

Does the Kinetic Chain Work in the Forehand Drive Open Stance? What Electromyographic Analysis of the latissimus Dorsi and the Posterior Deltoid Muscles Showed Us

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ABSTRACT

This study examines electromyographic activity of the latissimus dorsi and the posterior deltoid, which act as competitors and agonists, respectively, during the rotational movement in the forehand drive technique with an open stance, among young tennis players aged 12-16. Eleven athletes participated in the research. The average of the maximum activation of the latissimus dorsi recorded with EMG, in the movement of the forehand drive corresponds to $4,15 \pm 1,137$ and for the posterior deltoid, the maximum activation was $6,70 \pm 1,90$. The results of the measurements indicate differences in the sequence of activation between the two muscles. The posterior deltoid was the second muscle to contract after the latissimus dorsi. At the start of the rotating action, the latissimus dorsi was most fully activated, while the maximum activation posterior deltoid was towards the end of the movement. The t-test showed $P < 0.05$ between the two means. So, we found that the function of the motor chain follows the coordination of the involvement of the two muscles to perform the forehand drive with the open stance, which means that the rotational motion transfers significant energy which translates into speed and strength. These results are very important to coaches, physical trainers, and physiotherapists in providing appropriate treatment, training, and rehabilitation protocols not only for young athletes but also older in age.

Keywords: Forehand Drive with the Open Stance, Tennis, Surface Electromyography.

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I. INTRODUCTION

The most prevalent groundstroke used throughout games is the forehand drive (Johnson & McHugh, 2006). There are three basic stances, that a forehand drive can be executed. The open stance, the square stance, and the closed stance. Tennis players should know all three stances because each is used depending on the speed, spin, and height of the incoming ball that the player receives and the position that the player has on the court, and where he wants to send it. Additionally, Schonborn (1999) asserted that advanced tennis players play about 90% of their forehands with an open stance. Recent work by Reid *et al.* (2013) confirmed that 77% of Roger Federer's forehands on clay courts and 72% of his forehands on grass courts were struck from open stances. The forehand open stance results from the body's maximal rotation and calls for a lot of strength and flexibility in the torso and lower body (Crespo & Reid, 2009). In order to effectively transfer energy from the lower body through the core and into the racket and ball at impact, this shot calls for powerful hip and upper trunk rotation. The major movements that generate racket speed in the forehand are trunk rotation, horizontal shoulder abduction, and internal rotation (Roetert & Kovacs 2011). The forehand drive analysis by phase also showed that the majority of dominant shoulder and upper limb muscles are recruited at a low level during the preparation phase as opposed to a high level during the acceleration phase and a medium level during the follow-through phase (Ryu *et al.*, 1988; Morris *et al.*, 1989).

The middle and posterior deltoid, latissimus dorsi, infraspinatus, and teres minor perform concentric contractions of the shoulder and upper arm rotation in the transverse plane, which are followed by contractions of the wrist extensors. (Ryu *et al.*, 1988).

Regardless of skill level (Bahamonde, 1999), trunk rotation is a crucial factor in the development of racket speed, claim some authors (Seeley *et al.*, 2011). According to Elliott *et al.* (1997), the forward speed of the shoulder only makes up around 10% of the racket speed at impact. In addition, the research of the tennis forehand action revealed that the torso and the order in which the muscles of the upper extremities contract are independent of the tennis players' ages and skill levels. (Rouffet *et al.*, 2009).

Earlier electromyography (EMG) analyses of the forehand drive in adult tennis players concentrated on the dominant shoulder and upper limb muscle activation (Ryu *et al.*, 1988; Morris *et al.*, 1989). In these experiments, it was found that most muscles had low EMG levels during the pre-drive phase, moderate levels throughout the drive phase, and high levels during the acceleration period. According to Ryu *et al.* (1988), the acceleration phase is characterized by a quick internal rotation of the upper limb, which causes the pectoralis major muscle to contract heavily. Meanwhile, according to Morris *et al.* (1989), the upper limb muscles appear to stabilize the arm as a rigid extension of the racket.

