Proceeding

Supplementary Issue: Autumn Conferences of Sports Science. Costa Blanca Sports Science Events, 18-19 December 2020. Alicante, Spain.

Different electromyographic features of the gastrocnemius and the tibialis anterior muscles when comparing three types of service among young sportsmen and sportswomen

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ABSTRACT

This study examines the electromyographic activity of lower extremities and, in particular, of the tibialis anterior among young tennis players aged 12-16 years when performing three types of service, namely flat, slice and topspin. The study sample included 9 athletes. In order to record the muscle electric activity, three active surface electrodes were used with a pre-amplifier (Motion Control Co). Fluctuation analysis did not show statistically significant differences between parameters. Differences were observed in the activation sequence between the two muscles. In the flat service, the gastrocnemius is the first one activated, followed by the tibialis anterior. Maximum activation of the gastrocnemius occurs at initial lift-off, while the tibialis anterior towards the end of lift-off. In slice service, the two muscles are activated together and their maximum activation occurs when lift-off starts. In topspin service, the gastrocnemius is the first one activated, followed by the tibialis anterior. Maximum activation of the gastrocnemius occurs at initial lift-off, while the tibialis anterior towards the end of lift-off. Maximum activation of the two muscles occurred at the start of lift-off in all three service modes. In conclusion, young athletes need training to strengthen the tibialis anterior so as to improve lift-off velocity/acceleration in the service motion. Additionally, strengthening the tibialis anterior is a tool to improve foot lead. Such techniques are of the utmost importance during training so that skills as elaborate as those required for tennis service may be developed among young players.

Keywords: Electromyographic; Gastrocnemius; Tennis; Service.

Cite this article as:
Mourtzios, C., Arvanitidou, V., Athanailidis, I., & Kostopoulos, N. (2021). Different electromyographic features of the gastrocnemius and the tibialis anterior muscles when comparing three types of service among young sportsmen and sportswomen. *Journal of Human Sport and Exercise, 16*(2proc), S182-S194. doi:https://doi.org/10.14198/jhse.2021.16.Proc2.03

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Abstract submitted to: Autumn Conferences of Sports Science. Costa Blanca Sports Science Events, 18-19 December 2020. Alicante, Spain.
JOURNAL OF HUMAN SPORT & EXERCISE ISSN 1988-5202

doi:10.14198/jhse.2021.16.Proc2.03

INTRODUCTION

Increasing the height of the point at which the racket comes into contact with the ball gives the athlete higher probability of the ball landing point around 25-30 cm inside the service line (Vaverka & Cernosek, 2007). Hitting the ball at a higher point gives the player the advantage of a wider landing space within the service area. To achieve this, a leap is necessary, which transfers forces from the ground upwards. A significant role in transferring these forces is played by the ankle/instep muscles, which are actively involved in this movement.

The role of the tibialis anterior in executing such jumps has been investigated by Spagele et al., (1999), as this muscle is activated in the last stage of the jump. The authors assumed that the tibialis anterior may be involved in the preparation of the body before the gastrocnemius generates force. An earlier study concluded that activation of the tibialis anterior occurred before the gastrocnemius was activated (Nardone & Schieppati, 1998). The authors concluded that timely activation of the tibialis anterior could be considered as a preventive adjustment. In the normal standing position, the body weight tends to shift forward, ahead of the foot. The preventive action of the tibialis anterior is used to shift the body weight from the heel to the toes, so that the heel may push the ground and the toes may function as a pivotal point/fulcrum to lift the body upwards. Therefore, the role of the tibialis anterior as the main muscle of a jump, is to contribute to the preparation of the body so that the gastrocnemius may function effectively.

According to Spagele et al. (1999), at the start of a jump, there is intense mobility around the ankle/instep in plantar flexion, accompanied by activation of the gastrocnemius as well as the tibialis anterior, which, however, is activated less.

Other muscles, such as the biceps femoris, the rectus femoris and the tibialis anterior, contribute significantly, because they operate to ensure agonist-antagonist balance during the eccentric and concentric phases (Soest et al., 1995). It is, therefore, important to study these lower extremity muscles during the service movement, because they may well affect it and their contribution may improve and make tennis service execution more effective. Furthermore, it is important that their function should be studied when executing all three types of service, so that, if differences are noted, this can help both athletes and coaches to improve jumping performance during service, to reduce the rate of injuries, as well as implement different/varied methods to train the ankle/instep muscles.

