ROTATOR CUFF ACTIVATION DURING THE OLYMPIC SNATCH UNDER VARIOUS LOADING CONDITIONS

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The current study examined rotator cuff (RTC) muscle activation levels during different phases of the snatch under varied loading conditions, and evaluated shoulder abduction (ABD) angle during the catch. Nine male Olympic weightlifters currently training for competition had surface EMG electrodes attached to their supraspinatus, infraspinatus, and teres minor, then performed two lifts at 40, 60, and 80% of their maximum snatch. 2-D video was used to record each lift and synchronized with the EMG readings to evaluate RTC muscle activation. Markers were placed on the participants' upper extremity to evaluate shoulder ABD angle during these trials. Shoulder ABD angle at the catch did not differ between loading conditions. RTC activation varied throughout the snatch with the supraspinatus and infraspinatus becoming most active during the turnover and catch phases of the lift while the teres minor is most active during the first pull and transition.

KEYWORDS: electromyography (EMG), 2-D video, weightlifting, upper extremity

INTRODUCTION: Two lifts are currently performed in Olympic competition, the snatch (SN), and clean and jerk (CJ). In recent years, there has been mediocre increases in maximum weights lifted during the SN at the international level (Ho et al., 2014). The SN is performed by lifting the weight from the floor to overhead in one movement, and is more technically demanding (Ho et al., 2014) than the CJ but both begin with similar phases; the first pull, transition, second pull, turnover, catch, and recovery (Bartonietz, 1996; Chen et al., 2012; Ho et al., 2014; Narayana, 2010).

The SN utilizes every major joint and activates a wide array of muscles to successfully accomplish the lift. One primary joint that provides both assistance in the pulls and the catch is the glenohumeral joint (GHJ) (Bartonietz, 1996; Chen et al., 2012; Wu et al., 2008). During the catch and recovery phases of the SN, the shoulders are in full flexion and high ranges of ABD are reached. In this position, GHJ stability is key to a successful lift therefore both dynamic and static stabilizers are required. The static stabilizers are the bony configuration, the glenohumeral ligaments, and the glenoid labrum (Lugo, Kung, & Ma, 2008). The dynamic stabilizers are the muscles that act on the joint (Lugo et al., 2008).

The rotator cuff (RTC) consists of four muscles; the supraspinatus (SS), the infraspinatus (IF), the teres minor (TM) and the subscapularis, and provides stability to the GHJ during arm elevation. If the RTC does not have proper activation patterns during humeral elevation the humeral head can migrate superiorly causing impingement of the structures that lay under the acromial arch (DeMey, Danneels, Cagnie, & Cools, 2012; Escamilla, Yamashiro, Paulos, & Andrews, 2009; Lugo et al., 2008; Myers, Hwang, Pasquale, Blackburn, & Lephart, 2009; Pabian, Kolber, & McCarthy, 2011). Repeated superior translation of the humerus can lead to shoulder impingement which can be very debilitating, especially in overhead athletes (DeMey et al., 2012).

Shoulder injuries are prevalent in weightlifters and can cause significant amounts of lost training time (Neviaser, 1991; Pabian et al., 2011; Raske & Norlin, 2002). Many of the injuries frequently seen in weightlifters' shoulders are from overuse (Neviaser, 1991; Raske & Norlin, 2002), and can occur because of, poor technique, poor training habits, joint laxity, and poor muscle recruitment (Myers et al., 2009; Neviaser, 1991; Raske & Norlin, 2002). During the SN, the RTC is put into unfavorable positions which could cause injuries (Neviaser, 1991; Raske & Norlin, 2002).

Few studies have examined muscle activity of the upper extremity during the SN (Chen et al., 2012; Narayana, 2010; Wu et al., 2008). Most of these studies have focused on the large muscles around the GHJ. There is currently, no literature on RTC activation during the different phases of the SN. Many lifts are unsuccessful because the athlete cannot maintain the weight above their head. While there is more to a successful lift than just the upper extremity mechanics and stability,

there is the possibility that the RTC muscles play a crucial role in maintaining GHJ stability and positioning during the Olympic snatch. The purpose of this study was to examine the RTC muscles activation levels during the different phases of the SN under varied loading conditions, and to examine the shoulder ABD angle during the catch.

