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The Relationship of Training Load to Physical-Capacity Changes During International Tours in High-Performance Junior Tennis Players

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Purpose: Given the travel that punctuates junior tennis development, an understanding of the changes in fitness owing to touring and the association between training loads (TLs) and fitness on return is vital. The authors investigated physical-capacity changes from pretour to posttour, determining if those changes were related to the TL of athletes on tour. ***Methods:*** Thirty junior athletes completed fitness testing before and after 4-wk tours. Testing included double-leg countermovement jump (CMJ), dominant single-leg and nondominant single-leg CMJ, speed (5, 10, 20 m), modified 5-0-5 agility (left and right), 10 × 20-m repeated-sprint ability (RSA), and multistage fitness tests. Repeated-measures ANOVAs determined physical-capacity change, with effect-size analysis establishing the magnitude of change. To avoid regression toward the mean, a 1/3-split technique was implemented for comparative analysis (high to low TLs). ***Results:*** Moderate effects (d = 0.50–0.70) for reductions of up to 3.6% in 5-, 10-, and 20-m speeds were observed. However, all remaining changes were only of trivial to small magnitude (d < 0.40). Closer analysis of the interaction between TL and physical capacities (1/3-split) revealed that subjects who completed the greatest amount of total and tennis TL returned with a greater decline in speed and aerobic capacities (d > 0.80). Furthermore, it was observed that match load dictates on- and off-court TL, with an increase in matches won understandably stunting exposure to off-court TL. ***Conclusions:*** Specific training should be prescribed on tour to maintain speed characteristics over a 4-wk international tour. On-tour training schedules should be carefully monitored to maximize specific TL exposure after losses on tour.

Keywords: travel, physical capacities, intermittent sprint, racket sports

Elite tennis players travel extensively for tennis tournament play to gain or maintain ranking points.[1,2] Such travel, particularly in elite players, invariably interrupts the training process owing to a lack of access to appropriate facilities, coaches, and professional support.[3] Furthermore, the training load (TL) acquired on tour is highly variable as a result of the unpredictable nature of tournament scheduling, opposition draw, and match results, possibly leading to physiological maladaptation.[1] This potential deficit in TL may in turn lead to posttour reductions in physical capacities. Kovacs et al[3] previously showed that an extended, unsupervised time away from coach and support facilities leads to declines in a range of physical capacities. Specifically, a 5-week period of unsupervised training among college players resulted in significant reductions in speed, power, and aerobic capacity.[3] Although TL was not reported, subjects completed significantly lower training volume than in season (10 h tennis and 3.5 h gym per week),[3] therefore suggesting that the TL while away from training bases for extended periods (ie, on tour) may alter training stimuli and suppress physical capacities.

The demands of tennis tournaments (ie, volume and intensity of physical load) vary depending on the number of matches won and type of matches (ie, qualifying, main draw, doubles).[4] Subsequently, TL management is dependent on the number of days between matches or tournaments, associated travel to tournaments, and athlete recovery (ie, injury or soreness).[1,5] Previously, it has been reported that as players compete in a large number of matches, they may accrue certain fitness benefit or, more likely, limit physiological detraining.[5] However, on junior developmental tours, athletes generally travel in larger groups and therefore cannot simply leave a tournament venue for the next tournament until the entire tour group can be accommodated. As such, coaches provide supplementary training for losing athletes to reduce the magnitude of physiological decrements when matches no longer provide a physical stimulus.[5] Furthermore, individual athlete training dispositions will vary depending on tour success. While care is taken to ensure that athletes are in peak condition before tour departure, there is a lack of information available to coaches highlighting which physiological capacities are best maintained and how TLs and posttour fitness interact.

To understand posttour fitness states, coaches use physical-capacity testing batteries as quantifiable measures of changes in physical capacities over time.[6] Kovacs et al[3] identified key physiological variables for fitness testing of developing tennis players, including speed, agility, strength, muscle endurance, anaerobic power, aerobic capacity, and flexibility. While tennis is not afforded the same luxury as other sports in terms of rigid seasonal competitive structures, numerous studies have investigated the seasonal changes to certain physical capacities in team and individual sports (ie, hockey, volleyball, basketball, and swimming).[7–11] Endurance capacities such as maximal oxygen consumption appear to be easily maintained throughout competitive hockey, volleyball, and swimming seasons, given the predominantly aerobic demands typical of competition.[8,9,11] However, lower-body power in elite volleyball and basketball athletes (ie, leg extension, 30-s mean jump power, and

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vertical jump) is reported to reduce after completion of the season,[7,9] thus highlighting the potential maladaptation of physical capacities during competitive seasons or tennis tour schedules. That said, it is recognized that many of these physical-capacity tests do not directly inform about tennis performance but, rather, the physical capacities that may be relevant to tennis.