METHODOLOGY

Sample

The sample included 9 tennis players, aged 12-16 years, namely 5 boys and 4 girls, who are participating in the Tennis Federation Tournament (age: 14.1 ± 1.25 years; height: 168.4 ± 10.12 cm; body mass: 54.20 ± 11.58 kg

Measuring instruments

To record lower extremity muscle electric activity, three active surface electrodes were used with a pre-amplifier (Motion Control Co), (Figure 1). Each active electrode is directly connected to the analogue-digital (A/D) transformation/input card, which is the same for the force platform and the electromyograph device. The card used for jumps was KISTLER (5606A, Analog/digital input-16A/D channels).

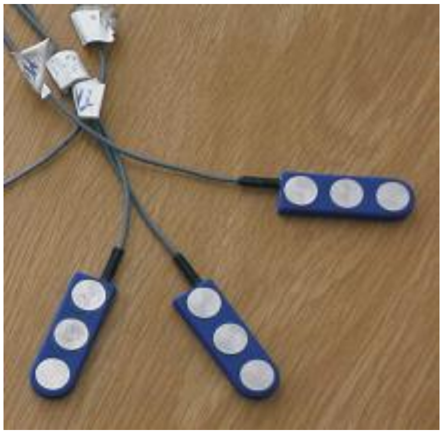


Figure 1. Surface electrodes (Motion Control Co).

Each one of the 3 active electrodes comprise two detecting surfaces, one at each of its two ends and a central reference surface. The distance between the two centres and the two detecting surfaces is 3.5cm and the diameter of each surface is 1.25cm.

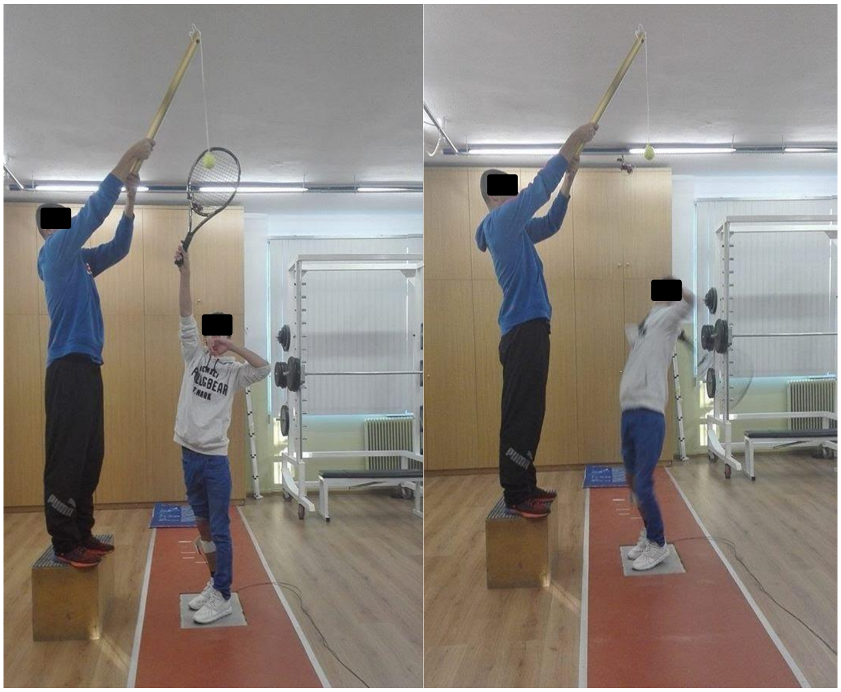


Figure 2. Scaffold, tennis ball and athlete ready to execute.

Procedure followed for the research

Measurements were performed at the Neuromechanics Laboratory of Serres TEFAA [Physical Education and Sports Science School at Serres, Aristotle University of Thessaloniki (AUTh)], using BioWare® Software Type 2812A. The athletes tested warmed up using a standardised routine, which was followed by a 10-minute execution of all three different service modes, while the tennis ball was fixed onto a scaffold, so as to be suspended in the air and ready to be contacted by the racket. A thick string was passed through the tennis ball and tied at the end of a pole, so that the tennis ball could be suspended in the air and ready to be contacted by the racket. All subjects were right-handed and initially simulated the movement; they did not throw the tennis ball themselves using their left hand. They executed three attempts for every type of service using the '*foot back*' technique. The best performance was chosen for each service mode based on the smooth curve of the electromyograph.

The recording procedure had the following stages:

1. Preparation of the subject.
2. Placement of the electrodes.
3. Adjustment/Calibration of the amplifier and recording control.
4. Recording reference values.
5. Main protocol.

Each subject was prepared by identifying and cleaning the site where the electrodes would be placed. This site was in the muscle belly, so that the signal would best represent the muscle examined. The European project titled '*Surface EMG for Non-Invasive Assessment of Muscles*' (Hermes et al., 1999) has published guidelines as to where electrodes should be placed to study human muscles. The muscles studied for their electromyographic activity were the gastrocnemius and the tibialis anterior of the right (hind) leg.

