Full Title: Playing not once, not twice but three times in a day: fatigue and performance in junior tennis players

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Abstract

This study examined physical and perceptual responses to multiple daily tennis matches. Six junior males completed 3 x 90 min singles matches, each separated by 45 min recovery. Physical capacity (agility, countermovement jump [CMJ]), shoulder internal and external rotation (IR, ER), serve performance, creatine kinase (CK) and perceptual (soreness, pain, and fatigue) measures were performed before match 1 and following each match. During matches, distances and speeds covered, stroke count and stroke acceleration magnitudes were assessed. Between-match changes (effect size ± 90% confidence interval [CI]) ≥75% likely to exceed the smallest important effect size (ES=0.20) were considered practically important. Movement distance (-0.63±0.90, 81% likely) and mean speed (-0.61±0.82, 82% likely) decreased only in match 2. Total strokes played also reduced in match 2 (-11.0±17.7, 84% likely), without changes in stroke acceleration magnitudes. Serve accuracy declined post-match 3 (0.76±1.15, 81% likely), though speed did not change. CMJ height was unchanged, though shoulder IR and ER declined (-0.57±0.44, 92% likely), as did agility (0.75±0.35, 99% likely) by post-match 3. CK, pain, fatigue and soreness ratings increased throughout. Same-day tennis matches impair physical capacities and increase fatigue and soreness. Between-match fluctuations in stroke count and movement also infer altered technical elements of match-play.

Keywords: racket sports, multiple matches, performance, match-play

Introduction

The nature of elite junior tennis competition can demand that players compete in multiple matches in a single day (Bergeron, 2009; Bergeron, 2014; Brink-Elfegoun et al., 2014). Tight schedules, combined with weather interruptions and unknown match durations often force scheduling changes that result in players needing to compete in multiple daily matches (Brink-Elfegoun et al., 2014). Internationally, tennis organisations implement their own policies to regulate the format and maximum number of daily matches in which junior players can compete, without any uniform standard. In part, this would seem related to the lack of previous literature reporting the effects of multiple same-day matches on the performance of junior tennis players.

Match-play tennis involves durations of 1.5-2 h, though can extend to >5 h in professional players (Reid & Duffield, 2014). Typically, point durations are 5-10 s with a 20 s break between points and 60 to 120 s during the change of ends (Fernandez-Fernandez, Sanz-Rivas & Mendez-Villanueva, 2009). Physiological responses to tennis match-play include moderate to high heart rate (HR) and oxygen consumption (VO_2) demands (Fernandez-Fernandez, Sanz-Rivas & Mendez-Villanueva, 2009). Further, increased post-match creatine kinase (CK) (Hornery, Farrow, Mujika & Young, 2007) and perceived ratings of muscle soreness (Gomes et al., 2014) suggest the existence of muscle damage. However, these various descriptive data sets represent the profile of a single tennis match, and are not a representation of junior tournament contexts whereby multiple matches can be played in a day.

Recently, a small number of studies have investigated the effects of playing consecutive days of tennis match-play, akin to tournament contexts. For example, impairments of rapid force development (RFD) and maximal voluntary contraction (MVC), along with increases in muscle damage and perceived soreness of the lower extremities were noted throughout a simulated 3-match tennis tournament (2 h per match on 3 consecutive days) (Ojala & Häkkinen, 2013). Similarly, another study reported elevated creatine kinase (CK) and muscle soreness ratings following 4 h of prolonged simulated tennis match-play across 4 consecutive days (Gescheit, Cormack, Reid & Duffield, 2015). Further, reductions in countermovement jump (CMJ) height, serve speed and accuracy and a decline in dominant shoulder internal rotation (IR) and external rotation (ER) MVC also existed over the 4 days. A more recent study further highlighted a reduction in the technical characteristics of match-play, with increased error rates with each day of competition (Gescheit et al., 2016). Despite the noted between-day reductions in physical performance, once more, it is unclear whether similar changes may manifest in high performance junior tennis players whom are required to play up to 3 or 4 matches within a single day.