To date, there is a lack of empirical evidence describing changes in athlete physical capacities after tennis tours or even a description of the type and role of TL on those changes in physical capacities. As such, the current study aimed to investigate the change in physical capacity and the association with certain amounts and types of TL of elite junior tennis athletes while on an international tour. Specifically, we aimed to describe changes from pretour to posttour and to determine if changes in physical capacities were related to TL. Due to potential regression of fitness changes toward the mean, additional analysis implemented a 1/3-split technique to critique mean data of the most positive and negative changes for the respective physical-capacity measures. We hypothesized that physical capacities would decline posttour, with lower strength (resistance-based exercise) and conditioning (energy-system derived) (S&C) TL and higher match load related to a reduction in physical capacities.

Methods

Subjects

Thirty high-performance junior tennis players (age 17 ± 1.3 y, matches/y 135 ± 22, International Tennis Federation [ITF] junior ranking 157 ± 112, Association of Tennis Professionals [ATP] ranking 1309 ± 370, World Tennis Association [WTA] ranking 792 ± 41) representing Australia at junior ITF events were recruited. The cohort consisted of 20 males (mass 66.9 ± 8.6 kg, height 176.7 ± 6.0 cm) and 10 females (mass 60.5 ± 5.5 kg, height 170.2 ± 3.8 cm). Subjects in the current cohort routinely complete 2 or 3 training sessions per day. Specifically, training weeks often include 11 on-court sessions (~120 min), 3 strength sessions (~60 min), and 2 conditioning sessions (~45 min). On- and off-court sessions are designed by coaches to address the specific priorities of each athlete. However, strength sessions will involve free-weight exercises, while conditioning sessions typically will involve high-intensity interval training. All subjects were given verbal and written description of all procedures and aims of the project. All subjects and parents provided written informed consent to the study, and a university human ethics review committee approved the investigation.

Research Design

The current study examined the TLs and physical-capacity changes associated with 4-week international tours (junior ITF) on elite developing tennis players. Subjects were chosen after selection onto a Tennis Australia international tour across 3 different 28-day tours (13.0 ± 4.5 matches across each tour). The current tour durations and match requirements represented typical tours for the study cohort and were scheduled by the assigned coaches. Tour 1 involved travel to New Zealand (~3.5 h travel); tour 2 to Thailand, Malaysia, and the Philippines (~10 h travel); and tour 3 to Japan and Korea (~10.5 h travel), with each tournament played on hard courts (acrylic). Two days before and within 2 days after the tour (allowing sufficient recovery from match- and travel-accumulated fatigue),[12] subjects completed physical-capacity testing protocols. Testing protocols were designed by Tennis Australia, and each athlete had prior familiarity with all procedures. Warm-up and testing procedures were standardized with the following order observed: double-leg (DL), dominant single-leg (DOM), and nondominant single-leg (NON) countermovement jump (CMJ); speed (5-, 10-, 20-m); modified 5-0-5 agility (left and right); 10 × 20-m repeated-sprint ability (RSA); and the multistage test (Tennis Australia Fitness Protocols, 2011). All physical activity and fluid and food intake for the 24 hours before testing were standardized and replicated posttour.

Measures

CMJ: Double, Dominant Leg, and Nondominant Leg. A CMJ protocol was used to determine lower-body power through peak height in vertical displacement using a yardstick (Vertec) jumping device with multiple vanes distanced 1 cm apart (Vertec, SWIFT Performance Equipment, Lismore, Australia).[13,14] The test was carried out first double-legged and then on the dominant leg and the nondominant leg. Subjects stood directly beneath the measuring vanes. Before jumping they were encouraged to execute a countermovement immediately before upward propulsion and were permitted to use upward arm swing. For each jump, athletes displace the vane at its maximum height (nearest 1 cm). Subjects completed 3 trials, with the best recorded for each protocol. The intraclass correlation coefficient (ICC) of CMJ-DL, CMJ-DOM, and CMJ-NON was .96. The technical error (TE) of CMJ-DL was 1.0 cm, while the TE of both CMJ-DOM and CMJ-NON was 2.0 cm.