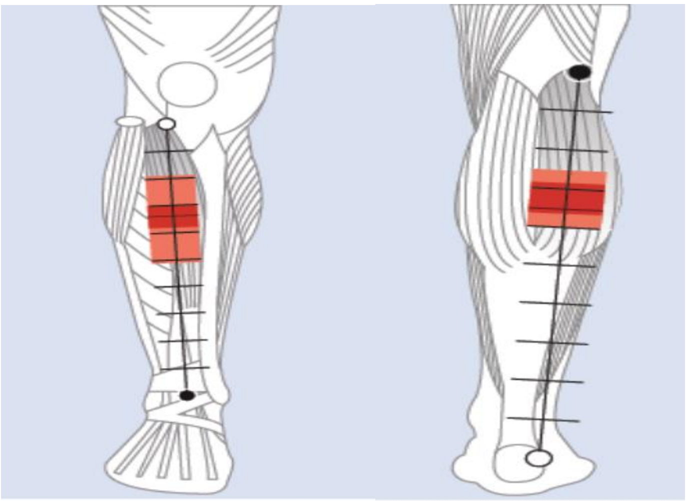


Figure 3.Electrode/Sensor placement sites according to SENIAM guidelines.

EMG Analysis

To extract EMG features, the raw signal was initially recorded for each muscle and then fully rectified and smoothed. Recording frequency was set at 1000 Hz and the frequency range from 20 to 500 Hz. To compare EMG parameters, it was considered necessary to smooth them. Smoothing, consequent rectification and further processing of EMG signals used the MATLAB (R2007b, version 7.5.0.342) mathematical program software. Specifically, for this given goal, the '*myos*' programme was used, which was created through the cooperation of Serres TEFAA [Physical Education and Sports Science School at Serres] with the Faculty of Engineering, AUTh (School of Electrical and Computer Engineering). The RMS (Root Mean Square) method was used to compare EMG data. According to De Louca (1997), the RMS method offers the best presentation of signal strength when examining voluntarily performed dynamic muscular activities. To perform EMG analysis the following variables were calculated:

1. Maximum activation value (RMS) for each muscle.

2. Time to achieve maximum activation [Max(x)] for each muscle.
3. Maximum vertical reaction force Max Fz.
4. Scale of activation Max (Y) for each muscle.
5. Supporting Time tstir = Stop x - Start x.

Statistical analysis

Statistical packet SPSS 25.0 for Windows was used to perform the statistical analysis. The significance level was set at $p < .05$. One-way ANOVA was used to examine the impact of dependent variables Max Fz, Max(Y), Max(X), RMS and tstir, which is the supporting time on the tibialis anterior and the gastrocnemius, while performing the three different service modes, namely flat, slice and topspin.

RESULTS AND DISCUSSION

Exhaustive investigation of International and Greek relevant literature indicates that this study is the first one to date that reports on the electromyographic activity of muscles among young tennis athletes during execution of three service modes, i.e., flat, slice and topspin. More specifically, this is the first time that EMG activity of the tibialis anterior and the gastrocnemius has been studied during the performance of three types of tennis service.

Given that the tibialis anterior muscle is involved and used to shift the body weight from the heel to the toes, so that the heel may be in a position to also lift off the ground the toes that function as a fulcrum/pivotal point to push the body upwards (Nardone & Schieppati 1998), the role of the tibialis anterior as the main muscle during service, is part of the preparation of the body, so that the gastrocnemius may function effectively. This is why the second muscle studied is the gastrocnemius, which performs an eccentric contraction when the ankle joint/instep moves, thus contributing to the transfer of forces upward through the kinetic chain to ensure an effective service is performed.

The results of measurements indicate differences in the sequence of activation between the two muscles. In the flat service, the gastrocnemius is the first one activated, followed by the tibialis anterior. Maximum activation of the gastrocnemius occurs at initial lift-off, while the tibialis anterior towards the end of lift-off. In slice service, it was observed that the gastrocnemius and the tibialis anterior are activated simultaneously and their maximum activation occurs at the moment lift-off starts. In topspin service, the gastrocnemius is the first one activated, followed by the tibialis anterior. Maximum activation of the gastrocnemius occurs at initial lift-off, while the tibialis anterior towards the end of lift-off.

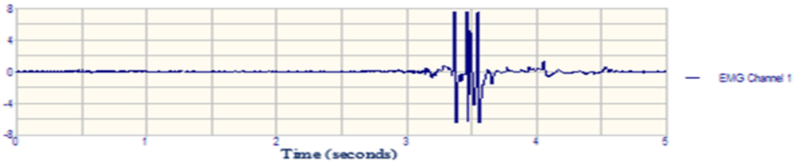
There not being any significant differences in the EMG results of this study is probably due to the fact that measurements were made for young tennis athletes, where muscular growth is not complete, and therefore did not allow much room for differences to be found among the three service modes.

