Journal of Human Kinetics volume 50/2016, 211-218 DOI: 10.1515/hukin-2015-0158

Section III – Sports Training

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The Activity Profile of Young Tennis Athletes Playing on Clay and Hard Courts: Preliminary Data

by

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The aim of this study was to compare the kinematic characteristics of tennis matches between red clay and hard courts in young tennis players. Eight young tennis players performed two tennis matches on different court surfaces. The match activities were monitored using GPS units. The distance covered in different velocity ranges and the number of accelerations were analyzed. The paired t test and inference based on magnitudes were used to compare the match physical performance between groups. The total distance (24% of difference), high-intensity running distance (15 - 18 km/h) (30% of difference), the number of high-intensity activities (44% of difference), the body load (1% of difference), and accelerations >1.5 g (1.5-2 g and >2 g 7.8 and 8.1 % of difference, respectively) were significantly greater in clay court than hard court matches (p < 0.05). Matches played on the red clay court required players to cover more total and high-intensity running distances and engage in more high-intensity activities than the matches played on the hard court. Finally, on the clay court the body load and the number of accelerations performed (>1.5 g) were possibly higher than on the hard court.

Key words: *kinematic analysis, GPS, racquet sports, accelerations.*

Introduction

The court surface determines technical and tactical features of a tennis match. O'Donoghue and Ingram (2001) reported differences in the players' technical/tactical outcome in Grand Slam tournaments after analyzing more than 250 singles' matches. Such differences may be related, among other factors, to the different surfaces on which the tournaments are held. On clay courts the velocity of the ball is slower than on hard courts due to the trajectory of the ball after it bounces on the ground and the selection of topspin (Haake et al., 2000; Reid et al., 2013). Furthermore, on clay courts, the duration of rallies is longer and more often played on the baseline than on hard courts. However, on hard surfaces, the number of shots performed per minute is higher than on clay courts along with a greater number of aces and serves to net rallies (O' Donoghue and Ingram, 2001).

The characteristics of the court surface on which the tennis match is played also demand different physical and physiological responses from the players. Previous studies have demonstrated that during matches the heart rate response, lactate concentration, and rating of perceived exertion are significantly higher on clay courts compared to hard courts (Fernandez-

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Authors submitted their contribution to the article to the editorial board.
Accepted for printing in the Journal of Human Kinetics vol. 50/2016 in March2016.

Fernandez, 2009; Murias et al., 2007). Accordingly, the kinematic profile is thought to differ in matches played on different surfaces. For instance, Murias et al. (2007) showed that the total distance and the distance covered per point are higher in clay court than hard court tennis matches. However, in a study by Murias et al. (2007), the method of kinematic analysis consisted of a grid drawn on a 21-in flat screen television with distance calculated from a proportionality model. The accuracy and reliability of this method has not been tested.

Comparing the activity profile in tennis matches played on different surfaces and analyzing the differences in the physiological responses is essential in characterizing the physical demands of each surface, in order to help coaches and conditioning trainers to plan specific training drills, according to the characteristics of the surface on which the tournaments will be contested. Although the physiological responses on different surfaces have been described, less attention has been paid to the kinematic differences between tennis matches played on different surfaces. The only study using the global positioning system (GPS) technology to quantify tennis players' locomotor activities comparing clay and hard courts involved solely training sessions composed of ball drills (Reid et al., 2013). No study to date has been conducted during tennis matches. Additionally, a recent study has addressed the locomotor activities performed by adolescent tennis players using the GPS during matches, showing its feasibility to this aim (Hoppe et al., 2014).

The aim of this study was to compare the kinematic characteristics of tennis matches played on clay and hard courts in young tennis players. It was hypothesized that the players would cover greater distances at higher intensity displacement ranges and would perform more accelerations as quantified by an accelerometer on the clay court.

Material and Methods

Participants

Eight youth Brazilian tennis players (15.5 ± 1.2 years, 177.2 ± 5.8 cm, 68.1 ± 11 kg) volunteered for this study. They were >100th position in the national ranking in the under-14 and under-16 age categories. The players competed at state and national tournaments and trained 10 to 15 h per week. The parents or legal guardians of the players gave written informed consent permitting the athletes to participate in the study, which had been approved by the Ethics Committee of the State University of Londrina.

