Trunk and Upper Limb Muscle Activation During Flat and Topspin Forehand Drives in Young Tennis Players

Isabelle Rogowski, David Rouffet, Frédéric Lambalot, Olivier Brosseau, and Christophe Hautier

This study compared EMG activity of young tennis players’ muscles during forehand drives in two groups, GD—those able to raise by more than 150% the vertical velocity of racket-face at impact from flat to topspin forehand drives, and GND, those not able to increase their vertical velocity to the same extent. Upper limb joint angles, racket-face velocities, and average EMG rms values, were studied. At similar joint angles, a fall in horizontal velocity and a rise in racket-face vertical velocity from flat to topspin forehand drives were observed. Shoulder muscle activity rose from flat to topspin forehand drives in GND, but not for drives in GD. Forearm muscle activity reduced from flat to topspin forehand drives in GD, but muscle activation was similar in GND. The results show that radial deviation increased racket-face vertical velocity more at impact from the flat to topspin forehand drives than shoulder abduction.

Keywords: racket sports, groundstroke, surface electromyography, kinematics, children

Many young tennis players undergo an intensive training from early in childhood. The first learning stage concerns flat strokes, which are quickly replaced by topspin strokes to permit increased ball velocity and spin, such that the error margin of the stroke is maintained. In adults, kinematics studies showed that the racket-face path was more horizontal during the acceleration phase of the flat forehand drive while it was downward-upward during that of the topspin stroke (Elliott & Marsh, 1989; Elliott et al., 1989; Takahashi et al., 1996). These different movement patterns between both forehand drives suggest that muscle activation patterns of trunk and upper limb muscles will be different.

Prior electromyographic (EMG) analysis of the forehand drive focused on the dominant shoulder and upper limb muscle activity in adult tennis players (Ryu et al., 1988; Morris et al., 1989). These studies have reported low EMG-levels in most muscles during the preparation phase, moderate EMG-levels during the follow-through phase and high EMG values during the acceleration phase of the forehand drive. The acceleration phase is characterized by a rapid internal rotation of the upper limb that results in a great activity in the pectoralis major muscle (Ryu et al., 1988), while the upper limb muscles appear to stabilize the arm as a rigid extension of the racket (Morris et al., 1989). In addition, previous kinematics analysis has shown that the main differences between flat and topspin forehand drives lie in different racket trajectories during the forward swing phase to create a higher vertical velocity of the racket-face at impact for topspin strokes (Elliott & Marsh, 1989). Takahashi et al. (1996) have observed an increase of about 10% of the combined palmar and lateral flexion contributions to the racket-face vertical velocity at impact between flat and topspin forehand drives. These kinematics data suggest that the wrist joint contributes to produce high vertical velocity of the racket-face at impact, especially for topspin forehand drives. These results show that players may display different trunk and upper limb muscle activity patterns as a function of the spin of the forehand drive.

In addition, it is commonly accepted that the best time to learn new skills is early in life, as proper organization of motor firing patterns is more easily obtained at this time (Kibler & Safran, 2000). This supports the approach that different types of tennis strokes and different types of shots must be learnt at the beginning of the player’s career. Nevertheless, improper learning early in life can have negative effects, such as the development of overuse injuries in the dominant upper limb (Kibler & Safran, 2000; Jacobson et al., 2005). Indeed, half of the injuries in pediatric tennis players are located in the upper limb; 25–45% at the shoulder joint, 18–45% at the elbow joint, and 5–30% at the wrist joint (Kibler & Safran, 2005). This overuse injury occurrence is linked to the age and duration of training (Maffulli et al., 2005). These data suggest that early in childhood, particular attention must be focused on an appropriate playing skill. Unfortunately, no data on muscle activity during groundstrokes in young tennis players are available.

Therefore, the aim of this study was to compare the EMG activity of selected trunk and upper limb muscles...
during flat and topspin forehand drives in young tennis players. It was hypothesized that trunk and upper limb muscle activity patterns would be different between flat and topspin forehand drives in young tennis players. It was also supposed that these differences would be related to the player’s ability to generate vertical velocity of the racket-face at impact.