Therefore, the differences presented in the maximum vertical force among the three service modes were minimal, with flat service taking the lead compared to the other two; this is due to the fact that flat service is the first service and is executed at higher velocities compared to the other two, and when young athletes execute it they exert higher maximum force. Furthermore, the time the gastrocnemius needed for its maximum activation presented minimal differences between the three service modes. At topspin service, maximum activation of the gastrocnemius was faster compared to slice service, which was slower. Additionally, the scale of gastrocnemius activation hardly showed any difference, with flat services taking the lead when compared to the other two types. Finally, the RMS for the gastrocnemius was more or less the same for the three service types. The time for achieving maximum activation for the tibialis anterior, as shown in the results, hardly differed for the three types of service, with slice service needing the longest, followed by the topspin and finally flat service. The scale of the activation of the tibialis anterior also showed hardly any differences, with topspin service notching the highest values, followed by slice and then flat service. The RMS for the tibialis anterior presented the highest values for slice service, followed by flat and then topspin service. Supporting time t stir = stop x – start x is longer for topspin service, followed by slice and then flat service. Irrespective of the technique used to perform the service, modifying supporting time is crucial for the service outcome. The highest mechanical strength during the push off phase is achieved with intermediate supporting times, which indicates that there is an optimal way for performing the jump. The optimal manner is determined by the hardness of the muscles surrounding the ankle/instep and the knee, by the pre-activation of the muscles and the scale of their activation (Arampatzis, Schade, Walsh & Bruggemann 2001).

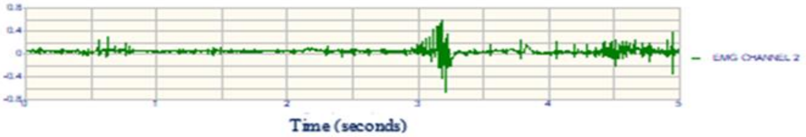
The results of this research illustrate that the tibialis anterior actively contributes to the service movement. It is a muscle that participates in the kinetic chain transferring forces from the lower extremities to the upper part of the torso. A successful service is the result of the sum of the forces that start from the ground and are transferred through the kinetic chain to the contact with the ball (Kibler, 1995). Bending the knees (eccentric contractions of the quadriceps) creates significant reaction forces from the ground, which are the first basic ones of the service movement. Knee bending is defined as loading of the lower body (Elliott, Marshall & Noffal, GJ. 1995). The gastrocnemius, the soleus, the quadriceps, the gluteus and the hip rotators contract eccentrically to load the legs and initiate hip rotation (Roetert & Kovacs, 2011). In the second half of the push off, the high activation of the gastrocnemius contributes to transferring energy from the knee to the ankle/instep (Bahamonte & Knudson, 2001). In particular, the simultaneous knee extension combined with the plantar flexion result in maintaining the length of the gastrocnemius at relatively stable levels. This way the gastrocnemius is working almost isometrically, producing high strength levels even when the ankle/instep velocity is high. Furthermore, the high activation of the gastrocnemius also serves another purpose: it ensures exceptionally high forces to be exerted, as the knee and ankle joint/instep extend. During the eccentric contraction of descent, the active muscle is the tibialis anterior, which is the ankle/instep flexor. Its activity is lower in the muscle group that works to extend the knee joint. The significant mechanism in this type of eccentric-concentric motion is the '*stretch-shortening cycle*' (Komi & Nicol, 2011). The elastic structures of agonist muscles stretch during descent and there is accumulation of the elastic energy used during the ascent (concentric contraction phase), which contributes to improving the jump of tennis service(Elliott, Reid & Crespo, 2003).

Girard et al. (2005) investigated muscular activity of the lower extremities during service execution; theirs was the first study to investigate EMG activity among tennis players of three different levels. Results indicated high EMG activity in lower extremity muscles, which were recorded near the end of the concentric phase of service, regardless of the athlete's performance level. The high EMG activity of the vastuslateralis, the vastusmedialis, and the gastrocnemius confirms that these muscles were responsible for the extension of the lower extremity during this phase. This study has included the tibialis anterior, which presents high activity and participates in the extension of the lower extremity during this phase. The high activity noted by Girard et al. (2005) in the extensor muscles of the knee during the concentric phase, is related to the finding that the highest motor energy or the forces created during the service develop in the lower extremities and the torso. These factors indicate that the efficiency of the service is closely correlated with the pre-loading of the muscles and the use of the elastic energy in the extensors of the lower extremity, which contribute towards increasing the velocity of the tennis ball and its contact at the highest point recorded. Finally, the use of the scaffold is a limitation for the study.