Speed: 5-, 10-, and 20-m Sprints. Dual-beam electronic timing gates were used to concurrently measure near-maximal 5-, 10-, and 20-m sprints over 20 m. Four gates were aligned and synchronized at 0 (start), 5, 10, and 20 m. The subjects started in their own time, sprinting with maximal effort without a racket. Three trials were completed, with the best time for each distance detailed to the nearest 0.01 second via telemetry to a computer (Speedlight, SWIFT Performance Equipment, Lismore, Australia).[13] The ICCs of the 5-, 10-, and 20-m sprints were .84, .87, and .96, respectively. The TE of each sprint distance (5-, 10-, and 20-m) was 0.06 second.

Agility: Modified 5-0-5 Left and Right. Agility was measured using a modified version (stationary start) of the 5-0-5 agility test.[13,15,16] One set of dual-beam electronic timing gates was used to determine athletes' ability to perform a single, rapid 180° change of direction over 5 m. The subjects started in their own time, sprinting with maximal effort without a racket. Three trials pivoting on both left and right feet were completed, with the respective best times recorded to the nearest 0.01 second (Speedlight, Swift Performance Equipment, Lismore, Australia). The ICC and TE of left and right modified 5-0-5 agility were .92 and 0.05 second, respectively.

Multistage Test. The multistage test was used to determine aerobic power using previously cited protocols.[13,17] Subjects performed continuous interval running over 20 m indicated by a compact disc (Australian Sports Commission, Canberra, Australia) emitting a bleep to commence each shuttle and increasing speed by 0.5 km/h every 2 minutes. Athletes were required to place 1 foot behind the 20-m mark at the sound of each bleep. Subjects failing to reach the distance were given a warning and eliminated from the test after subsequent failures. The level shuttle immediately preceding the eliminating bleep was recorded and converted into a decimal number. The ICC was .90, while the TE (reported as a decimal) was 0.5.

Repeated-Sprint-Ability Test. The 10 × 20-m RSA test protocol was used to evaluate the capacity to maintain maximum acceleration

and speed across multiple efforts.[13,18] Athletes sprinted the 20-m distance, with maximal effort, every 20 seconds 10 consecutive. Subjects started each subsequent 20-m repetition from where they finished the preceding repetition. All times were recorded to the nearest 0.01 second via telemetry to a computer (Speedlight, Swift Performance Equipment, Lismore, Australia) and summed for total time. The ICC was .86, while the TE of the RSA test total time was 0.61 second.

Load Monitoring

On tour, subjects took part in training (outside of matches) as prescribed by tour coaches, meaning researchers did not alter or ask coaches to alter training sessions in any way for the purpose of the investigation; that is, prescription was led purely by coaches. The TLs of all on- and off-court sessions were recorded using methods described by Foster et al,[19] multiplying session rating of perceived exertion by duration. TLs (arbitrary units; AU) were calculated for total (all sessions), total on-court (ie, all tennis-related sessions including matches), total off-court (ie, all S&C training sessions), singles matches, doubles matches, tennis training, strength training, and conditioning sessions. Rating of perceived exertion (RPE) was obtained 30 minutes after all sessions.[20] Tournament outcome data (matches won or lost) were collated on tour return.

Statistical Analysis

Results are presented as mean ± SD unless otherwise stated. Comparisons between physical-capacity test results were performed using repeated-measures ANOVA (measure × time). Significance was set at $P \leq .05$. Cohen *d* effect-size analysis established the magnitude of detraining effect pretour to posttour. Values <0.20, 0.20 to 0.40, 0.40 to 0.70, and >0.80 were considered trivial, small, moderate, and large effects, respectively.[21] Furthermore, 90% confidence intervals and percentage change determined the magnitude of change.[22] To avoid potential regression of physical-capacity testing results toward the mean, a 1/3-split technique was implemented, whereby the cohort was divided into 3 groups based on TL.[23] The top 1/3 and bottom 1/3 were then analyzed using an ANOVA (group × TL type) and effect-size analysis to closer investigate the impact of TL on posttour fitness status. Pearson correlation coefficients determined the association between TLs and physical capacity, as well as match outcome and changes in physical capacity. ANOVA and Pearson correlation were performed using SPSS (version 20, Chicago, IL, USA).