Procedures

Prior to involvement in the investigation, the players were briefed about the experimental procedures. Subsequently, on separate days, they were involved in tennis matches on clay or hard courts, in randomized order. The matches were played against the same opponents in a similar age category, and with technical equivalence attested by the coach. An interval of at least 48 h was respected between matches. All players were tested during the competitive period and their performance in the matches was assessed using GPS equipment. Data were obtained from the GPS relating to distances covered in different speed zones and the acceleration profile via accelerometry. Before the matches, a 5 min standardized warm-up was performed, comprising routine ball strokes and services. The matches were played in accordance with the rules of the International Tennis Federation (ITF) and the Association of Tennis Professionals (ATP) including the pauses between sets and side changes. Matches consisted of 2 sets with advantage and tie-break rules. In the case of a draw, the 3rd set was played in a super tie-break system (until 10 points had been won). The matches were played on courts with the same area around them. All the matches were played with a ballboy to avoid movements unrelated to match activities being included in the analysis. At the start of each match, the players received 3 new balls. The duration of the shortest match was set as the standard duration of all matches in the analyses in order to allow comparisons to be made between individuals over similar time periods. All the matches were analyzed throughout; however, the data from the period after 61.7 minutes, the duration of the shortest match, were excluded from the final analysis.

Kinematic Analysis

The activity profile of the tennis matches was obtained from the GPS units, sampling at 5 Hz (SPI Elite, GPSports Systems, Australia). The equipment was fitted to the upper back of each player using an adjustable neoprene harness. The GPS contained a tri-axial accelerometer system

(100 Hz) which was also used to quantify body accelerations. The units were turned on during the warm-up, to allow satellite detections and placed in the harness immediately before the onset of the match. All match activities were recorded from the start of the matches, including the pauses between rallies and sets.

The velocity categories were selected based on various previous studies in team sports (Aughey, 2010; Aughey, 2011; Austin and Kelly, 2013; Barros et al., 2007). The confined space of the courts did not permit tennis players to attain high velocities during tennis matches, thus the high-intensity and sprinting ranges chosen were not as high as in other team sports (e.g., soccer, rugby). The sprinting category was chosen based on the results from a 10 m test performed by tennis players from another tennis club (18 km/h) during their own routine assessments in our laboratory. This distance resembles the linear dimensions of a tennis court and allows athletes to reach very high velocities, comparable to those attained in maximal sprints during a match. The high-intensity lower bound category was defined as the speed corresponding to 15% below the sprint threshold (Castagna et al., 2009; Coutts et al., 2010). Therefore, the match activities were divided into the following categories: walking (0-5.5 km/h), jogging (5.5-7.0 km/h), cruising (7.0-10.0 km/h), striding (10.0-15.0 km/h), high-intensity running (15.0-18.0 km/h), and sprinting (>18 km/h). The validity and reliability of the GPS units had been previously tested in confined spaces such as tennis courts (Duffield et al., 2010; Vickery et al., 2014). The GPS underestimated the distance covered, mean speed and peak speed during court-based tennis movements and showed a low to high intraclass coefficient of correlation (ICC = 0.1 to 0.86) and a low to high coefficient of variation (CV = 3.5 to 22.8) (Duffield et al., 2010; Scott et al., 2015; Vickery et al., 2014). In a recent study, the GPS units were sensitive enough to detect locomotor activity changes in response to caffeinated energy drink ingestion in comparison to placebo (Gallo-Salazar et al., 2015). The acceleration profile was also used as a parameter of performance during the matches. The acceleration vector magnitude as a function of time (*i*) (AVM) was obtained from x (lateral), y (frontal/back) and z (vertical) axis components (i.e., acx, acy and acz, respectively) using the following equation:

$$AVM = \sqrt{(acx_{i+1} - acx_i)^2 + (acy_{i+1} - acy_i)^2 + (acz_{i+1} - acz_i)^2}$$

The number of accelerations performed is presented in the following categories based on "g" forces: < 0.5 g; 0.5-1 g; 1-1.5 g; 1.5-2 g; >2 g. Finally, the body load was calculated as the accumulated sum of all acceleration vector magnitude values. The results of accelerations and the body load were divided by 100 in order to simplify their expression and presentation (Goncalves et al., 2014). The AVM had demonstrated good reliability in treadmill running (ICC = 0.93 and CV = 5.9) and in Australian Rules Football (CV < 0.5 %) (Barrett et al., 2014; Boyd et al., 2011; Scott et al., 2015).