Materials and Methods

Twenty-nine young tennis players, 11 girls and 18 boys ranged from 9 to 14 years (mean ± SD age: 11.1 ± 1.5 yr; mass: 32.2 ± 8.1 kg, height: 146.2 ± 9.9 cm), volunteered to participate in this study. The participants had practiced tennis regularly for 5.8 ± 1.7 yr before the study and their average weekly training during the 6 months before testing was 8.3 ± 2.9 hr/week. All participants had successfully passed the detection program organized by the regional committee of tennis in Lyon (France) and were considered as national-level tennis players. Players and parents gave their written informed consent and the study was approved by the local ethical committee.

After a 15-min warm-up composed of rallies in the service area, baseline rallies and series of flat and topspin forehand drives, the participants performed seven isometric maximal voluntary contractions (IMVC of 3 s duration, repeated three times with a rest interval of 1 min) as described by Chow et al. (1999; Table 1). Then the players performed two series of flat crosscourt forehand drives and topspin crosscourt forehand strokes, randomly, with a rest interval of 3 min. The series stopped with three successful forehand drives with a maximum of 10 shots. All trials were conducted on an indoor acrylic tennis court. The impact zone was in the backhand side of the court and the target zone was defined in the backhand side of the opposite court. The target was a rectangle with a length of 5.5 m, defined between the serve line and the baseline, and a width of 1.40 m, defined from the alley to the court center (Rogowski et al., 2007). The participants used their own racket to ensure that they felt comfortable in performing each stroke. Each participant was instructed to hit the ball as fast as possible for both forehand drives and with maximal topspin in the case of topspin forehand drives, with a first ball bounce in the target zone, with a semiwestern grip and a square stance. The same coach delivered the balls for all the subjects; one ball per 3 s to allow players sufficient time to prepare their next shot.

Two high-speed video cameras (Basler, Ahrensburg, Germany, 100 Hz) were stationed on the court (Rogowski et al., 2007). Each participant had markers attached to the dominant hip and upper limb: anterior and posterior of the hitting-shoulder, medial and lateral epicondyles of the elbow, and radial and ulnar styloid of the wrist (Takahashi et al., 1996) and two markers were attached to the sides of the racket at the central axis of the racket-face. The 3D coordinates of the markers were calculated for the three successful strokes (rebound of the ball in the target zone) using SIMI Motion 7.0 (Unterschleissheim, Allemagne). From videographic recordings, the duration of the acceleration phase (from the picture corresponding to the first forward movement of the racket face to impact) was determined. The center of gravity of each joint (approximated by the mid point of the markers on the anterior and posterior aspects of the hitting-shoulder for the gleno-humeral joint, medial and lateral epicondyles for the elbow joint and radial and ulnar styloid for the wrist joint) was calculated from the pairs of two markers attached on both sides of each upper-limb joint. A model of four segments (trunk, arm, forearm, and racket) was defined for the dominant side. The extremity of each

<table>
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<th>Table 1</th>
<th>Procedure to perform the isometric maximal voluntary contraction (IMVC) of the seven studied muscles (Chow et al. 1999)</th>
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</thead>
<tbody>
<tr>
<td>Muscle IMVC</td>
<td>Description</td>
</tr>
<tr>
<td>Pectoralis major (PM)</td>
<td>The upper arm horizontal; the forearm vertical. Resistance applied backward against the elbow.</td>
</tr>
<tr>
<td>Latissimus dorsi (LD)</td>
<td>The upper arm horizontal; the forearm vertical. Resistance applied frontward against the elbow.</td>
</tr>
<tr>
<td>Middle deltoid (MD)</td>
<td>The upper limb horizontal. Resistance applied downward against the elbow.</td>
</tr>
<tr>
<td>Biceps brachii (BB)</td>
<td>The upper arm along the trunk, the forearm horizontal and supinated. Resistance applied downward against the wrist.</td>
</tr>
<tr>
<td>Triceps brachii (TB)</td>
<td>The upper arm along the trunk, the forearm horizontal and supinated. Resistance applied upward against the wrist.</td>
</tr>
<tr>
<td>Flexor carpi radialis (FCR)</td>
<td>Sitting on a chair; the forearm along the tight; supinated fist. Resistance applied downward against the hand.</td>
</tr>
<tr>
<td>Extensor carpi radialis (ECR)</td>
<td>Sitting on a chair; the forearm along the tight; supinated fist. Resistance applied upward against the hand.</td>
</tr>
</tbody>
</table>
segment was represented by the virtual markers, calculated from the center of gravity of the joints. Then, the upper limb angles were calculated at impact from three virtual markers (SIMI Motion 7.0): hip, shoulder and elbow for the shoulder angle, shoulder, elbow, and wrist for the elbow and shoulder and elbow, wrist and middle of the racket-face for the wrist angle. An increase in angles meant an increase in shoulder abduction, elbow extension and wrist extension, respectively. The horizontal, vertical, and resultant velocities of the racket-face were calculated at impact using the five-point linear extrapolation method, proposed by Knudson & Bahamonde (2001). The vertical velocity was used to define two groups of tennis players: the first group (GD) included players that were able to clearly differentiate the flat and topspin forehand drives, i.e., they increased by 150% or more the vertical velocity from the flat to the topspin forehand drives; the second group (GND) included players that were not able to clearly differentiate the two drives, i.e., the vertical velocity increased less than 150% between both forehand drives (Table 2).