Results

Table 1 summarizes the mean (± SD) values of pretour and posttour testing, alongside the change in physical capacities (% ± 90% confidence limits) and magnitude of that change (effect size, *d*). Speed testing demonstrated moderate effects for a decline in 5-m (3.6% ± 0.6%), 10-m (3.3% ± 0.6%), and 20-m (2.2% ± 0.6%) performance posttour ($d = 0.70$, 0.61, and 0.51, respectively; $P > .05$). CMJ-DL ($d = 0.18$, $P > .05$), CMJ-NON ($d = 0.13$, $P > .05$), and CMJ-DOM ($d = 0.21$, $P > .05$) demonstrated trivial to small changes in jump height pretour to posttour (CMJ-DL, –2.0% ± 0.7%; CMJ-NON, –1.8% ± 0.5%; and CMJ-DOM, –1.8% ± 0.6%). Similarly, the magnitude of change in modified 5-0-5 agility posttour was small, with slower test times for the left leg (1.5% ± 0.6%) and right leg (0.9% ± 0.7%) ($d = 0.41$ and 0.26, respectively; $P > .05$). Posttour comparison of the multistage and RSA tests also revealed detriments of small magnitude ($d = 0.23$, –1.9% ± 0.5%; $d = 0.30$, 1.4% ± 0.6%, respectively; $P > .05$).

Highest and lowest tour TLs (1/3 split; n = 10 each) are compared in Table 2. Speed analysis determined that subjects in the top 1/3 for total TL returned with significantly greater detriment ($d > 0.80$, $P < .05$) in 10-m and 20-m times. Furthermore, large effects ($d > 0.80$, $P > .05$) for reduced 10-m and 20-m speeds were also evident for those who completed greater tennis TLs. There were also large effects observed ($d > 0.80$, $P > .05$) for detriments to multistage and RSA results when total and tennis TL were in the highest 1/3, as well as multistage and CMJ-NON in the presence of greater match load. In contrast, large effects were evident for

Table 1 Pretour and Posttour Results for Physical-Capacity Test, Mean ± SD, Together With the Change in Testing Results and the Magnitude of That Change (Effect Size)

Measure	SWC (%)	Pretour	Posttour	% Change[a] ± 90% confidence limits	Effect size	Descriptor
CMJ-DL (cm)	1.43	48.7 ± 8.5	47.7 ± 8.2	–2.0 ± 0.7	0.18	Trivial
CMJ-NON (cm)	1.18	36.6 ± 8.2	35.9 ± 8.1	–1.8 ± 0.5	0.13	Trivial
CMJ-DOM (cm)	1.21	36.7 ± 8.2	35.5 ± 8.7	–1.8 ± 0.6	0.21	Small
5-m sprint (s)	0.01	1.13 ± 0.08	1.17 ± 0.08	3.6 ± 0.6	–0.70	Moderate
10-m sprint (s)	0.02	1.92 ± 0.14	1.98 ± 0.13	3.3 ± 0.6	–0.61	Moderate
20-m sprint (s)	0.04	3.30 ± 0.20	3.37 ± 0.20	2.2 ± 0.6	–0.51	Moderate
5-0-5 left (s)	0.03	2.68 ± 0.13	2.72 ± 0.12	1.5 ± 0.6	–0.41	Small
5-0-5 right (s)	0.04	2.68 ± 0.13	2.71 ± 0.13	0.9 ± 0.7	–0.26	Small
20-m shuttle test	0.24	12.8 ± 1.5	12.6 ± 1.5	–1.9 ± 0.5	0.23	Small
10 × 20-m RSA (s)	0.37	34.66 ± 2.27	35.15 ± 2.42	1.4 ± 0.6	–0.30	Small

Abbreviations: SWC, smallest worthwhile performance change (calculated as 0.2 × between-participants SD); CMJ, countermovement jump; DL, double-leg; NON, nondominant; DOM, dominant; RSA, repeated-sprint ability.

Note: Magnitudes of effect sizes were assessed using the following criteria: <0.2 = trivial, 0.2–0.49 = small, 0.5–0.79 = moderate, >0.8 = large.

[a] A negative % change shows detriments to physical capacities for all measures.