METHODS: Participants were nine male Olympic weightlifters training at the Olympic Training Site of Northern Michigan University (Mean $\pm$ SD: age = 19.33 $\pm$ 1.58 y; height = 167.88 $\pm$ 7.19 cm; weight = 74.59 $\pm$ 19.99 kg; Sinclair score = 309.35 $\pm$ 24.58; years of training = 1.89 $\pm$ 1.27 y). They had no upper extremity injury or surgery to the upper extremity in the previous year. All experimental procedures were reviewed by the Institutional Review Board and the participants completed an informed consent and PAR-Q before data were collected.
All EMG sites were prepared in the same way; the selected location was shaved if necessary, abraded, and cleaned with an alcohol pad (PDI; Mooresville, Indiana) to reduce impedance. Participants were then fitted with three Noraxon Dual Electrodes (Product #272 Noraxon USA; Scottsdale, AZ) and surface EMG probes (BTS Bioengineering Corp., Brooklyn, NY) placed on the belly of the muscles according to Cram and coworkers (Cram, Kasman, & Holtz, 1997).
After placement of the electrodes, participants were fitted with markers on the lateral epicondyle of the humerus, the posterior aspect of the humeral head and the superior aspect of the iliac crest. These markers were visible to the camera which was placed in the sagittal plane to evaluate shoulder ABD during the SN. Video was recorded with a Casio EX-ZR10 high speed camera (Casio America Inc., Dover, NJ) at 480 Hz. To evaluate muscle activation during different phases of the SN, the EMG system was synched to the video using a foot switch which indicated when the weight was lifted off the platform and phases were divided according to Bartonietz (1996).
Participants performed a warm-up consisting of stretching exercises, deadlifts, and pulls before resting for two minutes; and then performed a five second maximum voluntary isometric contraction (MVIC) for each muscle studied. Once the MVIC data were collected the first and last seconds were trimmed to produce a three second reading. A rest period was used after the MVIC and each trial. Following the MVIC rest period, each participant performed two lifts at each load beginning at 40% progressing to 60%, and 80% of 1 RM (Narayana, 2010)..
Video data were analyzed to find shoulder ABD angles using computer software (MaxTRAQ 2D, Innovision Systems Inc, Columbiaville, MI, USA). All EMG data were collected at 1000Hz, filtered using a Butterworth band pass filter (10-450 Hz), rectified, and integrated (50 ms) (BTS EMG Analyzer, BTS Bioengineering Corp., Brooklyn, NY). All EMG values were normalized compared to the participant's MVIC for each muscle. These normalized values were then used to analyze the percent of MVIC (%MVIC) muscle activation for each muscle during each phase of the SN within each participant. Statistical analyses were performed using SPSS version 22. All comparisons were made at p=.05 confidence level.

RESULTS & DISCUSSION: A one-way repeated measures ANOVA determined there was no significant difference within ABD angles during the catch of the SN across loading conditions (Mean $\pm$ SD; 40 % max, 129.72° $\pm$ 4.12°; 60% of max, 130.71° $\pm$ 3.71°; 80% of max, 128.29° $\pm$ 3.64°). This is can be explained because the participants were practiced Olympic weightlifters, and had been coached to place their hands with the same grip width on the bar during each lift. Therefore, when lifted overhead the ABD angle would not vary greatly between lifts or participants. Two-Way repeated measures ANOVA were used to determine differences within each muscles' activation levels at each loading condition through the different phases. There were no interactions between the loading conditions and the phases of each muscle. Comparisons of the SS for both the different loading conditions and within phases showed no differences except the following; the 40% of max trial was significantly different from both the 60% and 80% trials, but the 60% and 80% trials did not differ from each other, the catch phase was significantly different from all other phases except the second pull and transition. All other comparisons between phases were not