Groups of muscles determine when the trunk and upper limb muscles activate and deactivate, and this timing does not vary as the racket mass increases (Rogawski *et al.*, 2009).

Finally, when the speed of movement increases, these relationships have been reported to activate the agonist and antagonist muscle during slow upper limb movements performed (Antony & Keir, 2010; Brindle *et al.*, 2006; Marsden *et al.*, 1983) and high speeds (Illyés & Kiss, 2005). Additionally, according to (Kellis & Baltzopoulos, 1998), the antagonist IEMG action varies depending on the muscle under study. As shown by the IEMG activity of the antagonists in this work, the antagonist activity plays a significant role in determining the joint moment that results from isolated isokinetic maximal voluntary joint movements.

Although Knudson and Bahamonde (1999) examined trunk muscle activation in the collegiate players' open and square stance forehands measured in the rectus abdominis, erector spinae, and external oblique, our investigation concentrated on energy transfer to subsequent muscles that are crucial in the shoulder abduction and internal rotation that generates racket speed.

This study's objective was to ascertain the timing and degree to which two key muscles, the latissimus dorsi and the posterior deltoid, which function as competitors and agonists respectively, are engaged during the rotational movement in the forehand drive method with an open stance.

Therefore, this muscle activity study aims to help coaches understand the synergy of these two muscles in the open stance forehand to help enhance tennis young players' performance.

II. METHODS

Eleven right-handed juvenile tennis players, ages 12 to 16, who compete in events run by the Hellenic Tennis Federation and are placed at the top of the national list, participated in this study (5 males and 6 females). With training experience ranging from seven to eleven years, they participated in a 12±2 hours weekly tennis-specific training program (technical, tactical, and physical condition). Their ages ranged from 13.4±1.40 years and their heights and weights were 162.5±12.14 cm, and 50.20±10.22 kg, respectively.

Prior to participating in the study, all participants were questioned about whether they had experienced any musculoskeletal injuries or other issues. The ethics committee of the Faculty of Sport Science at the Aristotle University of Thessaloniki approved this study, and all methods followed the advice and principles outlined in the Declaration of Helsinki. Before participating, both participants and parents supplied written informed consent after being fully informed of all experimental methods. In the Neuromechanics lab, at least ten forehand drives were performed by each subject once they had mastered the forehand drive with an open stance.

A. Tools for Measurement

Three active surface electrodes and a pre-amplifier from Motion Control Co. were used to capture the electric activity of the muscles in the lower extremities (Fig. 1). The analog-digital (A/D) transformation/input card, used by both the electromyograph device and the force platform, is directly attached to each active electrode.

Each of the three active electrodes has a central reference surface, two detecting surfaces—one on each of its two ends—and one detecting surface in the middle. The diameter of each surface is 1.25 cm, and there is 3.5 cm between the two centers and the two detecting surfaces.

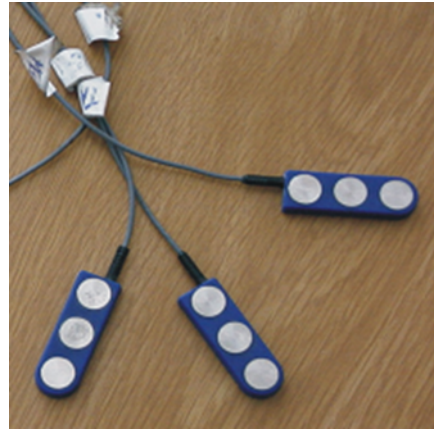


Fig. 1. Electrodes on the surface.

