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A comparison of the perceptual and technical demands of tennis training, simulated match-play and competitive tournaments

Abstract

Purpose: High-performance tennis environments aim to prepare athletes for competitive demands through simulated match scenarios and drills. With a dearth of direct comparisons between training and tournament demands, the current investigation compared the perceptual and technical characteristics of training drills, simulated match-play, and tournament matches.
Methods: Data were collected from 18 high-performance, junior tennis players (gender: 10 male, 8 female, age: 16±1.1 y) during 6±2 drill-based training sessions, 5±2 simulated match-play sessions, and 5±3 tournament matches from each participant. Tournament matches were further distinguished by win or loss, and against seeded or non-seeded opponents. Notational analysis of stroke and error rates, winners, and serves, along with rating of perceived physical exertion (RPE) and mental-exertion were measured post-session.
Results: Repeated-measures analyses of variance and effect-size analysis revealed training sessions were significantly shorter in duration than tournament matches ($p<0.05$; $d=1.18$). RPE's during training and simulated match-play sessions were lower than in tournaments ($p>0.05$;$d=1.26$,$d=1.05$ respectively). Mental exertion in training was lower than both simulated match-play and tournaments ($p>0.05$;$d=1.10$;$d=0.86$ respectively). Stroke-rates during tournaments exceeded those observed in training ($p<0.05$;$d=3.41$) and simulated match-play ($p<0.05$;$d=1.22$) sessions. Further, the serve was used more during tournaments than simulated match-play ($p<0.05$;$d=4.28$), while errors and winners were similar independent of setting ($p>0.05$;$d<0.80$).
Conclusions: Training in the form of drills or simulated match-play appeared to inadequately replicate tournament demands in this cohort of players. Coaches should be mindful of match demands to best prescribe sessions of relevant duration as well as internal (RPE) and technical (stroke-rate) load to aid tournament preparation.

Keywords: Training loads; periodisation; long-term athlete development; tournament preparation

Introduction

High-performance tennis athletes are exposed to a myriad of training stimuli in preparation for tournaments, including technical and tactical drills, and simulated match-play.[1-4] Whilst previous discrete[3,4] and catalogued drill studies[2] establish typical 'training loads' (TL's) associated with high-level tennis environments, comparisons of training sessions, simulated match-play, and tournaments within the same cohort are non-existent; with past research inferring insight from data gathered from different competition cohorts (i.e., developmental vs. elite).[3,4]. In a similar vein, given the significance attached to training during developmental years (i.e., 8-20y),[5] a more granular understanding of the actual training and competitive demands imposed on this particular cohort of players is needed.[6,7] Ideally, training drills and simulated match-play should mimic conventional or 'worst case' tournament scenarios (i.e., highest demands required during competition) depending on developmental stage of the involved players.[2,8] In other sports (i.e., rugby league), a primary objective of training is to replicate certain patterns of play, enabling players to cope with the highest demands placed upon them during competition.[9,10] Unfortunately, in tennis, current literature has provided negligible insight into the appropriate prescription of TL's to mimic competition play, particularly in specific cohorts through early - late developmental stages.[11]

The TL's of different cohorts of tennis players completing training drills, simulated match-play scenarios, and tournament play have been investigated through an assortment of internal (i.e., heart rate [HR], rating of perceived exertion [RPE], and mental exertion) and external (i.e., stroke-rate) measures. Previously we have described the internal and external TL's of various drill categories within a high-performance youth tennis population.[2] Specifically, Recovery/Defensive drills were of greatest internal TL (HR, RPE, and mental-exertion).[2] Physiologically, more 'open' drills were characterised by higher peak and mean-HR, whilst match-play and more 'closed' or technical drills presented with lower peak and mean-HR.[2] Reid et al.[3] earlier characterised four discrete, hand-fed, drills including the Star, Box, Suicide and Big X. Internal TL's were reported using HR (178-182 bpm), and RPE (5.0-7.6 au), while external TL's were documented through stroke count (0.7-2.3 strokes$\cdot$min^{-1}), ball velocity (113-123 m/s), and distance covered (76-114 m) via global positioning system (GPS) measures.[3] Furthermore, previous data suggests that stroke-rates during point-play and match-play in training are below the stroke-rates characterised in separately reported tournament data (2.7±2.2 - 4.7±1.4 strokes/rally).[2,12,13] Moreover, tournament RPE has been reported as ranging between 5-8 au (CR-10)[14,15] and 10-16 (Borg 20-point).[16-18] On the surface, while this empirical backdrop appears extensive, it is the aggregate of independent, discrete training and competition insights and lacks any consideration of training or matches within a single cohort, therein placing practitioners in situations that require ongoing assumptions to inform TL's.