significantly different (Figure 1). The %MVIC for the SS reached its highest point during the catch phase and showed a gradual increase in the %MVIC from the first pull through the end of the second pull (Figure 1). This demonstrates that the supraspinatus is active during all phases of the SN and its highest activation levels were during the catch and recovery. These findings demonstrate that the SS does contribute to GHJ stability during the catch and recovery and can help assist other larger muscles, deltoid and biceps, previously shown to provide GHJ stability through these phases (Chen et al., 2012).
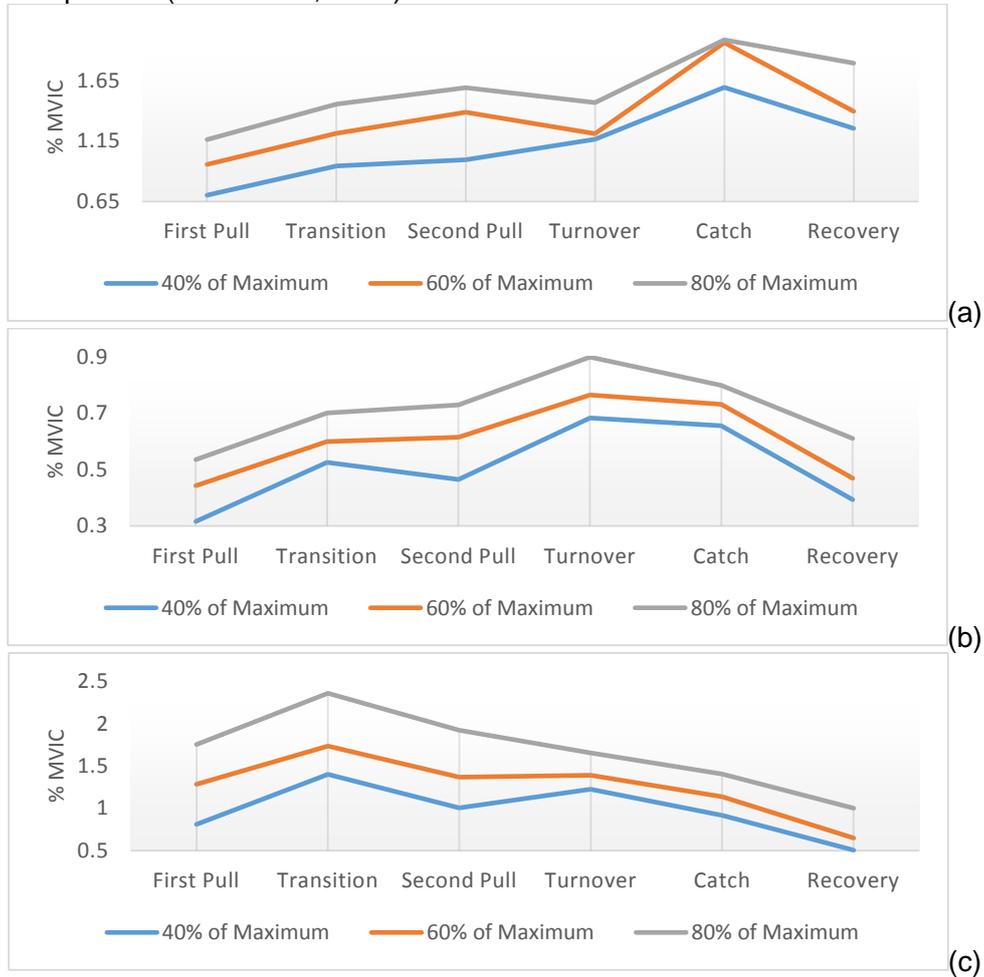

(a)

(b)

(c)

Figure 1. Percent of MVIC muscle activation for (a) Supraspinatus, (b) Infraspinatus, and (c) Teres Minor over the different phases of the snatch during various loading conditions.

Comparisons of the IF for the different loading conditions were all significantly different and the turnover and recovery phases differed from each other. All other comparisons between phases were not significantly different (Figure 1). The %MVIC for the IF followed a similar pattern as the SS, but reached its highest percent of activation during the turnover phase and then dropped slightly for the catch (Figure 1). Our data demonstrates that the IF does not contribute greatly to the SN until the turnover and catch phases. This can be attributed to two possible causes, the first being the shoulder is moving into external rotation from the turnover to the catch phase which is the primary motion of the IF, and secondly, that the IF could help provide GHJ stability during the overhead portions of the SN assisting the larger muscles around the GHJ.
Comparisons of the TM for both the different loading conditions and between phases showed no differences except the following; the 40% of max trial was significantly different from both the 60% and 80% trials, but the 60% and 80% trials did not differ from each other, the recovery phase was

significantly different from all other phases except the first pull. All other comparisons between phases were not significantly different. The TM did not follow similar %MVIC through the SN. The TM was primarily active during the first pull and transition then became less active through the remainder of the lift (Figure 1). Previous research has shown that the latissimus dorsi is highly active from the first pull to the transition (Chen et al., 2012; Narayana, 2010). This may explain the activation patterns seen in the TM because of potential cross talk from the muscle fibers that cover the TM when the GHJ is in low degrees of flexion and ABD (Lugo et al., 2008). The data demonstrates that the TM is active during the overhead portions of the SN and therefore does provide some stability to the GHJ, but to what degree cannot be stated by this study.

A limitation of this study was that one participants' %MVIC for all muscles and over every phase and loading condition were far in excess of 100% MVIC, therefore skewing the standard deviations for the %MVIC muscle activation, but all values were consistently higher and we were comparing all muscle activations within each participant so the data was used.

CONCLUSION: The RTC is active during the SN at all phases. The SS and IF are most active during the turnover and catch phases, while the TM is most active during the first pull and transition. In addition, the TM does stay highly active during the turnover and catch at all loading conditions. Our data demonstrates that the RTC helps stabilize the GHJ when the load is overhead. Shoulder ABD angle during the catch likely did not differ between loading conditions because the participants were practiced in SN technique and used the same grip width for every lift. Further research should examine the upper extremity musculature involved during the SN; including muscles that act on the GHJ and the muscles that help assist in scapulothoracic rhythm.

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