To date, there has only been one study that has investigated the physical performance response of tennis players competing in multiple singles matches, with three matches over a 36 h period (Brink-Elfegoun et al., 2014). The results revealed no significant decrease in CMJ height, 20-m sprint and isometric strength of the knee extensors following two 2 h tennis matches on day 1 and a third the following morning (Brink-Elfegoun et al., 2014). However, it is important to note that the study participants had an age of ≈26 y and played 2 matches of 2 h in duration separated by a 3 h recovery period on day 1. Whilst it seems intuitive for there to be performance ramifications following completion of multiple matches in a single day, the practical and empirical understanding remains limited. Therefore, the aim of this study is to determine whether playing multiple tennis matches in a single day influences the physical, physiological and perceptual responses in junior tennis players.

Methods

Participants

Six junior nationally-ranked male tennis players aged (mean ± SD) 12.8 ± 1.2 years, stature 162.6 ± 13.4 cm and body mass 51.4 ± 10.6 volunteered to participate in the study. Whilst 8 players commenced match 1, due to an injury concern to one player only 6 completed all ensuing matches and testing. Players had a mean Australian tennis ranking of 17 ± 19 within their age group (U/12 – U/14). Prior to the study, the nature and possible risks of the experiment were explained to the participants and their parents. Additionally, written informed consent was obtained from both the players and their parents. All procedures were approved by the University of Technology Sydney Research Ethics Committee (ETH16-0642).

Experimental Design

Prior to data collection, participants were familiarised with all experimental procedures. Participants played 3 singles matches on the same day for a duration of 90 min per match, with a recovery of ~45 min between matches (inclusive of post-match testing and 30 min recovery period). Physical capacity, physiological, and perceptual data collection were performed before match 1 and then immediately after each of the ensuing 3 matches. Participants performed a standardised warm-up consisting of general and specific movement drills, dynamic stretches and on-court hitting drills prior to physical and performance testing.

In order to more appropriately represent a tournament setting, participants played each competitive singles match against a different opponent with a similar age and national ranking. Each match was monitored by a research assistant, with scoring and rest periods consistent with the rules of the International Tennis Federation (International Tennis Fedaration, 2016). Participants were instructed to attempt to win the three set match - and then as many games as possible if 2 sets were already won - in the 90 min period. Incentives in the form of prizes were on offer for most matches and games won over the day to promote competitive matchplay. Matches were played on outdoor Plexicushion courts using Wilson tour tennis balls (Wilson, Illinois, USA), which were changed after every match. Environmental temperature and humidity were (mean ± SD) 20.9°C ± 1.2°C and 44.3% ± 4.1%, respectively according to a bureau of meteorology site located within 200 m of the vicinity. Water was provided throughout all matches for *ad libitum* consumption and a carbohydrate snack of 1.5g/kg body mass was provided following each match.

Match-Play Characteristics and External and Internal Load

A Polar Team^2 System (Polar Electro Oy, Kemple, Finland) continuously measured HR throughout each match-play session, with data downloaded on custom-specific software (Polar Team^2, Electro Oy, Kemple, Finland) to obtain peak and mean HR values per match. The movement patterns of each player were recorded during all matches via a Global Positioning System (GPS) devices (HPU, GPSports, Canberra, Australia) sampling at a frequency of 5 Hz that was interpolated to 15 Hz (CV 5-22%) were used to obtain speed and distance measures (Vickery et al., 2014) though the limitation of using GPS in tennis is certainly acknowledged (Duffield, Reid, Baker &

Spratford, 2010). GPS devices were activated 15 min prior to matches and worn by participants in custom-made harness positioned between the scapulae. High-intensity running for adolescent tennis was categorized as $\geq$ 15 km/h (Hoppe et al., 2014). A 100 Hz triaxial accelerometer embedded in the GPS device measured New Bodyload, representing the square root of the sum of all accelerations. An Inertial Measurement Unit ([IMU], I Measure U, Auckland, New Zealand) sampling at 500 Hz was placed on participants' dominant forearms in order to detect different strokes (backhand, forehand and overhead) and calculate total stroke count for each match. The average of magnitude of acceleration for all three dimensions (anterior-posterior, medial-lateral and vertical) was also recorded for all strokes. Following each match, IMU data was downloaded using proprietary software (IMU Lightning: IMeasure U, Auckland, New Zealand). A Custom MATLAB (Mathworks, Natick, MA) script then processed the accelerometer data to classify the type and number of strokes (with 97.4% accuracy) (Whiteside, Cant, Connolly & Reid, 2017).

