APPLICATIONS

The primary finding within this study was that pelvic and scapular muscle activation remained fairly consistent during both pre and post fatigue measurements in overhand positional throws. However, the increase in serratus anterior activation could be a possible attempt to compensate for the decreased activation of the lower trapezius following fatigue. Any imbalance or weakness in these muscles may interrupt the scapulohumeral rhythm, leading to shoulder injuries including muscular strain and impingement. With approximately one-third of all softball injuries occurring in the upper extremity, this study provides relevance for athletic trainers and clinicians with regards to injury prevention and rehabilitation for collegiate softball players [8]. Based on this information, focus should be placed on strengthening the scapulothoracic muscles, specifically the trapezius, in order to prevent overuse injuries. Nonetheless, further research on the pelvic and scapular stabilizers is necessary to fully understand the effect of fatigue on the overhand throw.

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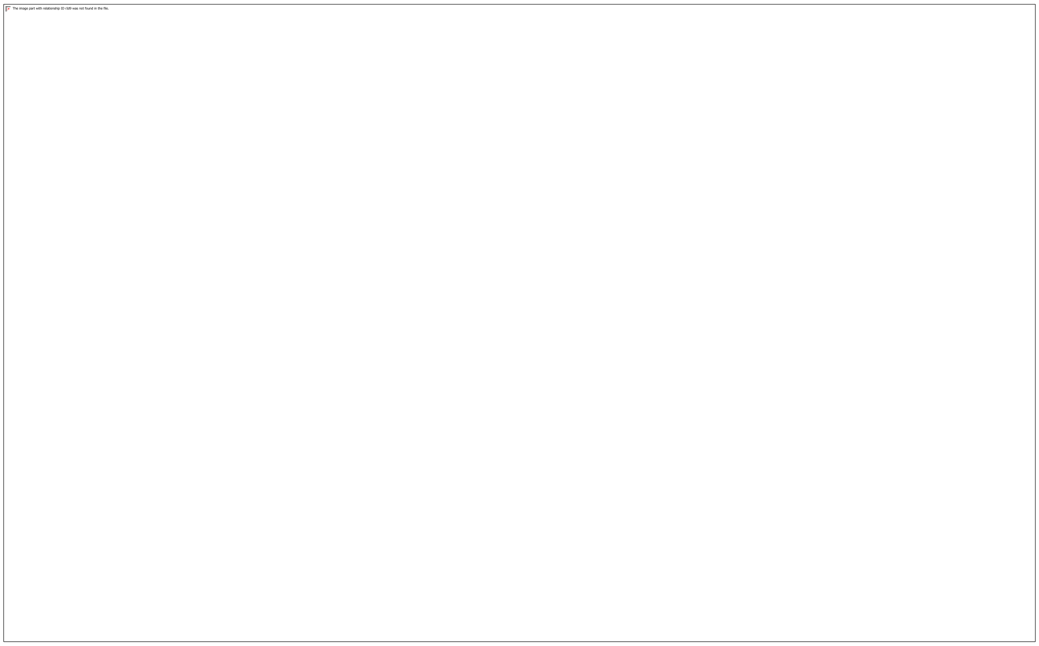
Figure Legend:

Figure 1. Means and standard deviations of muscle activations as a percent of MVIC.

*Indicates throwing side.



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