Table 2 Percentage Change in Physical Capacities Pretour to Posttour, Mean ± SD

		CMJ			Sprint			5-0-5			
	Load	DL	NON	DOM	5-m	10-m	20-m	Left	Right	Multistage	RSA
Total training load											
top 1/3	860 ± 50*#	–3 ± 5	–1 ± 6	–4 ± 6	–6.09 ± 3.41*	–7.69 ± 10.88*#	–4.44 ± 4.79*#	–1.88 ± 3.59	–0.38 ± 2.63	–3.46 ± 1.93*	–2.84 ± 2.82*
bottom 1/3	544 ± 68	–3 ± 4	–2 ± 7	–4 ± 5	–2.48 ± 5.11	–0.48 ± 3.04	–0.18 ± 3.04	0.02 ± 3.61	0.80 ± 3.54	–0.84 ± 6.10	–0.82 ± 1.93
Tennis training load (match and on-court training load)											
top 1/3	740 ± 30*#	–2 ± 6	–1 ± 6	–4 ± 5	–5.51 ± 3.79	–7.14 ± 11.22*	–4.23 ± 4.89*	–2.56 ± 2.85	–0.99 ± 1.53	–3.39 ± 1.99*	–2.66 ± 3.04*
bottom 1/3	461 ± 66	–2 ± 4	2 ± 10	–3 ± 5	–3.36 ± 6.07	–0.50 ± 2.48	–0.43 ± 3.45	–1.42 ± 5.73	–1.18 ± 3.75	–0.16 ± 6.06	–1.16 ± 2.33
Match load											
top 1/3	284 ± 38*#	–2 ± 6	–6 ± 8*	–5 ± 10	–2.59 ± 2.90	–1.82 ± 2.23	–2.59 ± 2.53	–0.98 ± 2.32	–0.57 ± 2.70	–3.42 ± 2.11*	–1.26 ± 2.36
bottom 1/3	140 ± 22	–2 ± 4	0 ± 6	–1 ± 3	–3.40 ± 6.00	–4.22 ± 11.88	–1.31 ± 5.65	–1.91 ± 6.17	0.36 ± 4.03	–0.18 ± 4.91	–1.56 ± 3.11
On-court training load (exclusive of match training load)											
top 1/3	302 ± 73*#	0 ± 6	0 ± 9	–1 ± 4	–4.25 ± 3.96	–3.02 ± 1.67	–2.93 ± 2.67	–1.00 ± 2.64	–0.30 ± 3.93	–2.94 ± 4.28	–0.61 ± 2.13
bottom 1/3	75 ± 18	–3 ± 3*	–1 ± 7	–4 ± 5*	–3.92 ± 2.27	–3.34 ± 3.46	–2.73 ± 2.01	–2.95 ± 3.96*	–1.89 ± 1.28*	–2.21 ± 1.50	–2.10 ± 2.19*
Strength-and-conditioning training load											
top 1/3	151 ± 18*#	–3 ± 4	2 ± 10	–2 ± 4	–6.38 ± 4.04*	–3.40 ± 3.66	–2.11 ± 2.23	–1.49 ± 5.31	–0.98 ± 2.78	–1.86 ± 2.45	–2.43 ± 2.06*
bottom 1/3	54 ± 13	–1 ± 6	–4 ± 5*	–2 ± 5	–2.36 ± 5.66	–4.27 ± 11.91	–2.69 ± 6.03	–1.53 ± 4.17	0.03 ± 3.23	–1.21 ± 6.58	–0.81 ± 2.91

Abbreviations: CMJ, countermovement jump; DL, double-leg; NON, nondominant; DOM, dominant; RSA, repeated-sprint ability.

*Large effect size for greater detriments posttour in test measures between top- and bottom-1/3 athletes ($d > 0.8$). #Significantly greater detriments posttour in test measures between top- and bottom-1/3 athletes ($P < .05$).

greater decline in CMJ-DL, CMJ-DOM, 5-0-5 agility (left and right), and RSA in subjects completing the least on-court TL ($d > 0.80$, $P > .05$). Finally, those completing greater S&C TL suffered greater detriment in 5-m sprint and RSA ($d > 0.80$, $P > .05$), while those who completed less S&C TL returned with poorer CMJ-DOM results ($d > 0.80$, $P > .05$).

Correlations comparing changes in physical capacity with TL (Figure 1) identified moderate positive relationships between total tennis TL completed on tour and reduced 10-m and 20-m sprint performance ($r = .45$ and .52, respectively). Furthermore, a moderate negative relationship between total tennis TL and the change in multistage test was observed ($r = -.44$). Figure 2 reveals that the number of singles matches won was highly correlated with match load ($r = .70$), while slight negative associations were observed between the number of singles matches won and total off-court ($r = -.23$), strength ($r = -.25$), and doubles TL ($r = -.25$). Finally, slight positive relationships were present between the number of matches lost and total off-court ($r = .25$) and conditioning TL ($r = .29$), while there was a slight negative relationship between the number of matches lost and tennis TL completed ($r = -.26$).