5-0-5 Agility

A 5-0-5 agility test was conducted on a neighboring outdoor Plexicushion tennis court with electronic timing gates (SpeedLight TT, Swift Performance Equipment, Queensland Australia). Participants used a flying 10-m run up prior to sprinting 5-m, turning 180° and sprinting another 5-m (Fernandez-Fernandez, Sanz-Rivas, Sarabia & Moya, 2016).

Serve Speed and Accuracy

Participants were instructed to perform maximal effort serves aiming for a zone marked on court 1 m from the center service line. Right-handed participants served from the deuce side of the baseline and left-handed participants served from the advantage side. Players were required to achieve 3 accurate serves, with additional serves permitted until this was achieved. A mounted radar gun (Stalker Sport 2, Stalker Plano TX, USA) was positioned 2 m directly behind to align with the player's ball-toss position to record serve velocity. The fastest accurate serve and the number of serves required to obtain 3 accurate serves (as the measure of accuracy) were recorded.

Countermovement Jump

CMJ was performed on a one-dimensional force platform (Onsport, Wollongong, Australia) sampling at 1000 Hz. Participants jumped for maximum height, with a self-selected level of countermovement, while hands remained on hips. Absolute peak force and power, jump height and eccentric: concentric peak force ratio were then determined as markers of lower body force and power.

Isometric MVC of the Dominant Shoulder

IR and ER were measured using a handheld dynamometer (Power Track II, JTech, Midvale, UT, USA). In accordance with previous research, (Gescheit, Cormack, Reid & Duffield, 2015) players stood with feet shoulder width apart with their dominant elbow flexed at 90° and upper arm touching their torso. The handheld dynamometer was placed on the outside of the wrist for shoulder ER and on the inside of the wrist for IR proximal to the pisiform. Participants were asked to meet the external resistance of the tester for a total of 5 s. Three trials of both IR and ER were performed, with the mean of the three results (kg) being recorded.

Capillary Blood Sampling

A sample of capillary blood 5µl was collected from the ear lobe. Prior to collection, the ear lobe was cleaned with 95% ethylic alcohol and the lobule pricked with a sterile, single-use lancet device (Accu-Check®, Safe-T-Pro Plus). The blood was immediately pipetted to a Reflotron Creatine Kinase strip, which was inserted into the Reflotron Analyser® (Boehringer, Germany) to measure CK as a marker of muscle damage.

Perceptual measures

Rating of perceived joint and muscle soreness along with a pain, recovery and fatigue rating were determined using a 11 point Likert scale (0, normal; 10 maximal soreness) (Cook, O'Connor, Eubanks, Smith, & Lee, 1997). Joint and muscle soreness and pain, recovery and fatigue ratings were completed prior to match one and then following all other matches on the same day. Immediately after all 3 matches, RPE was measured using Borg's category-ratio scale (0, rest; 10, maximal) to assess exercise intensity (Borg, 1978). All players were familiarized with RPE, recovery, soreness, fatigue and pain scales prior to testing.

Statistical analysis

The within-day changes in match responses were analysed using customized Microsoft Excel spreadsheets (Hopkins, 2007). A log transformation of values was perfomed to reduce bias due to non-uniformity of error, while magnitudes of difference were determined using the effect-size statistic ± 90% Confidence Interval (CI). Consistent with previous research, differences were considered likely positive/negative if they had a ≥ 75% chance of exceeding the smallest practically important effect, set as a standardised 0.2 (Batterham & Hopkins, 2006). Smaller changes were classified as trivial If 90% CI's overlapped substantially positive and negative values, differences were considered unclear. The results are presented as mean ± SD and differences as effect size ± 90% CI with a qualitative descriptor to represent the likelihood of exceeding the 0.2 threshold.

Results

Match-play characteristics

Table I presents total stroke count and mean magnitude of acceleration for each stroke. Total number of strokes likely reduced in match 2 (-11.0±17.7, 84% likely), via a likely decrease in forehand (1.24±0.87, 97% likely) and backhand strokes (-0.51±0.66, 80% likely) compared with match 1. In match 3, both forehand and total strokes likely increased compared with match 2 (1.38±1.01, 97% likely; 14.6±18.2, 87% likely). Irrespective of stroke volume, the magnitude of acceleration for strokes did not change between matches.