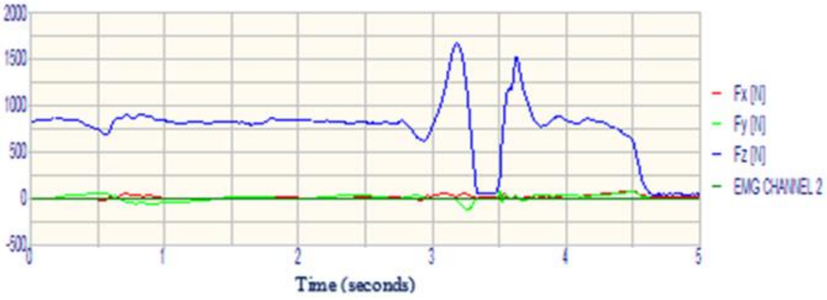
Preliminary examination of EMG results



Tibialis anterior.

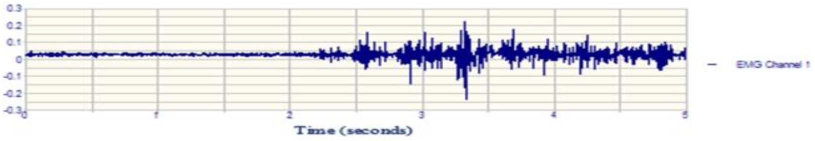


Gastrocnemius.



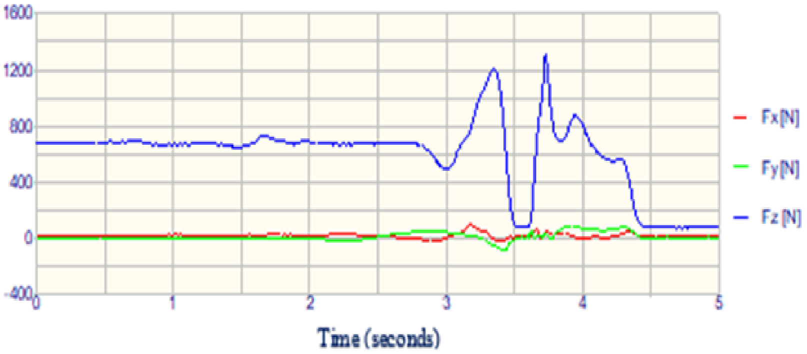
Ground reaction forces.

Figure 4. Example of EMG recording when flat service is executed.



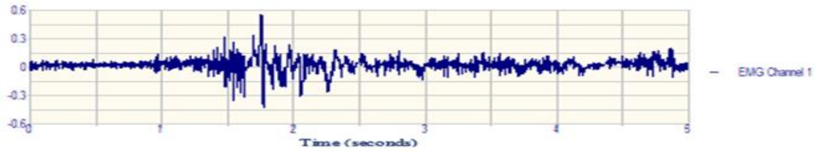
Tibialis anterior.

Gastrocnemius.



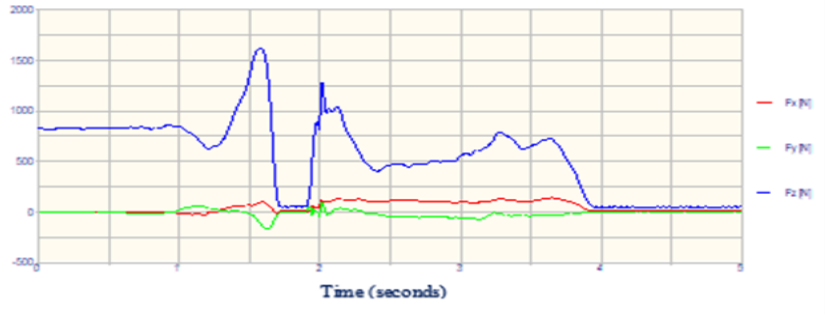
Ground reaction forces.

Figure 5.Example of EMG recording when slice service is executed.



Tibialis anterior.

Gastrocnemius.



Ground reaction forces.

Figure 6. Example of EMG recording when topspin service is executed.

EMG Results

Table 1. Maximum vertical force average.