EMG activity of the sternal head of the pectoralis major (PM), latissimus dorsi (LD), middle deltoid (MD), short head of the biceps brachii (BB), long head of the triceps brachii (TB), flexor carpi radialis (FCR) and extensor carpi radialis (ECR) muscles of the dominant side was recorded by means of seven surface triode electrodes (EMG Triode electrode, nickel-plated brass, interelectrode distance = 2 cm, Thought Technology, Montreal, Canada). Skin surfaces were shaved and treated with alcohol before the electrodes were attached. The electrodes were aligned in the direction of the muscles fibers. The EMG signals were collected using the Flexcomp Infiniti system (Thought Technology, Montreal, Canada, 2048 Hz). Raw EMG signals collected during the different IMVC and during the acceleration phase of the two forehand drives were filtered (Butterworth order 2, bandpass 10–500 Hz) before calculating root mean square values (EMGrms, 50 ms). Maximal EMGrms values were calculated from the EMG signals collected during IMVC and the average EMGrms values were determined from the EMG signals recorded during the acceleration phase of both forehand drives (defined from the videographic recordings after a postsynchronization of the videographic and EMG signals). Average normalized EMG values for each muscle in the two forehand conditions were then expressed as a percentage of the EMG level recorded during IMVC.

The kinematic and EMG data were averaged for the three successful flat and topspin forehand drives in each participant. All data are reported as mean ± SD. The normality of the data was verified. Then, t-tests for independent samples were performed to compare the age, tennis practice, weekly training, mass, height and racket-face vertical velocity at impact of the two groups of players (GD vs. GND). ANOVAs for repeated measurements (flat vs. topspin forehand drives) were used to determine differences between groups (GD vs. GND) for the kinematic data and muscle EMG normalized activity. When significant differences were observed, post hoc tests were applied, such as t-test for independent samples to compare the groups GD and GND and t test for paired samples to compare flat and topspin forehand drives in each group. For all the tests, differences were deemed significant at p < .05. All analyses were performed on SPSS version 11.0 (SPSS, Inc., Chicago, IL.).

Results

Table 2 presents the characteristics of the two groups of players. No significant difference was observed for the age, mass, height, tennis practice, and weekly training. The increase in the vertical velocity of the racket-face at impact from the flat to the topspin forehand drives was significantly higher for the GD compared with the GND group ($F = 2.996; p ≤ .001$).

Table 3 displays joint angles and racket-face velocities at impact. The shoulder joint angle and the horizontal and vertical velocities of the racket-face were influenced

| Table 2 Mean ± SD of the characteristics of the two groups of players with GD, the group of players that were able to clearly differentiate the flat and topspin forehand drives, and GND, the group of players that were not able to clearly differentiate the two drives. %Vz meant the increase in the vertical velocity of the racket-face at impact from the flat to the topspin forehand drives. |
|-----------------|-----------------|
| **N** | 15 | 14 |
| **Age (years)** | 11.2 ± 1.4 | 10.7 ± 1.7 |
| **Tennis practice (years)** | 5.8 ± 1.3 | 5.5 ± 1.9 |
| **Weekly training (hours)** | 8.8 ± 3.7 | 7.6 ± 1.7 |
| **Mass (kg)** | 40.2 ± 7.6 | 34.6 ± 6.6 |
| **Height (m)** | 1.48 ± 0.10 | 1.42 ± 0.09 |
| **%Vz (%)** | 185 ± 32 | 121 ± 17*** |

*** p ≤ 0.001; significance of the t test for independent samples.
by the interaction term between the group and the forehand drive type ($F = 4.2; p = .05$; retrospective statistical power = 0.51; $F = 10.6; p = .003$; retrospective statistical power = 0.88 and $F = 31.4; p \leq .001$; retrospective statistical power = 1.00, respectively). The shoulder angle at impact was significantly lower for the topspin forehand drive than for the flat forehand drive in GD ($p = .05$), while the shoulder angle tended to increase from the flat to the topspin forehand drive in GND ($p = .12$).