B. How the Research Was Conducted

Using Bio Ware® Software Type 2812A, measurements were carried out in the Neuromechanics Laboratory at Serres TEFAA [Physical Education and Sports Science School of Serres, Aristotle University of Thessaloniki (AUTH)]. The test subjects warmed up according to a set protocol, then performed an open stance forehand drive for 10 minutes with the tennis ball fastened to a scaffold so that it was hanging in the air and ready to be struck by the racket. So that the tennis ball could be suspended in the air and prepared to be struck by the racket, a thick thread was passed through it and tied at the end of a pole. Initially simulating the motion, all subjects were right-handed and did not throw the tennis ball with their left hand. Ten attempts were carried out. Using electromyography's smooth curve as a guide, the optimal performance for each service mode was selected.

The steps in the recording process were as follows:

The subject is prepared, and the electrodes are placed. Amplifier calibration and recording control adjustments. Keeping track of reference values. Main protocol.

In order to get ready, each participant had to locate and clean the area where the electrodes would go. This location was chosen so that the signal would accurately depict the muscle being studied. Guidelines for the placement of electrodes while studying human muscles have been published by the European project "Surface EMG for Non-Invasive Assessment of Muscles" (Hermes *et al.*, 1999).

One electrode was placed on the latissimus dorsi (LD), the other on the posterior deltoid (PD), and the ground on the protrusion of the A7 of the neck. In the beginning, the maximum effort for the posterior deltoid was measured, pushing the dominant upper extremity on a fixed surface (wall) facing backward with all its might. The maximum effort for the latissimus dorsi was then measured, with the practitioner pressing the dominant hand against the examiner's hand, apparently performing the rotational movement of the forehand drive. The execution of the movement followed. The practitioner started his swing by holding the racket ready in the backswing – preparation position behind – with the forehand drive open stance. The examiner holding the tennis ball with the construction we mentioned, at the point of contact, gave the signal to execute the blow. The practitioner thus performed a blow as fast as he could. The right hand's posterior deltoid and latissimus dorsi were the muscles whose electromyography activity was examined.

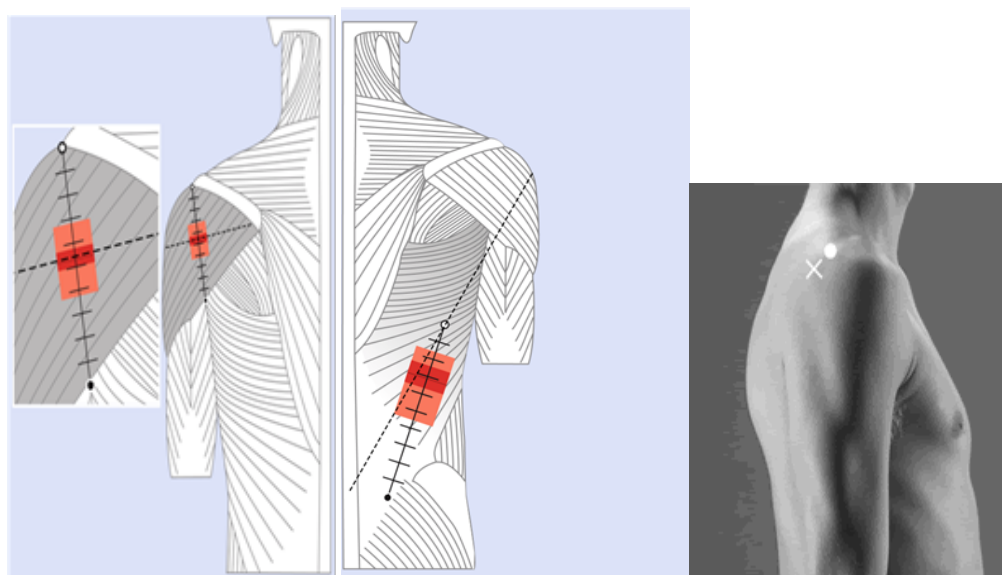


Fig. 2. Sites for electrode/sensor installation in accordance with SENIAM recommendations.

In the recording, we will see: are the muscles active? What is the difference in activity between two contractions? What is the activation order? How active is the muscle? If the kinetic chain function is applied.