	Average (N)	Lift-off velocity (N)
Flat	1303.33	258.20
Slice	1285.20	266.98
Topspin	1277.50	331.94

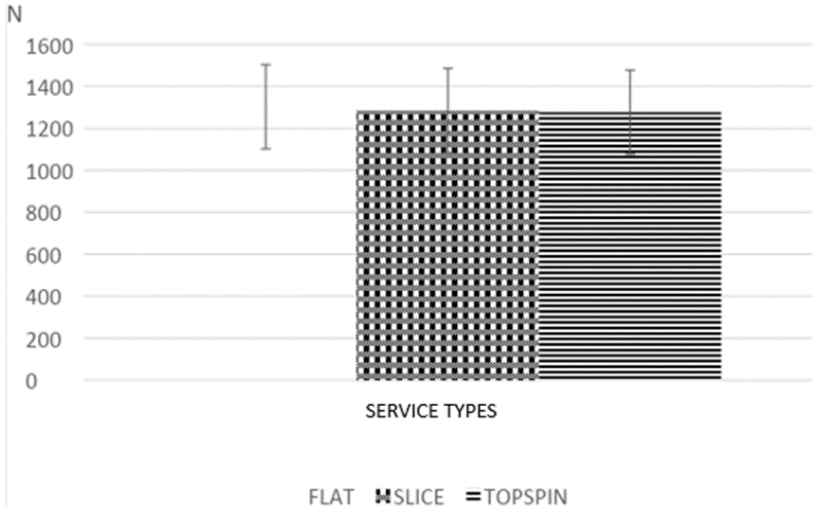


Figure 7. Maximum vertical force.

Time to achieving maximum activation of the gastrocnemius

Table 2. Time to achieving maximum activation of the gastrocnemius; in sec.

	Average (S)	Lift-off velocity (S)
Flat	1.64	23
Slice	1.66	39
Topspin	1.39	35

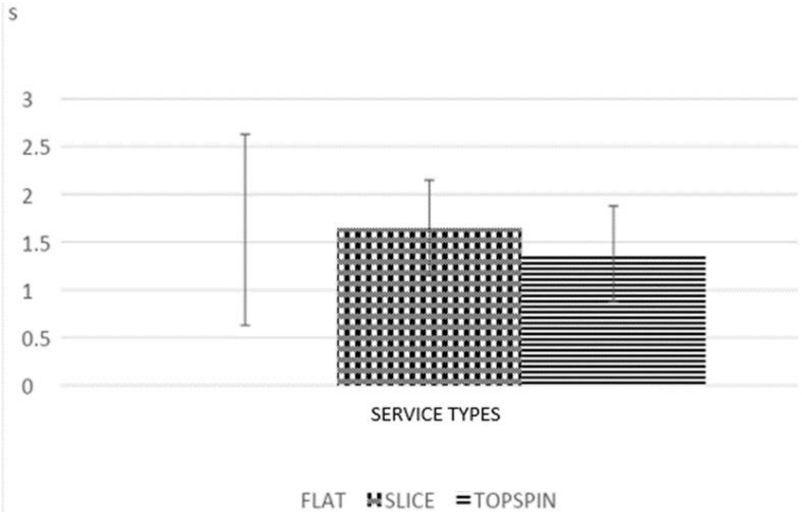


Figure 8. Time to achieving maximum activation of the gastrocnemius muscle.

Scale of activation of the gastrocnemius

Table 3. Scale of activation of the gastrocnemius.

	Average (mV)	Lift-off velocity (mV)
Flat	60	26
Slice	55	12
Topspin	50	12

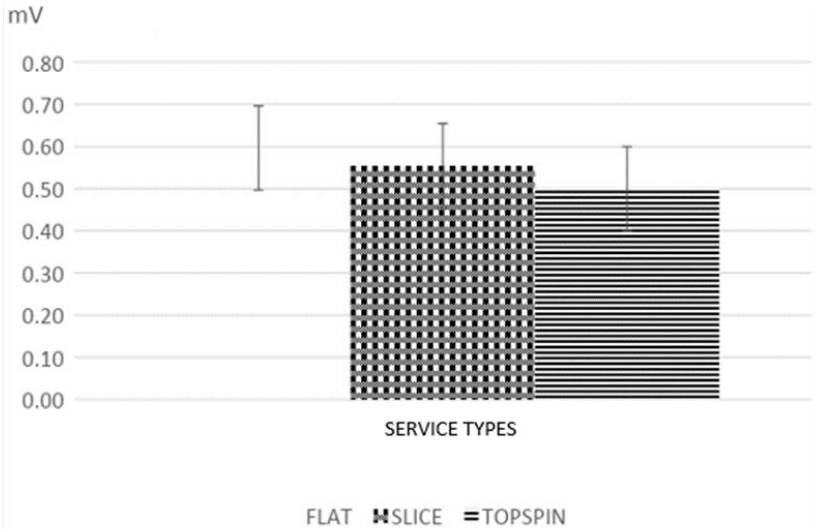


Figure 9. Average of the scale of activation of the gastrocnemius.