The horizontal velocity of the racket-face at impact was significantly higher in GD than in GND ($p = .008$) for the flat forehand drive and significantly decreased from the flat to topspin forehand drive in both groups ($p \leq .001$ for both groups). The vertical velocity of the racket-face at impact increased significantly from the flat to the topspin forehand drive in both groups ($p \leq .001$ for both groups); this velocity was significantly higher in GND than in GD for the flat forehand drive ($p = .001$), whereas no significant difference in the vertical velocity was observed for the topspin forehand drive between both groups. In addition, no significant differences between both groups or between both forehand drives were observed for the elbow and wrist angles and the resultant velocity of the racket face at impact.

The EMG normalized activities for PM and LD (Figure 1) were significantly larger in GD than in GND ($F = 4.5; p = .04$; retrospective statistical power = 0.54; $F = 4.9; p = .03$; retrospective statistical power = 0.57, respectively). The PM and LD activities were not influenced neither by the types of forehand nor by the interaction term between the group and the forehand drive type. No significant differences were observed between both forehand drives and both groups for BB and TB.

The MD, FCR and ECR muscle normalized EMGrms values (Figure 2) were influenced by the interaction term between group and forehand drive ($F = 8.1; p = .01$; retrospective statistical power = 0.78; $F = 4.0; p = .05$; retrospective statistical power = 0.49 and $F = 4.0; p = .05$; retrospective statistical power = 0.49, respectively). The post hoc test showed that the MD

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**Table 3** Mean ± SE for the shoulder, elbow and wrist angles (rad) and the horizontal, vertical and resultant velocities (m/s) at impact in GD, the group of players that were able to clearly differentiate the flat and topspin forehand drives, and GND, the group of players that were not able to clearly differentiate the two drives.

<table>
<thead>
<tr>
<th></th>
<th>GD Flat</th>
<th>GD Topspin</th>
<th>GND Flat</th>
<th>GND Topspin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder angle</td>
<td>0.75 ± 0.14</td>
<td>0.68 ± 0.13*</td>
<td>0.71 ± 0.26</td>
<td>0.76 ± 0.32</td>
</tr>
<tr>
<td>Elbow angle</td>
<td>1.79 ± 0.36</td>
<td>1.74 ± 0.31</td>
<td>1.85 ± 0.43</td>
<td>1.86 ± 0.44</td>
</tr>
<tr>
<td>Wrist angle</td>
<td>2.12 ± 0.24</td>
<td>2.17 ± 0.23</td>
<td>2.29 ± 0.26</td>
<td>2.28 ± 0.23</td>
</tr>
<tr>
<td>Horizontal velocity</td>
<td>15.86 ± 2.37</td>
<td>13.41 ± 2.23***</td>
<td>13.59 ± 1.86</td>
<td>12.89 ± 2.19* ††</td>
</tr>
<tr>
<td>Vertical velocity</td>
<td>4.67 ± 1.26</td>
<td>8.95 ± 1.97***</td>
<td>7.41 ± 2.56</td>
<td>8.79 ± 2.59*** †††</td>
</tr>
<tr>
<td>Resultant velocity</td>
<td>16.53 ± 2.50</td>
<td>16.32 ± 2.40</td>
<td>15.53 ± 1.60</td>
<td>15.69 ± 2.04</td>
</tr>
</tbody>
</table>

† Significant difference between groups for the flat forehand drives with †† $p < 0.01$ and ††† $p \leq 0.001$.

* Significant difference between the flat and topspin forehand drives in a group with * $p < 0.05$ and *** $p \leq 0.001$.