C. Data Analysis

The signal was corrected in all recordings. Then we got the max value for each record. Thus, we collected 11 max values for the latissimus dorsi (LD), 11 max values for the posterior deltoid (PD), and 11 max values for the recording of forehand drive movement. Then we divided each sample by the max values of movement with the max values of LD and max values of movement with the max values of PD. We divided all the values by 100. Thus, we found the percentage of activation of each muscle separately in each execution of the sample.

D. Statistical Analysis

In order to conduct the statistical analysis, IBM SPSS (Version 20; IBM, Armonk, NY, USA) was used. At $P < 0.05$, the significance level was established. For each variable, the mean and standard deviation were computed. The two means were then compared to check if there was a statistically significant difference using the t-test for dependent samples.

III. RESULTS

This study is the first to date that reports on the electromyography activity of muscles among young tennis athletes during the execution of the forehand drive with the open stance, according to an extensive review of International and Greek pertinent literature. More precisely, this is the first time that the EMG activity of the posterior deltoid and latissimus dorsi muscles has been examined when the forehand drive is being executed with an open stance.

The average of the maximum activation, as shown in Table I, of the latissimus dorsi recorded with EMG, in the movement of the forehand drive corresponds to $4,15 \pm 1,14$ (mV) and for the posterior deltoid, the maximum activation was $6,70 \pm 1,90$ (mV).

As shown in Table II, the measurements' findings suggest that the two muscles' activation sequences differ. The posterior deltoid was the second muscle to contract after the latissimus dorsi. The latissimus dorsi is most active at the start of the rotating action, whereas the posterior deltoid is most active near the finish of the motion.

The t-test for dependent samples was then used to see if the two means differed statistically significantly, setting $p < 0.05$. We found $P = 0.000 < 0.05$, with the two means differing statistically significantly and that the difference between the two means was 2.55.

TABLE I: LATISSIMUS DORSI AND POSTERIOR DELTOID MUSCLE ACTIVITY DURING FOREHAND DRIVE WITH AN OPEN STANCE

Variable	LD	PD	P
(mV)	$4,15 \pm 1,14$	$6,70 \pm 1,90$	0,00

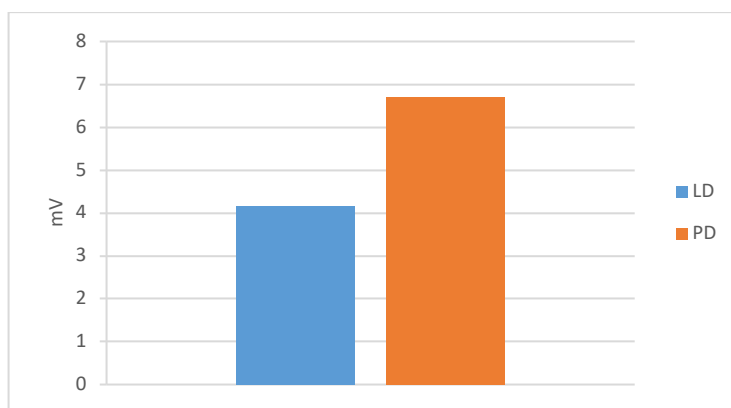


Fig. 3. The scale of activation of the latissimus dorsi, and the posterior deltoid muscles activity during forehand drive with an open stance.

TABLE II: TIME TO ACHIEVING MAXIMUM ACTIVATION; IN SEC. LATISSIMUS DORSI AND POSTERIOR DELTOID MUSCLES ACTIVITY DURING FOREHAND DRIVE WITH AN OPEN STANCE