Discussion

International tennis tours place athletes in unpredictable training and competition surroundings. Intensive travel, restricted access to facilities, and lack of professional support all result during overseas tennis tours and can jeopardize training and match preparation as part of long-term athlete development. Hence, the aim of this investigation was to determine whether physical capacities were affected after 4-week tours. A secondary aim was to determine whether changes in physical capacities were related to tour training and match loads. Current findings highlight moderate effects for reductions of up to 3.6% in speed characteristics. However, all

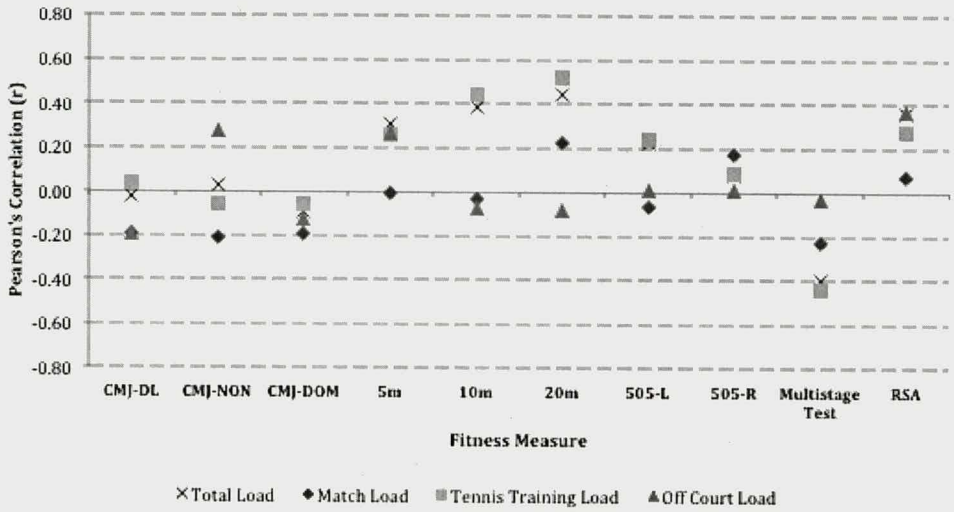

Figure 1 — Correlations between match, tennis, and off-court training loads while on tour and the change in physical-fitness tests of double (CMJ-DL), nondominant (CMJ-NON), and dominant (CMJ-DOM) countermovement jump; 5-, 10-, and 20-m sprint; left and right 5-0-5 (5-0-5-L, 5-0-5-R); multistage test; and 10 × 20-m repeated-sprint ability (RSA).

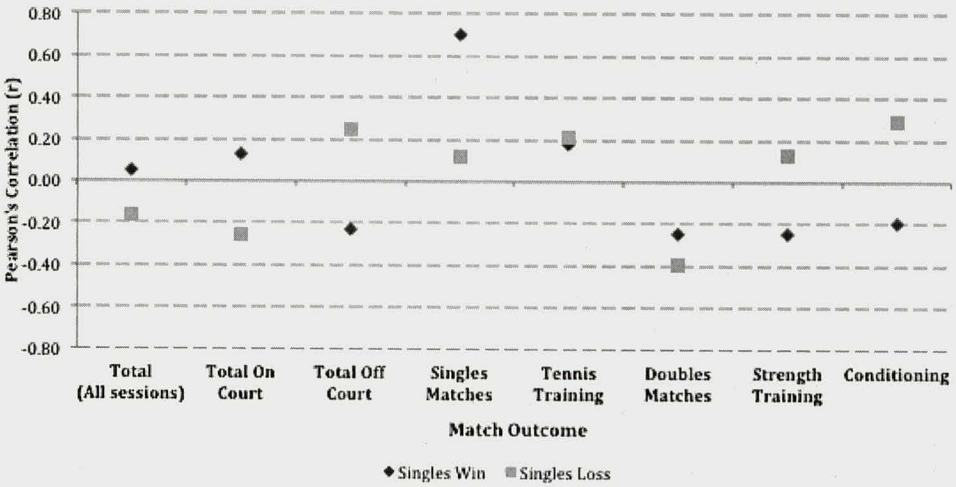

Figure 2 — Correlations of singles matches won and lost with total load, total tennis load, total off-court load, match load, on-court load, doubles load, strength load, and conditioning load.

remaining changes in testing measures were of only trivial to small magnitude. Moderate, positive correlations were evident between tennis TL completed on tour and deterioration in 10-m, 20-m, and multistage test performance. The impact of on-tour TL was further analyzed using a 1/3-split technique, with subjects completing more total and tennis TL returning poorer speed, aerobic, and anaerobic test results. Finally, the number of matches won shared high positive correlations with match load, while the number of singles matches won slightly and negatively correlated with off-court TL. Unexpectedly, slight positive relationships were present between matches lost and total off-court TL. Such findings highlight the unique effect that tours can have on physical capacities and the importance of appropriate physical-training foci while on tour.

