



UNITED STATES TENNIS ASSOCIATION

# Muscle Activation in Coupled Scapulohumeral Motions in the High Performance Tennis Serve

Kibler<sup>1</sup>, W.B., Chandler<sup>2</sup>, J.T., Shapiro<sup>3</sup>, R., Conuel<sup>3</sup>, M.

1. Lexington Clinic Sports Medicine Center, Lexington, Kentucky, 2. Jacksonville State University, Jacksonville, Alabama, 3. University of Kentucky, Lexington, Kentucky

This research was funded by the USTA Sport Science and Medicine Research Grant (1996)



JACKSONVILLE STATE UNIVERSITY

## INTRODUCTION

• Previous studies have utilized EMG (Electromyography) to investigate muscles in the tennis serve and have measured intensity of muscle activation as a percentage of maximal voluntary isometric contraction. These studies measured muscle activation in the various phases of the serve and have found that each of the muscles were active during all phases of the serve at varying levels of intensity.

• This study provides greater detail of the muscle activity during the serve by investigating patterns and sequencing of muscle activation. Specific patterns of activation are established and a clearer picture of how coupled activations accomplish the motions and positions of the arm in the tennis serve is given. In addition, guidelines for goals and content of rehabilitation and conditioning programs are suggested.

## PURPOSE

To evaluate muscle activation patterns in selected scapulohumeral muscles in the tennis serve. These patterns of muscle activation have not been evaluated in other studies of the tennis serve. Fine wire and surface EMG was used to calculate onset and offset timing of muscle activation.

## SAMPLE

This study was conducted on 16 accomplished tennis players (National Tennis Rating Program (NTRP) rating 4.5–6.5; club tournament level or higher). Subjects with a history or finding of shoulder problems, occult or overt instability, rotator cuff tendinitis, or other current shoulder pathology were excluded. The subjects were all males and ranged in age from 18–40 years. They were recruited from the local tennis community; all filled out personal data and injury forms, and were evaluated by the senior author before participation

## METHOD

• Muscle activation in selected muscles of the dominant arm was examined using a combination of surface and fine wire insertional electrodes. The muscles evaluated were the upper trapezius, lower trapezius and serratus anterior, all prime scapular stabilisers, the supraspinatus, infraspinatus and teres minor, components of the rotator cuff, and the anterior and posterior deltoids; the primary positioners of the arm.

• Surface electrodes were placed over the anterior and posterior heads of the deltoid, serratus anterior, and superior and inferior portions of the trapezius, and fine wires were inserted into the supraspinatus, infraspinatus and teres minor muscle bellies. All electrode placements were consistent with previously published protocols.

• After each electrode was placed, manual muscle testing was then performed to show proper placement and appropriate EMG signal. The surface electrodes were silver/silver-chloride with built-in pre-amplifier. The fine wire electrodes were introduced through a 23-gauge hypodermic needle. EMG signals were recorded at 2000 Hz on an AT-type personal computer. Quiet files were collected for each muscle, to establish the baseline from which muscle activity was determined.

## METHOD (cont.)

• Analog to digital conversion was performed with a Data Translation A to D board and subsequent analysis of EMG data was accomplished on a Sun SPARC 330 workstation. The signal was rectified and the mean established for the quiet file. Each muscle was considered "on" when its amplitude was 3 SD points above baseline signal for a 25 ms window. The duration of activation was measured, and the muscle was considered to be "off" when the amplitude dropped below 3 SD above baseline signal.

• The subjects reported no differences in their motion from the surface or the indwelling electrodes and the mechanics of the service motions were noted to be unchanged after the electrodes were placed, when compared with the preplacement service motions.

• The normal service motion was accomplished by having each subject take as many trials as were needed to feel comfortable with the electrodes and wires. Once the subjects felt comfortable and warmed up, the study trials were performed, using a Tennis Target Trainer (Tennis Target, Burbank, California, USA) as the target to aim for. The target trainer was placed the same distance away from the subject, as the net is located from the baseline on the tennis court. A successful trial occurred when the ball went through the target. Each subject had to complete three successful service trials.

• Four NAC 60/200 Hz black and white high-speed cameras at 200 frames/s recorded each service motion, and the video data was used to track arm motion and to delineate the phases of the service motion as they related to the arm motion: cocking, acceleration, ball impact, deceleration, and follow-through. Ball impact was considered as time zero. Arm motion was measured as glenohumeral rotation and as humeral motion in horizontal plane abduction and adduction.



## WHAT DID THE STUDY FIND?

Patterns of muscle activation were observed during the tennis serve motion.

- The serratus anterior (–287 ms before ball impact) and upper trapezius (–234 ms) were active in the early cocking phase, while the lower trapezius (–120 ms) was activated in the late cocking phase just before the acceleration phase.
- The anterior deltoid (–250 ms) was activated in early cocking, while the posterior deltoid (–157 ms) was activated later. The teres minor (–214 ms) was activated early in the cocking phase. The supraspinatus (–103 ms) was activated in late cocking.
- The infraspinatus (+47 ms after ball impact) was activated in follow-through. All muscles except infraspinatus were activated in duration of more than 50% of the service motion.

## CLINICAL IMPLICATIONS

- One of the goals of a conditioning program is to optimise muscle activation and one of the goals of rehabilitation is to restore optimal muscle activation. This study suggests some guidelines towards those goals. As different parts of the same muscle (upper and lower trapezius, anterior and posterior deltoid) are activated at different times, and for different durations, during the service motion, they can act as separate muscles. Conditioning or rehabilitation exercises must be directed at activation of each part of the muscle in their proper position and function.
- Second, as the muscle activations start at the scapular stabilisers and proceed towards the rotator cuff, conditioning and rehabilitation exercises should adhere to the same progression. They should emphasise scapular stability and control as a basis for rotator cuff activation, and should integrate the training of the muscles along kinetic chain principle. Eccentric activation of the scapular stabilisers, the anterior deltoid and the posterior deltoid should be implemented, and plyometric or stretch/shortening activities with medicine balls or tubing should be emphasised. A stable scapular base is required for maximal rotator cuff activation, so rotator cuff emphasis should be delayed until adequate scapular control is achieved.
- Third, most of the muscles are activated for a high percentage of the duration of the tennis serve motion. This implies that part of the training of these muscles should involve endurance exercises. The early activation of the serratus anterior in the cocking phase shows that this muscle should be rehabilitated as a scapular external rotator. The patient can progress to rotator cuff exercises after scapular control is regained.

## CONCLUSION

This study demonstrates that there are patterns of activation of muscles around the scapulohumeral articulation in the normal accomplished tennis serve. Rehabilitation and conditioning programs for tennis players should be structured to restore and optimize the activation sequences (scapular stabilizers before rotator cuff), task specific functions (serratus anterior as a retractor of the scapula, lower trapezius as a scapular stabilizer in the elevated rotating arm) and duration of activation of these muscles.

## REFERENCES

- Niemenen H, Takala EP, Vikari-Juntura E. Normalization of electromyogram in the neck-shoulder region. *Eur J Appl Physiol* 1993; **67**: 199–207.
- Kibler WB, McMullen J, Uhl TL. Shoulder rehabilitation strategies, guidelines, and practices. *Orthop Clin N Am* 2001; **32**: 527–38.
- Kibler WB, Sciascia AD, Dome DC. Evaluation of apparent and absolute supraspinatus strength in patients with shoulder injury using the scapular retraction test. *Am J Sports Med* 2006; **34**: 1643–7.

YEAR PERFORMED 2007