Nevertheless, based on a comparison of previously notated[13] and perceived match demands[14,15] with the observational data describing typical training sessions,[2] TL's in training and tournament play appear disparate. Indeed, this type of discrepancy may contribute to mismatches in the preparation of high-performance athletes for tournaments; albeit it is assumed – perhaps incorrectly – that players are training at suitable intensities and durations. Given the lack of empirical support for this assumption, the aim of this study was to analyse the technical and perceptual characteristics of drill-based training sessions in comparison to simulated match-play and tournaments in the same cohort of elite players. A secondary aim was to compare TL's within tournament matches won vs. lost, and against seeded vs. non-seeded opponents to further explore the nuances of TL responses related to match outcome. It was hypothesised that (a) training sessions would present lower TL's than simulated match-play, which would in turn be lower than tournament matches, and, (b) tournament demands would be elevated in matches lost and against seeded opponents.

Methods

Subjects

Eighteen high-performance, junior tennis players (gender: 10 male, 8 female, age: 16±1.1 y, mass: 63±16.2 kg, height: 171±11.4 cm, Australian junior ranking: 6±5, and International Tennis Federation [ITF] junior ranking 85±61) and their parents/guardians provided written consented following full explanation of the study. The University Ethics in Human Research Committee approved this investigation. Athletes routinely trained 2-3 sessions per day, completing 96±24 matches for the year. This study involved collection of internal and external measures from at least one training session per day, over a 10-week hard court training period (December-February; Australian summer). Athletes were well familiarised with each drill during each session as a result of extensive exposure during previous training blocks. Training sessions were selected when at least 2 subjects were included in the session, and coach designed session plans involved open nature drills (i.e., higher physical demands) with lesser emphasis on technical proficiency or outcomes.

Design

All training drills, simulated match-play and tournament matches were completed on a Plexicushion tennis court. Athletes each completed 6±2 open-drill training sessions, 5±2 simulated match-play, and 5±3 tournament matches. Athletes within the testing cohort were encouraged by coaching staff to standardise nutritional habits around training in preparation for competition. However, the inclusion of physical (S&C) sessions within the training day meant that additional energy intake was required. Similarly, owing to the real world settings, characterised by uncertain match start and finish times, travel demands and the variable selection and timing of meal/hydration options, nutritional practices were not standardised. This approach aligns to previous match investigations,[15] however, due to the within-cohort analysis, a similar approach was adopted for training also. However, whilst conditions across all sessions were dry and relatively warm (Australian summer), these were unattainable across all training sessions and matches, creating a limitation to the TL analysis. While the strength of the current investigation surrounds the within-cohort comparisons, it is recognised that the variety of training and match locations limits an ability to standardize environmental conditions and hydration state. Accordingly, this is recognised as a limitation of the present study.

Tournaments

Analysis of tournament TL (i.e., match load) was carried out across four, outdoor, hard court (i.e., category 4 court surface) tournaments within Australia. Specifically, the first two tournaments were domestic Australian tournaments (National title events in Sydney and Melbourne), the further two events were junior ITF events (grade 1 and A, respectively) All matches followed ITF junior guidelines and were best of three sets, contested between 0900 and 1900 hours. Further, tournament matches were distinguished by outcome (win or loss), and opponent (against a seeded or non-seeded opponent) as separate analyses, with data obtained from Tennis Australia and ITF websites.

Simulated Match-play

Simulated match-play sessions were organised by assigned coaches, ensuring similar between-player capabilities. Sessions began with coach instruction and session focus. However, aside from encouragement, coaches observed, but refrained from interference of technical or tactical feedback within the match. Each match was best of three sets, self-controlled using ITF rules, and conducted on outdoor, hard court (i.e., category 4 court surface).

