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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 [ $19.2 \pm 1.0$  years;  $68.9 \pm 8.7$  kg;  $168.6 \pm 6.6$  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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Effects of Fatigue 15

285 **Figure Legend:**

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

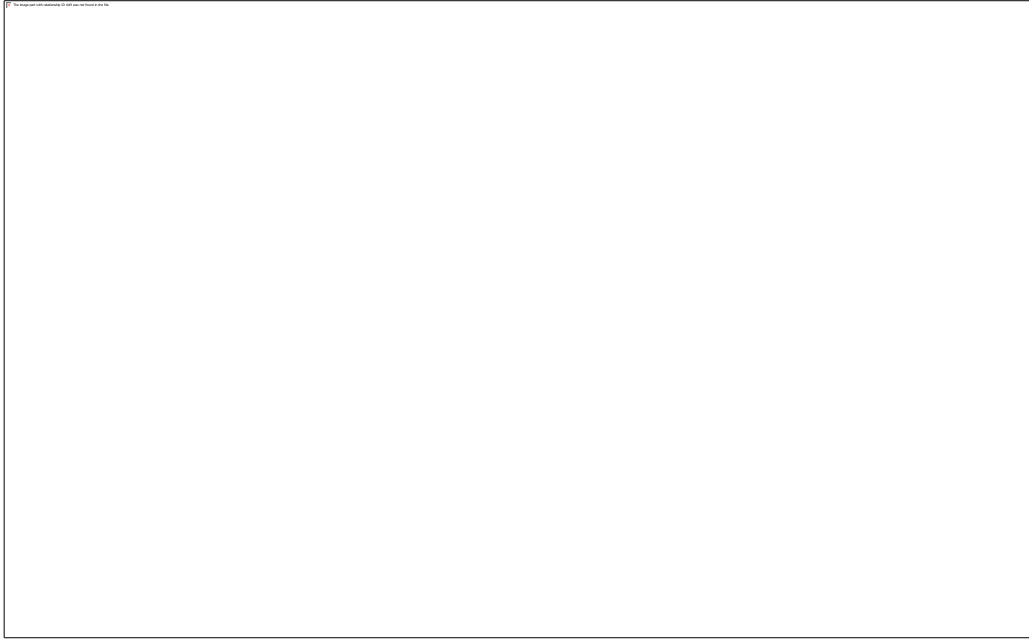
287 \*Indicates throwing side.



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Effects of Fatigue 16



288

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