RMS for the gastrocnemius

Table 4. Average values for the RMS for the gastrocnemius.

	Average (mV)	Lift-off velocity (mV)
Flat	08	02
Slice	07	02
Topspin	07	01

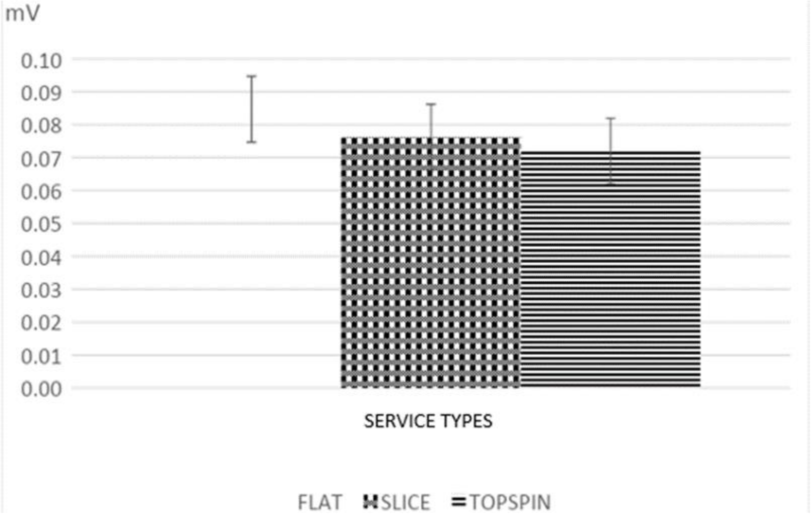


Figure 10. RMS for the gastrocnemius.

Time to achieving maximum activation of the tibialis anterior

Table 5. Time to achieving maximum activation of the tibialis anterior.

	Average (s)	Lift-off velocity (s)
Flat	1.58	27
Slice	1.83	53
Topspin	1.59	52

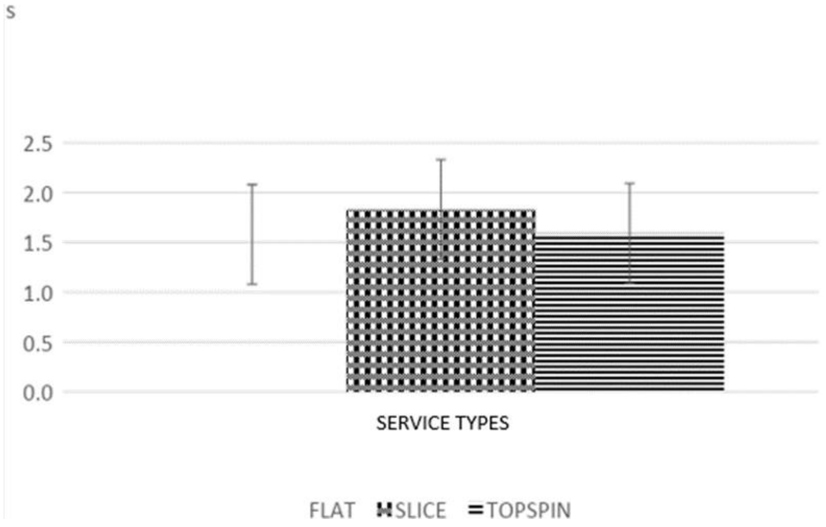


Figure 11. Time to achieving maximum activation of the tibialis anterior.

Scale of activation of the tibialis anterior

Table 6. Average values of the scale of activation of the tibialis anterior.

	Average (mV)	Lift-off velocity (mV)
Flat	0.39	14
Slice	0.42	20
Topspin	0.45	16

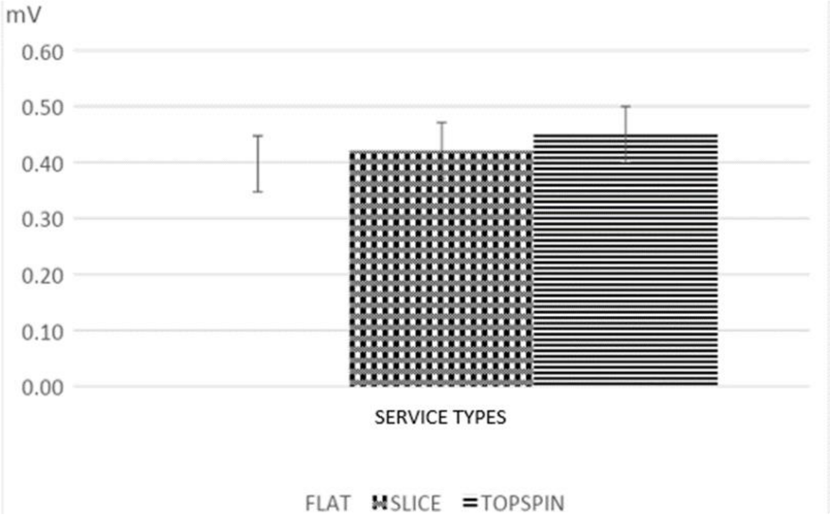


Figure 12. Scale of activation of the tibialis anterior.