Variable	LD	PD
(sec)	$1,30 \pm 0,53$	$1,35 \pm 0,57$

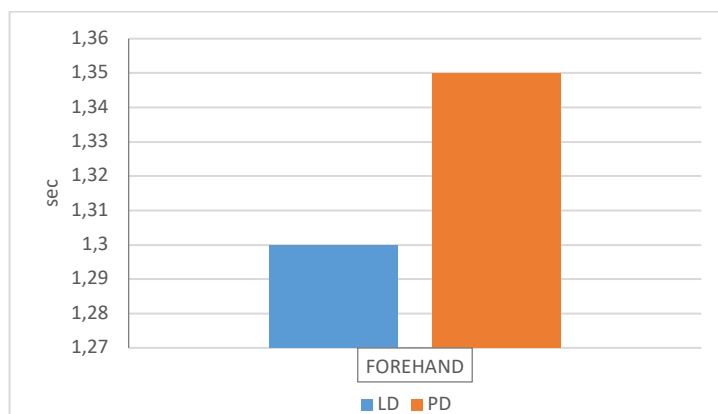


Fig. 4. Latissimus dorsi and posterior deltoid muscles at their peak of activity.

IV. DISCUSSION

The current study concentrated on the rotational movement during the execution of the open stance forehand drive technique and the sequence and degree to which two major muscles, the latissimus dorsi and the posterior deltoid, were enrolled. The Latissimus dorsi muscle swings the arm backward and rotates it inwards. The posterior deltoid muscle takes part in all movements of the upper arm. The results of the EMG showed us that first the latissimus dorsi is activated and then the posterior deltoid, which is in accordance with (Rouffet *et al.*, 2009), who states that LD muscle activated before impact to provides greater stiffness of the muscle-tendon complex to stabilize upper limb joints at impact and (Elliott, 2003) who noted that the earlier LD activation observed for the velocities near MBV might be explained by a more vigorous backswing to stretch the front-body muscles, and then the effects of the stretch-shortening cycle on these front-body muscles would be optimized to achieve high stroke velocity.

In comparison to the latissimus dorsi, the posterior deltoid was more active when the racket made contact with the ball. This is explained by the fact that, like an antagonist's muscle, the latissimus dorsi, which is engaged in the internal rotation of the upper limb, was recruited soon before impact as mentioned and by (Rouffet *et al.*, 2009). Subsequently, the posterior deltoid muscle acts as an agonist of the upper limb having greater activation, thus showing the transfer of forces from bottom to top, from one muscle to another. Also, the sequence of this kinetic chain is initiated by the larger muscle (LD), to transfer the energy to the smaller muscle (PD). So, we found that the function of the motor chain follows the coordination of the involvement of the two muscles to perform the forehand drive with the open stance, which means that the rotational motion transfers significant energy which translates into speed and strength.

V. CONCLUSION

Understanding when and how much shoulder muscles are active during the execution of the open stance forehand drive is very important to coaches, physical trainers, and physiotherapists in providing appropriate treatment, training, and rehabilitation protocols not only for young athletes but also for older age.

In fact, this type of study would make it possible to determine the links between muscle coordination and each forehand drive phase.

The modern game of tennis is often associated with open stance forehands since they allow for more power and take less time to execute. The open stance forehand is best used for fast incoming balls, high balls, and balls to the side.

REFERENCES

- Antony N.T., & Keir P.J. (2010). Effects of posture, movement and hand load on shoulder muscle activity. *Journal of Electromyography and Kinesiology*, 20, 191–8. <http://dx.doi.org/10.1016/j.jelekin.2009.04.010>.
- Bahamonde, R. (1999). Function analysis: new forehand options alter biomechanics of tennis. *BioMechanics Magazine, CMPMedica*, 51–60.
- Basmajian, J.V., & DeLuca, C.J. (1985). *Muscles Alive: Their Functions Revealed by Electromyography* (5th ed). Baltimore, MD: Williams & Wilkins.
- Brindle T.J., Nitz, A.J., Uhl, T.L., Kifer, E., & Shapiro, R. (2006). Kinematic and EMG characteristics of simple shoulder movements with proprioception and visual feedback. *Journal of Electromyography and Kinesiology*, 16, 236–49. <http://dx.doi.org/10.1016/j.jelekin.2005.06.012>.
- Crespo, M. & Reid, M.M. (2009). *ITF Coaching beginner and intermediate tennis players*. ITF Ltd. London.
- Elliott, B.C., Takahashi, K., & Noffal, G.J. (1997). The influence of grip position on upper limb contributions to racket head velocity in a tennis forehand. *Journal of Applied Biomechanics*, 13, 182–196. <http://dx.doi.org/10.1123/jab.13.2.182>.

