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Neuromuscular and stiffness adaptations in division I collegiate baseball players

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ABSTRACT

To compare bi-lateral shoulder EMG, active and short range glenohumeral stiffness, and examine its correlation to posterior capsule thickness (PCT) in collegiate baseball players. Surface and fine wire EMG was recorded on shoulder and scapular musculature during stiffness testing. Posterior capsule thickness was assessed separately using a diagnostic ultrasound. Serratus anterior EMG area and peak on the dominant arm was significantly greater compared to the non-dominant arm. The dominant arm had significantly greater active and short range glenohumeral stiffness compared to the non-dominant arm. Active glenohumeral stiffness was significantly correlated with PCT, however short range glenohumeral stiffness was not significantly correlated with PCT. Healthy collegiate baseball players present with adaptations of their stiffness regulation strategies. There were also correlations between stiffness and morphologic changes. Our results support the theory that PCT has an impact on the energy absorption capabilities of the shoulder during the deceleration phase of throwing. It also seems that tightening of the series elastic component within the posterior rotator cuff may be causing the increase in short range stiffness on the dominant arm.

1. Introduction

During the deceleration phase of the overhead throw, energy absorption must be distributed across musculotendinous and capsuloligamentous tissue within a limited range of motion, to minimize the likelihood of injurious stress (Kibler, 1991; Pink, 2001; Huxel et al., 2008). This is largely accomplished through exquisite control by the nervous system and its interaction with the musculoskeletal system, which regulates glenohumeral stiffness characteristics (Kandel et al., 2000). While the posterior rotator cuff and scapular stabilizing muscles optimize dynamic restraint, the posterior capsule is believed to be a critical static restraint (Wilk et al., 1997; Meister, 2000; Pink, 2001; Abboud and Soslowsky, 2002; Huxel et al., 2008). Together, dynamic and static restraints share the function of energy dispersion, minimizing excessive stress on any one structure. In overhead athletes, the posterior rotator cuff and scapular stabilizing muscles have a dichotomous role of simultaneously maximizing functional performance and maintaining glenohumeral joint stability. Preparatory and reflexive muscle recruitment patterns continuously modify shoulder stiffness during the follow through phase of the throwing motion and may adapt over longer periods of time (Lieber and Friden, 1993; Swanik et al., 1997; Riemann and Lephart, 2002).

Greater muscle recruitment during arm deceleration, infers that the posterior rotator cuff and scapular stabilizers must contract simultaneously to absorb the high level of rotational energy created during the acceleration phase (Jobe et al., 1983, 1984). A longer latency in the rotator cuff and scapular stabilizers has also been observed with injured populations, which suggests the initial delay in energy absorption by muscles may place excessive stress on static restraints such as the posterior capsule. Lastly, greater co-contraction of the rotator cuff and scapular stabilizers has been observed in individuals with subacromial impingement syndrome, (Cools et al., 2007; Myers et al., 2008) which implies muscular imbalances unequally distribute stresses during the deceleration phase of the overhead throw.

One static restraint that is thought to undergo adaptive changes is the posterior capsule (Ticker et al., 2000; Burkhart et al., 2003a,b). The capsule has been shown to provide a significant amount of resistance to passive motion and therefore cannot be neglected when assessing energy absorption in overhead athletes

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(Johns and Wright, 1962). Chronic eccentric loading during the deceleration phase may prolong fibroblastic activity within the posterior capsule, causing tissue hypertrophy (Burkhart et al., 2003a,b). Advances in sonography now provide evidence of fibroblastic hypertrophy in response to repetitive stress (Thomas et al., 2011a,b).

Stiffness is defined as the ratio of change in torque relative to change in position (Oatis, 1993; Huxel et al., 2008). Thus joint stiffness must be optimized during the deceleration phase as an adaptive strategy to maintain stability and dissipate energy. Lieber and Friden (1993) suggests that joint stiffness may be a better measure of joint function and stability, when compared to strength, due to the relatively large increases in stiffness at moderate muscle activation levels (Sinkjaer et al., 1988; Lieber and Friden, 1993; Huxel et al., 2008). Active joint stiffness is comprised of a combination of passive (capsule, ligaments, tendons, resting muscle tone and joint friction) and dynamic (volitional muscle contraction and reflex responses) components due to the passive components being static elements that cannot be removed from the measurement. In addition, short range stiffness or the stiffness within the first few degrees of motion that results from tendon compliance and reverse pivoting of sarcomere crossbridges (Rack and Westbury, 1973, 1974; Morgan, 1977; Flitney and Hirst, 1978a,b) may be particularly advantageous to energy absorption (Morgan, 1977; Flitney and Hirst, 1978a,b). Combined, these dynamic structures alone are capable of increasing joint stiffness 10-fold, (Sinkjaer et al., 1988; Zhang et al., 2000) however there is limited data reporting active glenohumeral joint stiffness or short range stiffness in baseball players. Therefore, the objective of this study was to identify if healthy baseball players present with uni-lateral differences in neuromuscular control, posterior capsule thickness and stiffness regulation due to adaptive mechanisms from repetitive throwing. We hypothesized that there would be alterations in neuromuscular control and stiffness regulation on the dominant arm and that posterior capsule thickness would correlate with shoulder stiffness.