****Table I near here****

In match 2, a likely reduction in both total distance covered (-0.63±0.90, 81% likely) and mean movement speed (-0.61±0.82, 82% likely) was evident compared with match 1 (Table II). Further, peak running speed likely increased in match 2 (0.47±0.58, 80% likely) compared to match 1. No other movement variables differed in match 3 compared to match 1 and 2. No change was observed in both maximum and mean heart rates between matches. However, RPE increased in match 2, but returned to a similar value in match 3 as match 1 (0.56±0.99, 75% likely; Table 2).

****Table II near here****

Physical performance and creatine kinase responses to match-play

CMJ, shoulder IR and ER MVC, 5-0-5 agility and CK results are presented in Table III. No change was observed in CMJ height or peak force after all matches. However, CMJ peak power likely increased in post-match 3 compared to both post-match 1 (0.38±0.32, 85% likely) and post-match 2 (0.54±0.64, 83% likely). The eccentric: concentric ratio of CMJ likely decreased in post-match 3 (-0.79±0.85, 89% likely) compared to post-match 1.

Shoulder IR MVC likely declined at post-match 1 (-0.41±0.53, 77% likely) and post-match 2 (-0.79±0.47, 97% likely) compared to pre-match 1. Shoulder ER MVC was also likely reduced in post-match 2 (-0.85±0.65, 95% likely) and post-match 3 (-0.57±0.44, 92% likely) compared to pre-match 1.

Both 5-0-5 agility right leg (RL) and left leg (LL) times were likely slower in post-match 1 (0.33-0.41 76-84%, likely), post-match 2 (0.36-0.69, 80-97% likely) and post-match 3 (0.75-0.93, 99%, likely) compared to pre-match 1. In Post-match 3, both 5-0-5 agility RL and LL times were likely slower compared to post-match 1 (0.45-0.53, 80-89% likely). CK was elevated in post-match 1 (0.64±0.52, 93% likely), post-match 2 (1.91±1.00, 99%) and post-match 3 (1.97±0.98, 99%) compared to pre-match 1.

****Table III near here****

There was no change in serve velocity after all three matches (Table IV). However, serve accuracy likely declined in post-match 2 (0.77±0.72, 91% likely) and post-match 3 (0.76±1.15, 81% likely) compared to pre-match 1.

**** Table IV near here****

Perceptual responses

Muscle soreness was likely elevated in post-match 2 (0.78 ± 0.68, 93% likely) and post-match 3 (1.13 ± 0.81, 97% likely) compared to pre-match 1 (Table V). Joint soreness also likely increased in post-match 2 (0.77 ± 0.67, 93% likely) and post-match 3 (1.07 ± 0.69, 97% likely). Pain and fatigue ratings likely increased after each match, particularly post-match 2 (1.19 ± 0.50, 99% likely) and post-match 3 (1.36 ± 0.54, 100% likely) compared to pre-match 1 (Table V). However, increased fatigue was most evident in post-match 3 (1.29 ± 0.87, 97% likely) compared to pre-match 1 (0.64 ± 0.30, 98% likely). Rating of recovery was substantially reduced in post-match 2 (-1.35 ± 0.75, 99% likely) and post-match 3 (-1.64 ± 1.22, 97% likely) compared to pre-match 1.

****Table V near here****

Discussion

This study assessed the physical, physiological and perceptual responses to three 90 min tennis matches in one day. An increase in soreness, fatigue and pain ratings and CK concentration were evident following the 3 tennis matches. Parallel decreases in shoulder IR and ER MVC, alongside slower change of direction speeds, were observed with each match played. However, whilst total stroke count, movement distance and mean movement speeds were reduced after match 2, in match 3 they returned to values similar to match 1, potentially inferring pacing between matches. These results highlight that playing multiple tennis matches in a single day may predispose junior players to elevated fatigue levels and compromised movement despite match-play characteristics otherwise remaining unchanged in the final match.