- Elliott B.C. (2003). The development of racquet speed. In: Elliot B., Reid M., Crespo M. (editors), *Biomechanics of advanced tennis* (pp. 33–47). International Tennis Federation.
- Illyés A., & Kiss, R.M. (2005). Shoulder muscle activity during pushing, pulling, elevation and overhead throw. *Journal of Electromyography and Kinesiology*, 15, 282–9. <http://dx.doi.org/10.1016/j.jelekin.2004.10.005>.
- Johnson, C. D., & McHugh, M. P. (2006). Performance demands of professional male tennis players. *British Journal of Sports Medicine*, 40, 696–699.
- Hermens, H.J., Freriks, B., Merletti, R., Hägg, G., Stegeman, D., Blok, J. *et al.*, (1999). *SENIAM 8: European recommendations for surface electromyography*. Roessingh Research and Development B.V., results of SENIAM project. Enschede, Netherlands.
- Hirashima, M., Kudo, K., & Ohtsuki, T. (2003). Utilization and compensation of interaction torques during ball-throwing movements. *Journal of Neurophysiology*, 89, 1784–1795. <http://dx.doi.org/10.1152/jn.00674.2002>.
- Kellis, E., & Baltzopoulos, V. (1998). Muscle activation differences between eccentric and concentric isokinetic exercise. *Medicine and science in sports and exercise*, 30, 1616–23. <http://dx.doi.org/10.1097/00005768-199811000-00010>.
- Marsden, C.D., Obeso, J.A., Rothwell, J.C. (1983). The function of the antagonist muscle during fast limb movements in man. *Journal of Neurophysiology*, 335, 1–13. <http://dx.doi.org/10.1113/jphysiol.1983.sp014514>.
- Morris, M., Jobe, F.W., Perry, J., Pink, M., Healy, B.S. (1989). Electromyographic analysis of elbow function in tennis players. *The American Journal of Sports Medicine*, 1, 241–7. <http://dx.doi.org/10.1177/036354658901700215>.
- Reid, M., Elliott, B., & Crespo, M. (2013). Mechanics and learning practices associated with the tennis forehand: a review. *Journal of Sports Science and Medicine*, 12, 225–231.
- Rogowski, I., Creveaux, T., Faucon, A., Rota, S., Champely, S., Guillot, A. (2009). Relationship between the muscle coordination and racket mass during tennis forehand drive. *European journal of applied physiology*, 107, 289–98. <http://dx.doi.org/10.1007/s00421-009-1124-4>.
- Rouffet, D., Hautier, C., Brosseau, O., & Rogowski I. (2009). Coordination musculaire lors du droit lift chez les jeunes joueurs de tennis. *Science, and Sports*, 24, 111–4.
- Ryu, R.K., McCormick, J., Jobe, F.W., Moynes, D.R., Antonelli, D.J. (1988). An electromyographic analysis of shoulder function in tennis players. *The American Journal of Sports Medicine*, 16, 481–5. <http://dx.doi.org/10.1177/036354658801600509>.
- Roetert, P., & Kovacs, M. (2011). *Tennis anatomy, Human Kinetics*. Champaign IL.
- Rota, S., Hautier, C., Creveaux, T., Champely, S., Guillot, A. & Rogowski, I. (2012). Relationship between muscle coordination and forehand drive velocity in tennis. *Journal of Electromyography and Kinesiology*, 22(2), 294–300.
- Schonborn, R. (1999). *Advanced techniques for competitive tennis*. Meyer and Meyer Sport: Aachen.
- Seeley, M., Funk, M., Denning, W., Hager, R. and Hopkins, J. (2011). Tennis forehand kinematics change as post-impact ball speed is altered. *Sports Biomechanics*, 10(4), 415–426.



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