Statistical Analysis

The Shapiro-Wilk test was initially used to test the data normality. To analyze the differences in kinematic activities between the clay and hard court matches, the differences based on magnitudes (Batterham and Hopkins, 2006) and a paired *t* test were calculated. The quantitative chances for the clay or hard court data, using a confidence interval of 90%, having better or poorer values were assessed qualitatively as follows: <1%, almost certainly not; 1 to 5%, very unlikely; 5 to 25%, unlikely; 25 to 75%, possible; 75 to 95%, likely; 95 to 99%, very likely; >99%, most likely. If the chances of having better and poorer results were both >5%, the true difference was assessed as unclear. The non-normal data were transformed in natural logarithms and qualitatively assessed using the same categories. However, for the sake of clarity and practicality, they were presented in back-transformed values. We used the spreadsheet made available by Hopkins (2004). The statistical significance level was set at $p \leq 0.05$.

Results

The duration of the shortest match was 61.7 min, which was used as the standard to make the comparisons between the clay and hard court matches. Table 1 shows the comparison of distance covered, in the different velocity ranges, between the clay and hard court matches. The total distance covered and the distance covered at 0-5.5, 5.5-7, 7-10, and 10-15 km/h were *most likely* higher in clay court than hard court matches

($p \leq 0.05$). The distance covered at high-intensity (15-18 km/h) was *likely* higher on the clay court than the hard court ($p \leq 0.05$). The difference in the sprinting distance between the matches played on the different court surfaces was rated as *unclear* ($p > 0.05$). The comparisons between the number of actions at different intensity ranges between the clay and hard court matches are presented in Table 2. The number of actions at 0-5.5, 5.5-7, 7-10, and 10-15 km/h were *most likely* higher on the clay court than the hard court ($p \leq 0.05$). The number of actions performed at high-intensity (15-18 km/h) was *very likely* higher on the clay court than the hard court ($p \leq 0.05$). The difference in the number of sprinting actions between the matches on the two court surfaces was rated as *unclear* ($p > 0.05$).

Figure 1 shows the comparison of the body load between clay and hard court matches. The body load was *possibly* higher in clay court than hard court matches (clay: 3874.8 ± 145.2 u. a.; hard: 3836.6 ± 117.1 u. a.; $p \leq 0.05$). Figure 2 depicts the number of accelerations in different intensity ranges on the clay and hard courts. No differences in the number of accelerations performed were observed between the two surfaces in the 0-1.5 *g* range ($p > 0.05$). In contrast, in the 1.5-2 *g* and >2 *g* ranges the tennis players *possibly* performed more accelerations on the clay court than the hard court (1.5-2 *g* clay: 169.6 ± 16.8 accelerations; hard: 156.4 ± 22.2 acceleration; $p \leq 0.05$. >2 *g* clay: 107.6 ± 33.1 accelerations; hard: 98.8 ± 24.7 accelerations; $p \leq 0.05$).

Table 1

Distance covered (m) in different velocity ranges in clay and hard court matches (Mean ± SD)

Velocity Ranges	Clay	Hard	Chance % +/Trivial/-	Qualitative Inference
0 - 5.5 km/h	2054.5 ± 139.9 m	1651.3 ± 220.9 m*	100/00/00	Most Likely
5.5 - 7 km/h	244.6 ± 83.3 m	156.6 ± 68.5 m*	100/00/00	Most Likely
7 - 10 km/h	211.1 ± 38.9 m	117.8 ± 36.3 m*	100/00/00	Most Likely
10 - 15 km/h	122.3 ± 32.6 m	66.3 ± 18.7 m*	100/00/00	Most Likely
15 - 18 km/h	18.6 ± 13.3 m	13.0 ± 7.9 m*	81/15/04	Likely
> 18 km/h	5.8 ± 5.8 m	7.2 ± 9.3 m	20/31/49	Unclear
Total Distance	2656.9 ± 220.2 m	2012.3 ± 295.8 m*	100/00/00	Most Likely

*$p \leq 0.05$

Table 2

The number of actions in different velocity ranges in clay and hard court matches (Mean ± SD)

Velocity Ranges	Clay	Hard	Chance % +/Trivial/-	Qualitative Inference
0 - 5.5 km/h	401.5 ± 152.0	230.6 ± 111.6*	100/00/00	Most Likely
5.5 - 7 km/h	459.8 ± 159.6	251.8 ± 112.8*	100/00/00	Most Likely
7 - 10 km/h	199.9 ± 42.2	88.4 ± 25.9*	100/00/00	Most Likely
10 - 15 km/h	60.1 ± 15.9	27.4 ± 10.1*	100/00/00	Most Likely
15 - 18 km/h	10.4 ± 7.6	5.8 ± 4.7*	95/01/04	Very Likely
> 18 km/h	2.5 ± 2.6	1.9 ± 1.6	59/30/11	Unclear