Playing multiple matches with limited recovery is suggested to result in accumulated fatigue (Fernandez-Fernandez, Sanz-Rivas & Mendez-Villanueva, 2009) and thus reduced match-play performance. In the current study, total stroke counts reduced in match 2 compared to match 1, yet then increased in match 3. Such a pattern implies the existence of pacing or tactical alterations (Ojala & Häkkinen, 2013; de Morree & Marcora, 2013) For example, players may have taken more recovery time between points and were less inclined to run for challenging opponents' shots, as indicated through the reduction of total distance in match 2. The notion of altered pacing is tennis match-play has precedent, as previous research highlighted a decreased total strokes (and games played) in the first 3 days, before an increase on day 4 of a simulated tennis tournament (Gescheit et al., 2016). However, those findings are from stroke volumes, so a novel addition here is a marker of hitting intensity, as determined by stroke acceleration measures. Despite the reduction in stroke count, the magnitude of stroke acceleration for all stroke categories did not differ throughout the day. Thus players are able to maintain acceleration of their dominant arm throughout repeated tennis match-play (Maquirriain, Baglione & Cardey, 2016). Further, the maintenance of stroke intensity may be due to an adjustment in stroke volume or playing style due to a change in match-play engagement and motivation from players.

The movement profiles of the players mirrored the changes observed in stroke-play, with players covering less total distance at lower mean speed in match 2, despite no change in high-intensity efforts. This observed reduction in movement profiles and stroke counts (without reduction in hitting magnitudes) in match 2, provides further evidence of likely altered tactical engagement (Gescheit, Cormack, Reid & Duffield, 2015). However, whether the change in match-play movement is a result of an accumulation of fatigue responses, such as physiological load and muscle damage, or the result of players altering their tactical play remains unknown (Reid & Duffield, 2014). However, the increased RPE in match 2 highlights that as the technical demands of tennis intensify, the discrepancy between physical and mental exertion measures may increase (Murphy, Duffield, Kellet & Reid, 2014).

Increases in both CK and muscle soreness values as well as slower 5-0-5 agility times highlight increased physiological load and impaired physical capacity following multiple tennis matches in one day (Ojala & Häkkinen, 2013). Increased serum CK concentrations and muscle soreness have previously been reported in individual (Hornery, Farrow, Mujika & Young, 2007) and consecutive-day (Ojala & Häkkinen, 2013; Gescheit, Cormack, Reid & Duffield, 2015) tennis match-play. It has been suggested that damage to type II muscle fibers may impair tennis performance by reducing movement ability between points and stroke execution (Hornery, Farrow, Mujika & Young, 2007). Whilst muscle damage may be one explanation for reduced movement, the low absolute CK values observed may result from the junior cohort having lower muscle mass and immediately post-match collection (given CK may not peak until 24 h post-exercise). Regardless, peak CMJ lower-body power was maintained throughout the day, suggesting muscle damage is not the only reason for reduced change of direction ability. These results may suggest that neuromuscular fatigue does not accumulate during consecutive matches on the same day, particularly if individual matches were not excessively long (Hogarth, Burkett & McKean, 2015).

The outcomes of competitive tennis match-play often hinge on the effectiveness of the serve (Maquirriain, Baglione & Cardey, 2016). In the current study, serve velocity was maintained after all 3 matches, although a decrease in serve accuracy was observed post-match 2 and 3. The influence of upper-body fatigue during tennis is unclear, as previous studies have reported conflicting results in relation to tennis serve velocity (Hornery, Farrow, Mujika & Young, 2007). A recent study (Gescheit, Cormack, Reid & Duffield, 2015) reported similar results to the current study, with no change in serve velocity but a decline in serve accuracy following 4 prolonged tennis matches over 4 consecutive days. The reduction of accuracy in the tennis serve may be attributed to a trade-off between speed and accuracy (Girgenrath, Bock & Jungling, 2014) which might be more apparent when serving under fatigue. Further, the reduction in MVC of the dominant shoulder IR and ER was evident, which is important in overhead kinematics and critical in the tennis serve (Perry, Wang, Feldman, Ruth, & Signorile, 2014). A decline in shoulder ER may suggest the possibility of alterations in the serve kinematics in order to maintain velocity of the tennis serve after multiple same-day tennis matches (Martin, Bideau, Delamarche & Kupla, 2016).