Posttour testing demonstrated increased (ie, slower) 5-m, 10-m, and 20-m times. Subsequent analysis (1/3 split) demonstrated slower sprint results (10-m and 20-m) in subjects who completed greater total and tennis TL; however, subjects completing greater S&C TL returned with poorer 5-m results. Such detriments to speed may be a consequence of a lack of specific training, that is, limited short-duration, maximal-sprint training resulting in maladaptation of acceleration characteristics. Previously, in an acute tennis study that investigated the effect of 3 consecutive days of competitive play on an indoor hard court (Greenset comfort), there was no change in precompetition-to-postcompetition 5-m-sprint time.[1] As such, 1 tournament seems too short to elicit an overt reduction in peak speed, with such acute tournament durations and loads being insufficient to elicit maladaptation.[1,5] Conversely, Kovacs et al[3] demonstrated that after 5 weeks of unsupervised (yet prescribed) training, 5-m, 10-m, and 20-m times were all slower postbreak. The discrepancy may describe a time effect, in that longer periods without sufficient training stimuli (ie, high-speed running) can result in the detriments noted in the current study. Kovacs et al[3] suggest that because tennis points are generally 4 to 7 seconds, detraining in speed qualities could be detrimental to match performance. However, given the fact that most tennis movements are within a 3- to 4-m radius, there is rarely a chance for tennis players to reach maximum speed, and when extended movements (>4 m) do occur, immediate deceleration follows.[24] Furthermore, due to the court size, subjects who completed greater tennis TL (therefore less S&C TL) are seldom exposed to such sprint distances (>10 m). These results suggest that continued match play may not provide enough training stimulus for extended sprint speeds, and when match play dominates over training for extended periods, speed capacities can suffer. Moreover, while 5-m-sprint times deteriorated most in subjects completing greater total TL, this decline may relate to increased S&C TL, rather than tennis TL, highlighting the likely correspondence between on-court demands and shorter-distance tests (5-m and 5-0-5 agility). Such limited exposure to peak velocity movements and increased eccentric loading provide a rationale for reduction in speed qualities (>10 m), while agility and lower-body power measures were maintained.

Despite the aforementioned reduction in linear speed, there were limited changes in 5-0-5 agility, although 1/3-split analysis noted greater detriment in those completing the least on-court TL. Kovacs et al[3] also failed to find any change in agility (spider agility test) among players returning from an unsupervised college break. The spider agility test differs in duration (16–18 s) from the 5-0-5 agility test (2–3 s), which more closely resembles the duration and movement intensity of an acute end-range stroke and midcourt recovery (2–4 s).[25] The lack of reduction in 5-0-5 agility noted here may be explained by the specificity of movement and energy-system demands (ie, movement patterns specific to baseline shuttles). For example, the similarity between the 5-0-5 movement pattern and typical movements in tennis training and match play may result in a sufficient training stimulus. As the current 1/3-split analysis further highlights, those completing less on-court TL suffered greater decline in 5-0-5 agility, which can be interpreted to further reinforce the importance of TL continuation after tournament exit, with on-court and eccentric loading demands crucial to agility maintenance.

There were no reductions in any lower-body power tests after tours, suggesting that power can be maintained throughout a 4-week tour. Subjects who completed the least on-court TL suffered the greatest decline in CMJ-DL and CMJ-DOM. However, CMJ-NON was of greatest decrement for subjects who completed greater match load, while the same was observed with a reduction in S&C TL. The interaction between lower-body power, match loads, and total TL may be due to incidental increases in muscle recruitment for the nondominant leg, given the repeated eccentric loading of the landing foot during the serve.[26] Kovacs et al[3] investigated changes in lower-body power using standing long jump. Although standing long jump measures maximal power in a horizontal plane, no changes occurred after the 5-week unsupervised break.[3] Previously, Ojala and Häkkinen[1] found no changes to CMJ or 5-jump tests after 3 days of consecutive match play. The current investigation sampled from a significantly greater duration than Ojala and Häkkinen[1] (4 wk), and as yet no literature currently reports posttournament changes in tennis-related physical capacities. Presently, it seems that the TLs associated with a 4-week international tennis tour are sufficient to maintain CMJ, although, it is important that coaches ensure on exiting a tournament that players maintain on-court TLs to avoid declines in CMJ-DL and CMJ-DOM.