*$p \leq 0.05$

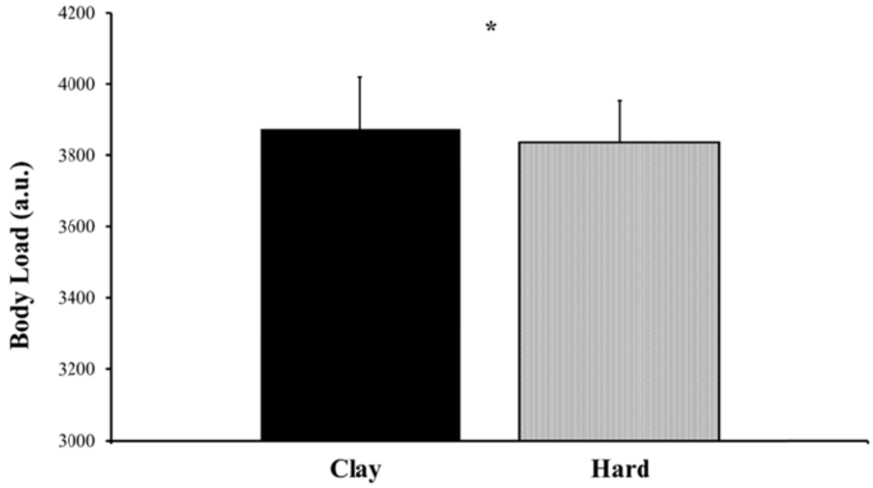

Figure 1

*Body load (a.u.) in clay and hard court matches (Mean ± SD). The percentage of +/Trivial/- and the qualitative inference in the body load between the two different courts' surfaces was 73/27/00 (Possibly higher on a clay court). *p ≤ 0.05*

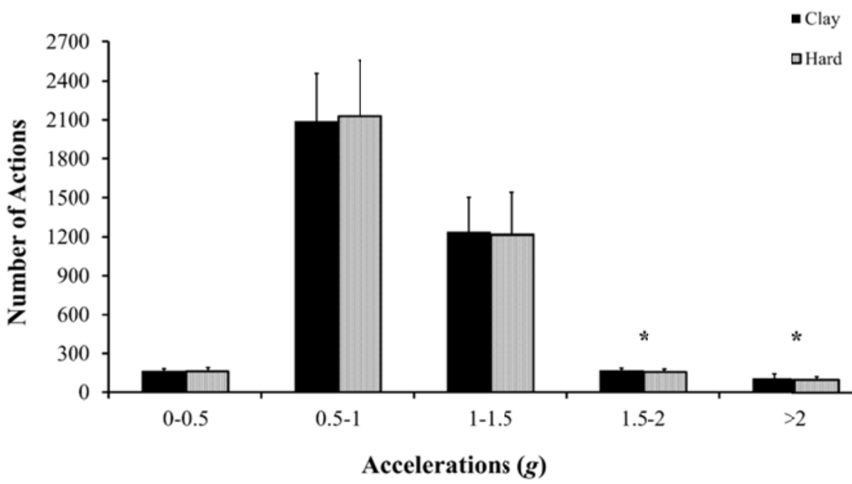

Figure 2

*The number of accelerations performed at different intensities based on the g force in clay and hard court matches (Mean ± SD). The percentage of +/Trival/- and the qualitative inference in the number of accelerations between the two different court surfaces were: 0-0.5 g, 58/24/14 (Unclear); 0.5-1 g, 00/88/12 (Likely Trivial); 1-1.5 g, 11/88/01 (Likely Trivial); 1.5-2 g, 89/09/02 (Likely higher on a clay court); >2 g, 72/27/01 (Possibly higher on a clay court). *p ≤ 0.05*

Discussion

The main results of this study were as follows: a) greater total and high intensity running distances were covered by young tennis players during the matches performed on a clay court, b) young tennis players executed more high intensity activities in clay court matches, and c) the body load and the number of accelerations performed >1.5 g were possibly higher in clay court matches. The current results are in agreement with the initial hypothesis that the players would cover higher distances at higher intensity displacement ranges and would perform more accelerations as quantified by an accelerometer on the clay courts.

