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Effects of fatigue on pelvic and scapular stabilizers in overhead throwing

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Effects of Fatigue 1

1

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

This paper is in fulfillment of University of Arkansas Honors College Honors thesis for Julie Sherrill. This paper was formatted by the author guidelines of the Journal of Strength and Conditioning Research [<http://edmgr.ovid.com/jscr/accounts/ifauth.htm>]
These data are a part of a larger data set that is under manuscript consideration. The use of this information is prohibited without consent from Gretchen D. Oliver, PhD, FACSM, ATC, Auburn University, Auburn AL.

3 **ABSTRACT**

4 Human movement is based on proximal to distal sequencing of the kinetic chain.
5 Efficiency of the shoulder is dependent upon the stability and function of the pelvis and
6 scapula. **PURPOSE:** To determine if pelvic and scapular muscle activations are altered
7 in overhead throwing following fatigue. **METHODS:** Eleven [19.2 ± 1.0 years; 168.9 ±
8 6.6 cm; 68.9 + 8.7 kg] softball players volunteered. Surface electromyographic [sEMG]
9 electrodes were placed on bilateral gluteus medius, throwing arm latissimus dorsi, lower
10 trapezius [LT], middle trapezius [MT], and serratus anterior [SA]. Participants had to
11 catch a simulated hit ball and perform their positional throw. Infielders caught and threw
12 to second base and outfielders crow hopped and threw to second, simulating a game
13 setting where a runner was trying to steal. After 5 throws, participants threw a 2 kg ball
14 into a rebounder until maximum perceived fatigue on 0-3 scale [3 = fatigue]. Following
15 fatigue, 5 more throws were performed. The fastest throw pre and post fatigue were
16 selected for sEMG analysis using a paired T-test. **RESULTS:** There were no significant
17 differences in muscle activation pre and post fatigue during the acceleration phase of
18 throwing. It was revealed that all muscles activation was increased post-fatigue
19 excluding LT. **CONCLUSION:** The SA and LT provide a force couple to stabilize the
20 scapula in arm elevation. Thus, while no statistical differences were observed, the
21 increase in SA and decrease in LT could be an indicator of possible scapular instability
22 following fatigue. Further research is needed to understand the effects of fatigue on
23 pelvic and scapula stabilization during overhead throwing.

24 *Key words: softball; EMG; throwing*

25 INTRODUCTION

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

35

36 When focusing on the lower extremities, the gluteus medius serves a major role as a
37 pelvic stabilizer [18]. The coordinated activation of this muscle along with several others
38 provides lumbopelvic stabilization and the transfer of energy throughout the dynamic
39 movements of throwing [15]. In addition to the importance of the lower extremity
40 musculature that supports the lumbopelvic hip complex [LPHC], shoulder musculature is
41 dependent on having strong anchor muscles to stabilize the scapula [20, 10, 6]. The
42 scapular stabilizers [serratus anterior, lower trapezius, middle trapezius, and latissimus
43 dorsi] allow the scapula to act synchronously with the rotator cuff to maintain the
44 glenohumeral center of rotation within a physiologic range during the throwing motion
45 [18, 15].

46

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

55

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

69

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

86

87 **METHODS**

88 In this controlled laboratory research, eleven Division I National Collegiate Athletic
89 Association softball players [19.2 ± 1.0 years; 68.9 ± 8.7 kg; 168.6 ± 6.6 cm]
90 volunteered to participate. Participant inclusion criteria included coach recommendation,
91 multiple years of playing experience prior to this study, and freedom from injury.
92 Participants were excluded if they had suffered an injury within the past 6 months, which

93 required medical attention, to avoid any biomechanical compensation that may have
94 developed affecting the throwing mechanics. Testing was conducted in the University of
95 Arkansas Health, Physical Education, Recreation, and Dance building. The University of
96 Arkansas Institutional Review Board approved all testing protocols. Approved testing
97 procedures were explained to each participant and proper informed consent and
98 participant agreement were obtained before testing began.

99

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

109

110 Electromyographic data were collected via a Noraxon Myopac 1400L 8-channel
111 amplifier [Noraxon USA, INC, Scottsdale, AZ]. The signal was full wave rectified and
112 root mean squared at 100 ms. Surface EMG data were sampled at a rate of 1000 Hz.
113 The surface EMG data were notch filtered at frequencies of 59.5 and 60.5 Hz,
114 respectively [2].

115

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

121

122 Following set-up, participants were allotted an unlimited time to perform their own
123 specified pre-competition warm-up routine. Participants spent an average of 10-12
124 minutes for their warm-up. Once the participants deemed themselves warm, they were
125 instructed on the protocol. The participant had to catch a simulated hit or pitched ball
126 and perform their positional throw to a designated positional player standing on base to
127 prevent a runner from advancing to that base. Infielders caught a simulated line drive
128 and threw to a positional player at second base. Outfielders caught a simulated fly ball,
129 crow hopped, and threw to a positional player at second base. Catchers caught a
130 simulated pitched ball and threw down to second base where a positional player
131 received the ball. All three positional players [infielder, outfielder, and catcher] threw the
132 same average distance of 25.6 m. For each throw, a position player was on the
133 designated base to catch the ball. Only those throws where the position player on base
134 was able to catch the ball without stepping off the base were recorded. A JUGS radar
135 gun [OpticsPlanet, Inc., Northbrook, IL] positioned in the direction of the throw
136 determined ball speed.