Posttour comparison of aerobic capacity and RSA revealed no changes after international tours. However, the split technique showed that those who completed the greatest total and tennis TLs had a larger reduction of both aerobic capacity and RSA. Furthermore, greater aerobic fitness reductions occurred in those completing greater match load. Kovacs et al[3] reported significant reductions in maximal oxygen consumption (11%) and Wingate anaerobic fatigue index (7.15%) after a 5-week break from supervised training. Such changes, for aerobic capacity in particular, have been previously reported in detraining literature and have been attributed to reductions in blood volume.[3,27] Furthermore, other reports describe that TL reductions often result in a rapid decline in maximal oxygen consumption for highly trained athletes.[3,28] Such findings may prove true for conventional detraining studies; however, in the current investigation there was no cessation of TL—instead TLs were largely dependent on match outcome. As such, the current data suggest that match loads are sufficient for sustaining endurance capacities. However, the negative relationship between total tennis TL and aerobic test performance suggests that an increase in match load (ie, resulting in increased total tennis TL and decreased time available for conditioning TL) has the potential to interfere with the maintenance of aerobic capacities.

It is clear that the amount and type of TLs completed on tour during and between tournaments contribute to the associated changes in physical-capacity characteristics. Nevertheless, match loads (ie, as dictated by the number of matches won and lost) affect the amount of match load completed and subsequent weekly and total TL. As expected, the current findings reveal a strong relationship between matches won and match load. Correspondingly, there were trends for reduced off-court TLs completed as players won more matches. Such findings may be an artifact of player preparation, as coaching staff structure physical preparation toward a maintenance focus while athletes are winning matches (ie, reduced

volume).[5,29] However, on exit from a tournament, after appropriate recovery, off-court training becomes a priority, as demonstrated by the positive relationship between matches lost and off-court TL.[5,29] Due to supervisory obligation, exited junior athletes must remain with the tour, and therefore strategies should be put in place to ensure maintenance of TLs to deter physical-capacity maladaptation—particularly for speed characteristics, as previously highlighted.

Practical Applications

With extensive travel being a necessity for professional tennis players, junior elite programs attempt to prepare promising athletes through international tours. An understanding of the TLs associated with such tours and the impact that tours have on physical-capacity characteristics therefore becomes vital. Current findings reveal speed reductions, with no detrimental effect on agility, lower-body power, or aerobic and anaerobic capacities. The current study further highlights the importance of speed-training exposures over a 4-week international tour, especially when match TLs are high. Furthermore, we observed that match load dictates on- and off-court TL, with an increase in matches won stunting exposure to off-court TL. Acknowledgment of reduced off-court TL completed with greater match success will allow coaches to either alter training priorities on tour or plan appropriate training sessions on return, specifically targeting training to maintain speed characteristics. More research in this area is needed to describe typical TLs completed pretour and investigate the appropriateness of tapers and overreaching immediately before tour departure.

Conclusions

This investigation is the first to describe and compare the physical-capacity changes, TLs, and performance outcomes associated with a 4-week international tennis tour. Results indicate reductions in 5-, 10-, and 20-m sprints. Furthermore, relationships were observed between tennis TL completed on tour and 10-m and 20-m sprints and the multistage test. Finally, correlations of TL and match outcome also revealed match and off-court TL to be heavily dependent on matches won and lost. That said, some limitations of this study should be acknowledged. As discussed earlier, as TLs experienced on tour were highly reliant on match outcome, each tour may represent a different training response. Furthermore, the lack of flexibility in the testing protocols as prescribed by Tennis Australia means that there was some restriction from including strength-testing protocols due to the high eccentric loads associated with the maximal-testing protocols inherent of the national body. We would envisage that strength testing in future research would provide a clearer picture of the musculoskeletal changes associated with tennis tours. It seems, however, that there is potential for speed and aerobic characteristics to decline throughout international tennis tours. As such, information on specific relationships between match outcome and TL is important to recognize trends of reduced TLs or decline in physical capacities, to employ a targeted training focus in subsequent periodization. Such findings emphasize the effect that tours can have on fitness characteristics and, in turn, long-term athlete development.

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