The total distances covered in this study (2656.9 ± 220.2 m vs. 2012.3 ± 295.8 m on clay and hard courts, respectively) are within the typically reported range of 1300 to 3600 m per hour (Fernandez-Fernandez, 2009; Hoppe et al., 2014), and higher than that shown in a study by Murias et al. (2007) (1447 ± 143 m vs. 1199 ± 168 m on clay and hard courts, respectively). Although the players involved in the previous study were in the same age category as the present one (~16 years old), comparisons between the studies are difficult to carry out due to the differences in the kinematic analysis method used. The higher rally time reported in clay court compared to hard court matches suggests more involvement in match actions (i.e. the number of strokes) (O' Donoghue and Ingram, 2001) which is probably reflected in the physical responses resulting in the higher total distance covered in clay court matches in the present study. Unfortunately, the present study did not use video analysis as an evaluation tool. This limitation should be considered when interpreting our results.

Several previous studies on different team sports have reported that elite players can cover greater distances in high-intensity running than sub-elite players (Brewer et al., 2010; Mohr et al., 2003). Therefore, high-intensity distance running seems to be important to discriminate different fitness levels of athletes (Aughey, 2011; Brewer et al., 2010; Mohr et al., 2003). In addition, it has already been reported that fitness levels assessed by the Hit & Turn Tennis Test are related to the differences in the level of players' performance (national vs. regional levels) (Pereira et al., 2015) and to players of different ages (Ferrauti et al., 2011). However, in the present study, the difference observed in high-intensity running cannot be attributed to the physical performance differences, as a within-subject design was used. This difference is probably due to the higher tempo (more shots and runs per point) in clay court matches, demanding more involvement in high-intensity actions as compared to hard court matches. This was also apparent while measuring accelerations performed >1.5 g, which may be used by coaches and conditioning physical trainers to distinguish efforts on different court surfaces.

In the sprinting category, no differences were observed between playing surfaces. Actions performed at maximal velocity are not as frequent in tennis as the slower velocity ranges (Table 2). It is possible that the limited space of a tennis court, associated with technical/tactical decisions during the matches, reduced the number of actions performed at high velocities. Moreover, the 5 Hz GPS units used in the present study had presented low reliability in fast and short movements (Duffield et al., 2010; Vickery et al., 2014). For this reason, the accuracy of this equipment to detect sprinting velocities could also be limited.

The possible differences shown in the body load between clay and hard court matches could be partially accounted for by the higher total and high-intensity distances covered and possibly the longer rally duration as previously described by O'Donoghue and Ingram (2001), which influence the tri-axial body accelerations. The total body load observed in this study was not as high as in other sports involving collisions (e.g., rugby union) (Cunniffe et al., 2009), hence the possible difference between clay and hard courts, although meaningful, does not appear to demand special attention regarding orthopedic injuries. Actually, there are reports suggesting that the prevalence of injuries is higher on hard courts than clay courts possibly due to loading patterns of the foot in subtle accelerations and decelerations (Dragoo and Braun, 2010). Therefore, future studies should investigate whether the accelerations in specific joints related to tennis movements are linked to orthopedic injuries.

In conclusion, when playing on clay court surfaces tennis players were required to cover more total and high-intensity running distances and engage in more high-intensity activities than on hard courts. In addition, the body load and the number of accelerations performed >1.5 g were possibly higher when played on a clay court. This suggests that the intensity of physical demand required from tennis players is directly influenced by the playing surface.

References

Aughey RJ. Australian football player work rate: evidence of fatigue and pacing? *Int J Sports Physiol Perform*, 2010; 5: 394-405

Aughey RJ. Applications of GPS technologies to field sports. *Int J Sports Physiol Perform*, 2011; 6: 295-310

Austin DJ, Kelly SJ. Positional differences in professional rugby league match play through the use of global positioning systems. *J Strength Cond Res*, 2013; 27: 14-19

Barrett S, Midgley A, Lovell R. PlayerLoad™: Reliability, Convergent Validity, and Influence of Unit Position during Treadmill Running. *Int J Sports Physiol Perform*, 2014; 9: 945-52

Barros RM, Misuta MS, Menezes RP, Figueroa PJ, Moura FA, Cunha SA, Anido R, Leite NJ. Analysis of the distances covered by first division brazilian soccer players obtained with an automatic tracking method. *J Sports Sci Med*, 2007; 6: 233-242