Increased muscle and joint soreness and a decreased perception of recovery were evident post-match 2 and 3. Fatigue and pain ratings also increased following all matches. These responses highlight that perceptual fatigue accumulates over consecutive tennis matches in a single day. A similar study reported increased muscle soreness after matches 2 and 3 compared to the start of their simulated tournament (Ojala & Häkkinen, 2013). Research has suggested that disturbance to psychological states or mental fatigue alters athletes’ sense of effort and requires a down-regulation of exercise intensity (Marcora, Staiano & Manning, 2009) Therefore, increases in perceptual fatigue may influence the physical and technical performance of tennis players competing in multiple matches in one day. It seems plausible that increases in ratings of fatigue and pain and reduced ratings of recovery, along with heightened muscle and joint soreness may have contributed to the decline and changes in the external load noted in match 2.

Despite the novel findings reported here, it is important to recognize some of the limitations in this study. Firstly, the small sample size is a limitation of the study, though it represents a homogenous group of players with similar rankings that were available in the geographic region and not in tournaments at the time of testing. Despite this, it may be difficult to generalize these results to other age groups or female players. Additionally, in contrast to previous research (Gescheit, Cormack, Reid & Duffield, 2015), players competed against different opponents in each match, which may limit commentary on the causality of the effect of multiple-matches, as opposed to a different opponent. Further, the effective playing time of each match was not recorded which may have provided a better understanding of time taken between points, games and sets (although all matches were observed by a researcher). Finally, players competed in a simulated environment, and only played 90 min matches, neither of which may be a true representation of a live tournament with best of 3 set match outcomes and points/ranking motivation.

Conclusion

In conclusion, this study found an increase in CK concentrations, soreness, pain and fatigue ratings following 3 consecutive tennis matches in a single day. Moreover, whilst no changes were observed in CMJ performance, decreases in right and left change of direction speeds and dominant shoulder IR and ER MVC were observed after the successive tennis matches. However, total stroke count, movement distance and mean movement speeds only reduced following match 2, returning to similar values in match 3 as the opening match. These results highlight the decrement in important physical capacities related to tennis performance. However, changes in stroke count and movement load, even in the context of reduced physical capacities, infers an element of pacing between matches or changes in technical match-play.

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Table I. Total forehand, backhand and overhead stroke count and acceleration magnitude (mean ± SD).

	Match 1	**Match 2**	**Match 3**
Total forehand strokes (#)	222 ± 23	177 ± 35*	229 ± 34^
Forehand Acceleration magnitude (m/s^2)	79 ± 11	75 ± 13	78 ± 11
Total backhand strokes (#)	168 ± 29	149 ± 45*	163 ± 25
Backhand acceleration magnitude (m/s^2)	65 ± 7	62 ± 11	63 ± 8
Total overhead strokes (#)	82 ± 19	94 ± 17#	90 ± 16#
Overhead acceleration magnitude (m/s^2)	148 ± 39	144 ± 38	142 ± 35
Total strokes (#)	472 ± 44	426 ± 82*	481 ± 42^
Mean acceleration magnitude (m/s^2)	87 ± 15	86 ± 18	86 ± 17

*≥75% likely negative change (decrease) compared to match 1. #≥ 75% likely positive change (increase) compared to match 1. ^≥ 75% likely positive change (increase) compared to match 2.

Table II. Physical, physiological and perceived exertion responses to tennis match-play (mean ± SD, N = 6).

	Match 1	Match 2	Match 3
Distance (m)	3785 ± 356	3509 ± 364*	3661 ± 476
High Intensity running (m)	140 ± 67	111 ± 47	134 ± 51
Peak speed (km/h)	18.3 ± 1.5	19.0 ± 0.9#	18.3 ± 1.6
Average speed (km/h)	2.5 ± 0.2	2.3 ± 0.2*	2.4 ± 0.3
Sprint count (#)	31 ± 16	24 ± 8	28 ± 11
Sprint maximum acceleration (km/h)	3.7 ± 0.2	4.0 ± 0.7#	3.7 ± 0.4
New Body load (au)	76 ± 26	79 ± 34	84 ± 33
Average heart rate (beats.min^{-1})	142 ± 17	139 ± 14	144 ± 8
Maximum heart rate (beats.min^{-1})	180 ± 14	177 ± 13	180 ± 6
RPE (au)	5.5 ± 1.5	6.2 ± 0.8#	5.7 ± 1.0

*≥75% likely negative change (decrease) compared to match 1. #≥ 75% likely positive change (increase) compared to match 1. Abbreviations: au: Arbitrary Units; RPE: Rating of Perceived Exertion.