137

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

146

147 **RESULTS**

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

157 *Please insert Figure 2 here.*

158

159

160

161 **DISCUSSION**

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

171

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

181

182 The changes in lower trapezius and serratus anterior activation found within our study
183 were comparable with the findings of Mithun and colleagues [11], who noted a decrease

184 in lower trapezius activity and no change in serratus anterior activity in overhead
185 athletes following fatigue. Mithun's study [11] utilized surface electromyography to
186 measure muscle activation of 25 overhead athletes including baseball players, tennis
187 players, volleyball players, and swimmers. The subjects were required to follow a
188 diagonal movement pattern, using a specific hand held weight, which was guided by an
189 apparatus built from foam padding and polyvinyl chloride pipe. The movement simulated
190 a similar movement pattern that these athletes would actually perform in their respective
191 sport. This motion involved flexion, abduction, and external rotation at the shoulder
192 during the ascending phase and extension, adduction, and internal rotation at the
193 shoulder during the descending phase. The participants completed five trials utilizing
194 the apparatus before the fatigue protocol and five trials following the fatigue protocol
195 [11].

196

197 The major findings of the Mithun study involved a decrease in lower trapezius activation,
198 an increase in infraspinatus activity, and no changes in serratus anterior and upper
199 trapezius activity [11]. While both our study and Mithun's study did find a decrease in
200 lower trapezius activation, other discrepancies regarding the results from this study
201 compared to our study could be contributed to the fatigue protocol. Mithun et al [11]
202 attempted to achieve fatigue through abduction of the shoulder using a weighted
203 dumbbell with the participant lying in a prone position. The subject continued shoulder
204 abduction until he or she could no longer lift the weight or was unable to keep pace with
205 the metronome. In contrast, our study required participants to continue with the
206 overhead throwing motion using a weighted ball while standing, and measured fatigue

207 based on a 0-3 maximum perceived fatigue scale. These differences in the methods
208 utilized to achieve and measure fatigue could provide a possible explanation for the
209 variations in the results. The use of varying methods and fatigue protocol limits the
210 comparisons that can be made regarding fatigue in overhead athletes. Therefore, it may
211 be useful for future investigations to address these discrepancies in protocol in order to
212 produce results that may be compared to current research.

213

214 **PRACTICAL APPLICATIONS**

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

228

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285 **Figure Legend:**

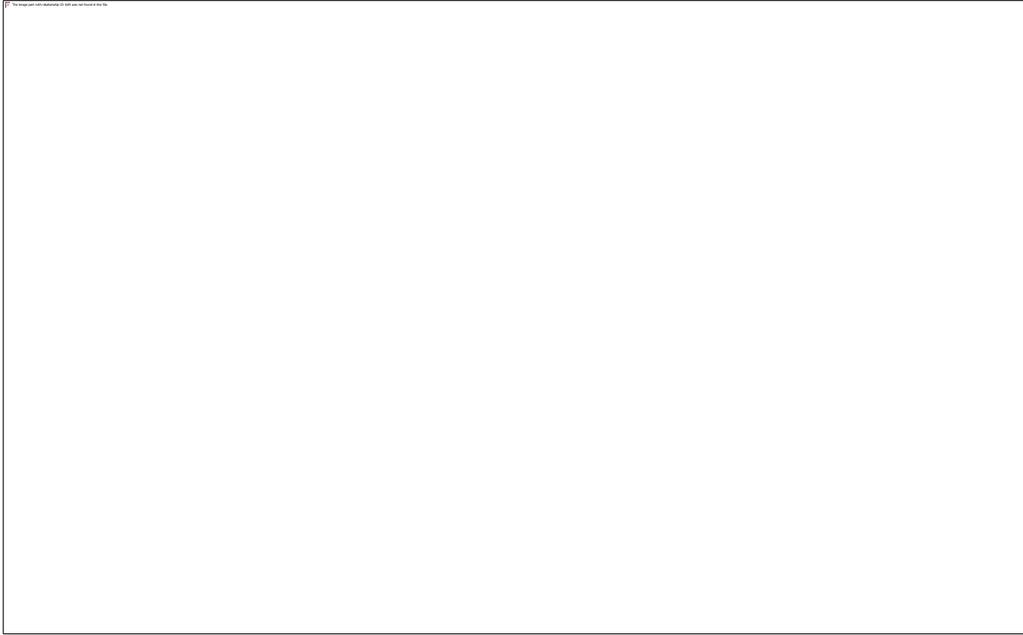
286 Figure 1. Means and standard deviations of muscle activations as a percent of MVIC.

287 *Indicates throwing side.

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288

289 **Figure 1.** Means and standard deviations as a percent of MVIC. *Indicates throwing
290 side.