2. Materials and methods

2.1. Research design

A post-test only design was used to assess eight dependent variables and one independent variable. The independent variable was arm (dominant and non-dominant). The dependent variables were preparatory and reactive EMG (area, peak, time to peak, onset, and co-contraction), active glenohumeral joint stiffness, and posterior capsule thickness.

2.2. Participants

Twenty-four healthy collegiate baseball players (pitchers: $n = 12$; age = 19.4 ± 1.16 years SD, mass = 88.14 ± 4.81 kg SD, and height = 188.38 ± 5.61 cm SD; position players: $n = 12$; age = 19.8 ± 1.48 years SD, mass = 90.19 ± 6.67 kg SD, and height = 184.15 ± 2.97 cm SD) volunteered to participate in this study. Exclusion criteria consisted of previous injury and/or surgery in the past 6 months and subjects were not allowed to throw in the 5 days prior to testing. The study was approved by a University Institutional Review Board. Informed consent and a Health History Questionnaire were obtained from participants prior to testing.

2.3. Instrumentation

2.3.1. Electromyography (EMG) assessment

The Konigsberg EMG telemetry unit (Konigsberg Instruments, Pasadena, CA, USA) was used to measure myoelectric activity with self-adhesive Ag/AgCl biopolar surface electrodes (Phillips Medical Systems, Andover, MA, USA) and fine wire electrodes (California Wire Company, Grover Beach, CA, USA). A single ended amplifier (impedance >10 MΩ) was used (gain 1000) with a 4th order Butterworth filter (20–500 Hz) and a common mode rejection ratio (CMRR) of 130db at dc (minimum 85 db across entire frequency of 10–500 Hz). A receiver with a 6th order filter (total gain 2000) further amplified the signal. The signal was then converted from analog to digital data with an A/D card (Keithley Metrabyte DAS-1000, Keithley Instruments Inc., Tauton, MA, USA), passed to a computer where raw EMG data was sampled at a frequency of 2400 Hz and further analyzed with LabVIEW software (National Instruments, Austin, TX, USA).

2.3.2. Active glenohumeral stiffness and short range stiffness assessment

Glenohumeral stiffness was measured by a customized Stiffness and Proprioception Assessment Device (SPAD) (Huxel et al., 2008). The SPAD includes a brushless Danaher/Kollmorgen servo motor (B-404-B-B4) and gearbox (UT018-050, 50:1) connected to an amplifier/controller (Copley Xenus driver XSL-12-36-R). The SPAD device is operated with a customized LabVIEW motor control program.

2.3.3. Posterior capsule thickness assessment

Ultrasound scanning of the glenohumeral joint posterior capsule thickness was performed with a 10 MHz linear transducer and a commercially available compact ultrasound system (Sonosite Titan, Sonosite Inc., Bothell, WA, USA), which has a measurement accuracy of 0.15 mm. A priori intratester reliability of posterior capsule thickness was assessed by the primary investigator and is reported in previous work (Thomas et al., 2011a,b).

2.4. Procedures

2.4.1. Electromyography assessment

Myoelectric activity from the upper, middle, lower trapezius and serratus anterior muscles was recorded with surface electrodes using standard procedures (Huxel et al., 2004, 2008). The ground electrode was placed over the ipsilateral acromioclavicular joint (AC). Intramuscular fine wire bipolar electrodes were placed into the supraspinatus, infraspinatus, and teres minor under sterile conditions using the single-needle technique described by Basmajian and Deluca (1985) and previously used in our lab (Huxel et al., 2004, 2008). Fine wire EMG was required to accurately record EMG from the rotator cuff muscles which are deep to the superficial muscles of the shoulder. The wire electrodes were attached to connector cables and completed the circuit by connecting the electrode/wires to the amplifier (Fig. 1). Correct placement of all electrodes was confirmed by monitoring activity during isolated muscle testing of the specific muscle and EMG signal identification on a personal computer running EVaRT 5.1 software (Motion Analysis Co., Santa Rosa, CA, USA). These measurements were taken bilaterally for all subjects.

2.4.2. Glenohumeral stiffness assessment

The shoulder and elbow were positioned in the 90°/90° position with 0° of external rotation to replicate the deceleration phase of the overhead throwing motion. Participants were instructed to perform a maximum voluntary isometric contraction (MVIC) for external rotation. This value was used to calculate the amount of force participants used during the active stiffness condition (constant external rotation force of 50% MVIC). Once positioned, participants were instructed to produce and maintain an external rotation force, with visual biofeedback, against the attachment arm (Fig. 2). A perturbation was randomly applied within a 10-s