Batterham AM, Hopkins WG. Making meaningful inferences about magnitudes. *Int J Sports Physiol Perform*, 2006; 1: 50-57

Boyd LJ, Ball K, Aughey RJ. The reliability of MinimaxX accelerometers for measuring physical activity in Australian football. *Int J Sports Physiol Perform*, 2011; 6: 311-321

Brewer C, Dawson B, Heasman J, Stewart G, Cormack S. Movement pattern comparisons in elite (AFL) and sub-elite (WAFL) Australian football games using GPS. *J Sci Med Sport*, 2010; 13: 618-623

Castagna C, D'ottavio S, Granda Vera J, Barbero Alvarez JC. Match demands of professional Futsal: a case study. *J Sci Med Sport*, 2009; 12: 490-494

Coutts AJ, Quinn J, Hocking J, Castagna C, Rampinini E. Match running performance in elite Australian Rules Football. *J Sci Med Sport*, 2010; 13: 543-548

Cunniffe B, Proctor W, Baker JS, Davies B. An evaluation of the physiological demands of elite rugby union using Global Positioning System tracking software. *J Strength Cond Res*, 2009; 23: 1195-1203

Dragoo JL, Braun HJ. The effect of playing surface on injury rate: a review of the current literature. *Sports Med*, 2010; 40: 981-990

Duffield R, Reid M, Baker J, Spratford W. Accuracy and reliability of GPS devices for measurement of movement patterns in confined spaces for court-based sports. *J Sci Med Sport*, 2010; 13: 523-525

Fernandez-Fernandez J, Sanz-Rivas C, Mendez-Villanueva A. A review of the activity profile and physiological demands of tennis match play. *Strength Cond J*, 2009; 31: 15-26

Ferrauti A, Kinner V, Fernandez-Fernandez J. The Hit & Turn Tennis Test: an acoustically controlled endurance test for tennis players. *J Sports Sci*, 2011; 29: 485-494

Gallo-Salazar C, Areces F, Abián-Vicén J, Lara B, Salinero JJ, Gonzalez-Millán C, Portillo J, Muñoz V, Juarez D, Del Coso J. Enhancing physical performance in elite junior tennis players with a caffeinated energy drink. *Int J Sports Physiol Perform,* 2015; 10: 305-310

Goncalves BV, Figueira BE, Macas V, Sampaio J. Effect of player position on movement behaviour, physical and physiological performances during an 11-a-side football game. *J Sports Sci*, 2014; 32: 191-199

Haake SJ, Chadwick SG, Dignall RJ, Goodwill S, Rose P. Engineering tennis – slowing the game down. *Sports Eng*, 2000; 3: 131-143

Hopkins WG. How to interpret changes in an athletic performance test. *Sportsci*, 2004; 8: 1-7

Hoppe MW, Baumgart C, Bornefeld J, Sperlich B, Freiwald J, Holmberg HC. Running activity profile of adolescent tennis players during match play. *Pediatr Exerc Sci*, 2014; 26: 281-290

Mohr M, Krustrup P, Bangsbo J. Match performance of high-standard soccer players with special reference to development of fatigue. *J Sports Sci*, 2003; 21: 519-528

Murias JM, Lanatta D, Arcuri CR, Laino FA. Metabolic and functional responses playing tennis on different surfaces. *J Strength Cond Res*, 2007; 21: 112-117

O' Donoghue P, Ingram B. A notational analysis of elite tennis strategy. *J Sports Sci*, 2001; 19: 107-115

Pereira LA, Freitas V, Moura FA, Urso RP, Loturco I, Nakamura FY. Match analysis and physical performance of high-level young tennis players in simulated matches: a pilot study. *J Athl Enhancement,* 2015; 4: 1-7

Reid MM, Duffield R, Minett GM, Sibte N, Murphy AP, Baker J. Physiological, perceptual, and technical responses to on-court tennis training on hard and clay courts. *J Strength Cond Res*, 2013; 27: 1487-1495

Scott MT, Scott TJ, Kelly VG. The validity and Reliability of Global Positioning Systems In Team Sport: A Brief Review. *J Strength Cond Res,* 2015; In Press

Vickery WM, Dascombe BJ, Baker JD, Higham DG, Spratford WA, Duffield R. Accuracy and reliability of GPS devices for measurement of sports-specific movement patterns related to cricket, tennis, and field-based team sports. *J Strength Cond Res*, 2014; 28: 1697-1705

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