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**Figure 1** — Mean ± SE values for pectoralis major (PM), latissimus dorsi (LD), biceps brachii (BB), and triceps brachii (TB) normalized activities for flat and topspin forehand drives with GD, the group of players that were able to clearly differentiate the flat and topspin forehand drives, and GND, the group of players that were not able to clearly differentiate the two drives.
muscle activity increased significantly from the flat to topspin forehand drive in GND ($p = .005$). For the FCR muscle, its activity was larger in GD than in GND for the flat forehand drive ($p = .01$); moreover, the FCR muscle activity decreased significantly from the flat to topspin forehand drives in GD ($p = .02$), whereas no difference was observed between both forehand drive in GND. For the ECR muscle, no significant difference was observed between both groups for the two types of strokes. However, the ECR muscle activity decreased significantly from the flat to topspin forehand drives in GD ($p = .02$), whereas the ECR muscle activity was similar for both forehand drives in GND.

**Discussion**

The main results of this study showed that all the players had a similar PM, LD, BB, and TB muscle activity during the acceleration phase of flat when compared with topspin forehand drives. In addition, the players differentiating clearly the flat and topspin forehand drives (GD) presented a significant decrease in the FCR and ECR muscle activity and a similar MD muscle activity from the flat to topspin forehand drives. The players that were less able to clearly differentiate the two drives (GND) displayed a significant increase in the MD muscle activity and similar activity in the FCR and ECR muscle activity from the flat to topspin forehand drives.

The two groups of players defined after the experiments, displayed similar age, mass, height, tennis practice and weekly training (Table 2). The increase in the vertical velocity of the racket-face at impact from the flat to topspin forehand drives was significantly larger in GD than in GND, confirming that the group GD were able to differentiate the flat and topspin forehand drives while the group GND, who recorded a higher value for the flat forehand did not increase their vertical velocity by the same extent. Concerning the kinematic results at impact (Table 3), the angle values of upper limb joints at impact were similar to those reported in the literature for the flat forehand drive (Knudson, 1990). The shoulder and elbow joint angle values during topspin forehand drive were marginally lower, while the wrist joint angle was higher than those previously observed in adult players (Elliott & Marsh, 1989; Elliott et al., 1989). The mean resultant velocity of 15.82 m s$^{-1}$ for the racket face at impact for the flat forehand drive (Table 3) was close to those reported for players aged 19 years (Takahashi et al., 1996) or intermediate level adult players (Knudson & Bahamonde, 1999). The lack of difference in resultant velocities from the flat and topspin forehand drives in both groups showed that all players impacted the ball with a similar intensity. This also suggested that the contributions of horizontal and vertical velocities in the resultant velocity were different (Table 3). Indeed, the horizontal velocities decreased from the flat to topspin forehand drives whereas the vertical velocity increased, as previously observed by Takahashi et al. (1996). A posteriori video qualitative analysis showed that all players used a semiwestern grip with a square stance. These

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**Figure 2** — Comparison of middle deltoid (MD), flexor carpi radialis (FCR), and extensor carpi radialis (ECR) normalized activities between forehand drives and groups, with GD, the group of players that were able to clearly differentiate the flat and topspin forehand drives, and GND, the group of players that were not able to clearly differentiate the two drives. † Significant difference between the two groups for the flat forehand drive with † $p < .05$. * Significant difference between the flat and topspin forehand drives in a group with * $p < .05$, and ** $p < .01$. 

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observations associated with the significant increase in the vertical velocity from the flat to topspin forehand drives demonstrated that all the players complied with the hitting instructions. However, this increase in the vertical velocity from the flat to topspin forehand drives was lower in GND than in GD (Table 3), that could be explained by some differences in trunk and upper arm muscle activity.