Table III. Countermovement jump (CMJ), shoulder external and internal rotation (ER; IR), maximal voluntary contraction (MVC), 5-0-5 agility and creatine kinase (mean ± SD, N = 6).

	Pre-match 1	Post-match 1	Post-match 2	Post-match 3
CMJ height (cm)	27.7 ± 7.0	28.0 ± 7.0	27.0 ± 7.7	27.2 ± 7.5
CMJ peak force (N)	1070 ± 238	1086 ± 253	1100 ± 303	1104 ± 302
CMJ peak power (W)	2295 ± 922	2005 ± 688	1847 ± 934*	2450 ± 1075^‡
CMJ ecc:con force ratio (au)	0.89 ± 0.20	0.93 ± 0.08	0.88 ± 0.13	0.79 ± 0.18•
MVC Shoulder ER (kgs)	7.3 ± 1.1	7.0 ± 1.0	6.3 ± 0.9*•	6.6 ± 1.0*•
MVC Shoulder IR (kgs)	7.4 ± 1.9	6.6± 1.2*	6.0 ± 1.1*•	6.7 ± 1.1‡
5-0-5 agility right leg (s)	2.48 ± 0.12	2.53 ± 0.12#	2.53 ± 0.17#	2.59 ± 0.09#^
5-0-5 agility left leg (s)	2.50 ± 0.13	2.56 ± 0.13#	2.61 ± 0.18#	2.65 ± 0.17#^
Creatine Kinase (U/L)	181 ± 48	230 ± 76#	367 ± 122#^	385 ± 166#^

*≥75% likely negative change (decrease) compared to pre-match 1. #≥ 75% likely positive change (increase) compared to pre-match 1. •≥ 75% likely negative change (decrease) compared to post-match 1. ^≥ 75% likely positive change (increase) compared to post-match 1. †≥ 75% likely negative change (decrease) compared to post-match 2. ‡≥ 75% likely positive change (increase) compared to post-match 2. Abbreviations: au: Arbitrary Units.

Table IV. Serve velocity and accuracy performance test (mean ± SD, N = 6).

	Velocity (km/h)	Accuracy (#)
Pre-match 1	148 ± 20	7 ± 3
Post-match 1	147 ± 20	8 ± 3
Post-match 2	142 ± 16	11 ± 3#^
Post-match 3	144 ± 17	12 ± 6#^

#≥ 75% likely positive change (increase) compared to pre-match 1. ^≥75% likely positive change (increase) compared to post-match 1.

Table V. Muscle and joint soreness and pain, recovery and fatigue responses to tennis match-play (mean ± SD, N = 6).

	Pre-match 1	Post-match 1	Post-match 2	Post-match 3
Muscle soreness	4.0 ± 1.9	4.5 ± 2.1	5.8 ± 2.0#^	6.7 ± 2.3#^‡
Joint soreness	2.7 ± 2.1	3.0 ± 1.8	4.2 ± 1.3#^	5.5 ± 1.8#^‡
Pain	2.8 ± 1.3	4.5 ± 1.6#	5.5 ± 1.9#^	6.2 ± 2.1#^‡
Recovery	7.2 ± 1.2	6.7 ± 1.2	5.5 ± 1.4*•	5.3 ± 1.9*•
Fatigue	3.2 ± 2.0	4.2 ± 1.3#	5.3 ± 1.9#^	6.5 ± 1.4#^‡

*≥75% likely negative change (decrease) compared to pre-match 1. #≥ 75% likely positive (increase) change compared to pre-match 1. •≥ 75% likely negative change (decrease) compared to post-match 1. ^≥ 75% likely positive change (increase) compared to post-match 1. ‡≥ 75% likely positive change (increase) compared to post-match 2.