RMS for the tibialis anterior

Table 7. Average RMS values for the tibialis anterior.

	Average (mV)	Lift-off velocity (mV)
Flat	0.16	15
Slice	0.24	29
Topspin	0.07	04

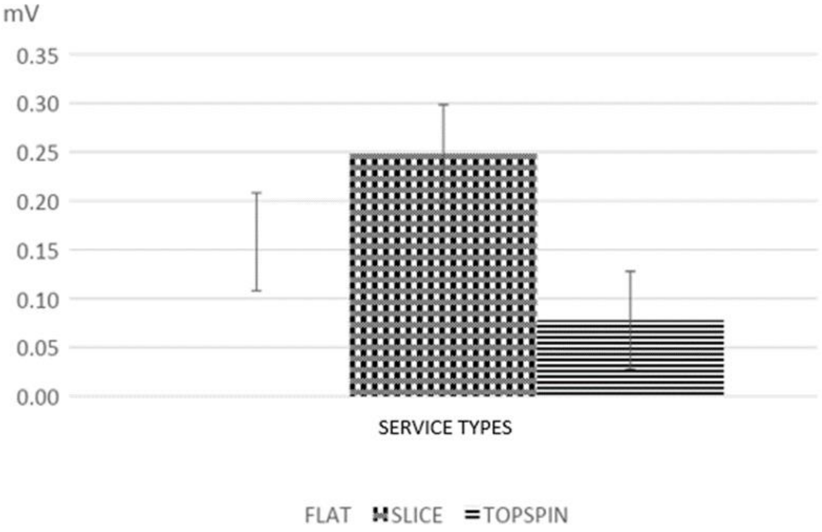


Figure 13. RMS for the tibialis anterior.

Supporting time t stir = stop x–start x

Table 8. Supporting time stop x– start x for the three service modes.

	Average (s)	Lift-off velocity (s)
Flat	0.99	0.36
Slice	1.01	0.28
Topspin	1.02	0.19

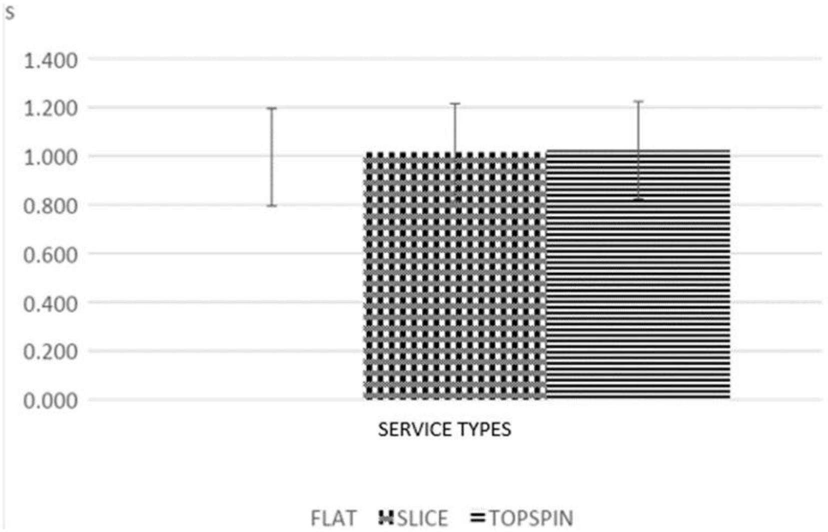


Figure 14. Supporting time stopx – startx for the three service modes.

CONCLUSIONS - A COACH'S PERSPECTIVE ON SERVICE

In conclusion, the results of this study indicate that young athletes need training to strengthen the tibialis anterior, so as to improve lift-off velocity/acceleration in the service motion. Therefore, tennis coaches should pay particular attention when drafting their training plans: they should add exercises for the tibialis anterior, which will help tennis players execute services using a better technique and having the best possible result and include another basic element in their training schedule. Furthermore, the results of this study support that tibialis anterior should be strengthened as a tool aiming to improve the '*leg drive*' lead and, therefore, enhance service performance. Such techniques are of the utmost importance during training so that such elaborate skills as those required for tennis service may be developed among your players.

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