During the acceleration phase of flat and topspin forehand drives, the EMG-levels of the seven studied muscles (Figures 1 and 2) followed the same hierarchy observed in the literature (Van Gheluwe & Hebbelinck, 1986; Ryu et al., 1988; Morris et al., 1989), with high EMG-levels for the PM, ECR and FCR muscles (up to 60%, as defined by Ryu et al. (1988)), moderate EMG-levels for the BB, LD and MD muscles (between 30 and 60%) and a low EMG-level for the TB muscle (less than 30%). During this phase, the main movement contributing to the horizontal velocity of the racket-face at impact is the internal rotation of the upper limb (Takahashi et al., 1996) although this movement was not kinematically measured in this study. The higher horizontal velocity of the racket-face in GD than in GND (Table 3) could be related to the higher PM EMG-level that was also accompanied by a stronger LD activity identified in GD when compared with GND (Figure 1). The muscle LD has three main functions; it adducts and extends the upper limb, and it rotates internally the upper limb, when this one is placed along the trunk. Consequently, it can be hypothesized that the two first functions of LD were involved during this movement. Thus, the LD muscle was coactivated to stabilize the dominant shoulder during the acceleration phase (Rouffet et al., 2009), and/or to slowdown the arm segment to increase the inertial transfer to forearm and racket segments at the end of the acceleration phase. Furthermore, the LD muscle could be activated to anticipate the necessary slowdown of the upper limb—racket complex after impact (Ryu et al., 1988). Concerning the MD muscle (Figure 2-MD), the results showed that its EMG-level was higher in GD than in GND for the flat forehand drive, while it was similar in both groups for the topspin forehand drive. These differences could be explained by the position of the upper arm during the forward swing phase. Indeed, the MD muscle is involved in the shoulder abduction when the shoulder is internally rotated. The decrease in the shoulder abduction at impact in GD between flat and topspin forehand drives (Table 3) could explain the decrease in the MD EMG-level and inversely, the increase in the shoulder abduction (Table 3) could result in the increase in MD EMG-level from the flat to topspin forehand drives in GND. This increase from flat to topspin forehand drives in GND would be caused by an upward movement of the upper limb to generate the vertical velocity of the racket-face. As the topspin forehand drive is one of the most played groundstrokes (Johnson & McHugh, 2006), this upward movement could result in a repetitive tensile overload of the shoulder muscle that could induce overuse injuries (Kibler & Safran, 2005). Concerning the arm muscles, the results of this study showed no differences in BB and TB EMG-levels between groups for each forehand technique. This could be explained by the constant elbow joint angle during the acceleration phase of both forehand drives (Elliott & Marsh, 1989; Elliott et al., 1989; Knudson, 1990; Takahashi et al., 1996), in line with the similar elbow joint angle values observed at impact (Table 3). Concerning the forearm muscles, the FCR and ECR muscle activity followed the same evolution from the flat to topspin forehand drives in both groups (Figure 2—FCR and ECR). The higher FCR muscle for the flat forehand drive in GD when compared with GND suggested that this muscle was recruited to flex the hand to generate the fast forward movement of the racket-face at the end of the acceleration phase (Elliott & Marsh, 1989; Takahashi et al., 1996) and could also explain the higher horizontal velocity of the racket-face at impact in GD (Table 3). In addition, the decrease in ECR and FCR muscle activity from the flat to topspin forehand drives in GD could indicate that the vertical velocity of the racket-face at impact was generated by radial deviation, involving the recruitment of no studied muscles, such as the extensor carpi radialis longus and the extensor carpi radialis brevis. Regarding the group GND, the FCR and ECR EMG-levels were similar for both forehand strokes, suggesting that the FCR and ECR muscles were only recruited to grip the racket handle strongly at impact (Chow et al., 1999). These results tended to confirm that the increase in the vertical velocity of the racket-face at impact from the flat to topspin forehand drives was primarily produced by hand abduction in GD and shoulder abduction in GND.

The main limitations in the current study were associated with the normalization assessment of EMG signals (Rouffet & Hautier, 2008). The normalization assessment, based on maximal isometric contractions, was used because this study focused mainly on the comparison between two types of forehand drives and because no simple, economic and reliable method was available to normalize the EMG signals for upper limb and trunk muscles during dynamic movement. In addition, different muscle activation patterns of trunk and upper limb muscles have been observed between flat and topspin forehand drive and between groups of players, suggesting different movements patterns; but only a complete kinematical study associated with an EMG analysis could allow the linking of muscle activity and upper limb mechanics to be more closely related. Further studies will use more complex biomechanical models of the upper limb to describe fine movements, such as internal rotation of the arm, radial, ulnar, and palmar flexion.

In conclusion, the results of this study showed that differences in trunk and upper limb muscle activity patterns were highlighted between the flat and topspin forehand drives, depending on the subject’s ability to clearly differentiate each forehand drive technique. The young players differentiating clearly flat and topspin forehand drives were able to produce lateral flexion at the wrist while those having more difficulty to differentiate both
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shots generated the vertical velocity of the racket-face by increasing shoulder abduction. The players using a wrist movement were able to increase more the vertical velocity of the racket-face at impact from the flat to topspin forehand drives than the players using shoulder abduction, which could be a causative factor involved in producing shoulder overuse injuries. Combining these findings with future studies to determine muscle activity during strength conditioning and technical training could help to develop more specific programs for performance improvement and injury prevention in young tennis players.

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References