Training Sessions

Training drill sessions were selected for drills that were of open nature only (in accordance with our previously reported data), as these drills types are of greatest physical and mental demands of typical elite-oriented tennis drills.[2] Specifically, these types of drills consisted only of "Recovery/defensive", Open-pattern", and "2-on-1 open" drill categories. These drills were each typified by high strokes rates (>0.9 strokes per 6 sec), RPE (>5.5 AU), mental-exertion (5.8 AU) and % HRmax (>89%). Sessions were excluded from analysis post hoc if the aforementioned criteria were not met. All sessions were conducted on outdoor, hard court (i.e., category 4 court surface).

Methodology

All sessions were filmed using a video camera (DSR-PDX10P, Sony, Japan) positioned 10-m above and 6-m behind one baseline. The footage was later notated to establish stroke-rate, and unforced errors. Strokes were summated throughout the entire session or match involving any time in which the ball struck the racquet face. Errors in training sessions were distinguished inside the coach-prescribed constraints (if any) of the particular drill, which were clearly described by the assigned coach to both the athlete and the research team. Strokes, errors, winner and serves were counted and analysed relative to session/match duration (mins). Work durations - the effective playing time - were distinguished from the point of a successful serve until a winner or error, (analysed only for simulated match-play and tournaments). Rest durations were then calculated as remaining time within simulated match-play or tournament matches (i.e., change-over rest periods). Standard match rules were implemented for errors in both simulated match-play and tournament play.[19,20] Athletes were familiarised with physical RPE and mental-exertion as measures of internal load collected daily within their environment. Athletes provided RPE (Borg CR-10)[21] and mental-exertion evaluations (0-10 Likert scale) for each drill session, simulated match-play , and tournament match 30 mins following completion.[14,22] Session-TL, as an arbitrary number (au), was calculated through multiplication of duration and RPE.[14] Mental-exertion rating (0-10 Likert scale) was used to establish a holistic rating of mental intensity perceived. Athletes rated based on descriptions of mental demand.[22] All perceptual ratings were provided privately to ensure no predisposition or bias. As RPE and duration are the main measures of the current investigation, it is useful to note that previous research on adolescents has reported correlation coefficient between RPE and HR as strong (r=0.74).[23] Furthermore, a trained analyst (Coefficient of Variation <2%) who was familiarised with the notational analysis system (The Tennis Analyst, V4.05.284, Fair Play, Australia), conducted all notational analysis post-session. These measures are commonly used within training and post-tournament analysis to provide feedback and monitor external TL.[1,2]

Statistical Analysis

External and internal TL data were reported as mean (±SD), unless otherwise specified. Comparison of external and internal TL responses between different scenarios i.e., training, simulated match-play, or tournaments, was undertaken by repeated measures two-way (Session Mode x Measure) ANOVA's with Tukey HSD post-hoc tests to locate differences. Statistical significance was set at $p<0.05$. Cohen's *d* effect size analysis established the magnitude of difference TL. Effect size results were interpreted as described by Christensen & Christensen.[24] with effect sizes of <0.2 classified as small, 0.4-0.6 as medium, and >0.8 as large. Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) (Version 20, SPSS Inc., Chicago, IL, USA).

Results

Figure 1 shows session duration and the internal TL measures (session-TL, RPE and mental-exertion) for training drills, simulated match-play and tournament play. Furthermore, session duration and internal TL measures for tournament matches won vs. lost, and against seeded vs. non-seeded opponents are presented in Figures 2 and 3, respectively. No significant differences in session-TL were present between session types ($p>0.05$; $d<0.80$). However, there was significantly lower session duration evident for training compared to tournament play ($p<0.05$; $d=1.18$). Simulated match-play durations were similar to both training and tournaments ($p>0.05$; $d<0.80$). Large effects indicated a greater session RPE in tournaments than training ($p>0.05$; $d=1.26$) and simulated match-play ($p>0.05$; $d=1.05$). Matches within tournaments that were won were perceived to be of significantly greater RPE than matches lost ($p<0.05$; $d=1.40$). Furthermore, large effect sizes suggest a greater mental exertion was perceived during simulated match-play and tournaments than training drills ($p>0.05$; $d=1.10$, $d=0.86$ respectively).

***** Figures 1, 2 and 3 near here *****

External TLs (i.e., stroke-rate and work/rest durations) and technical outcomes (winners, serves and errors) of drills, simulated match-play and tournaments are presented in Table 1 (relative to session durations). Stroke-rates ($str \cdot min^{-1}$) in training were significantly lower than both simulated match-play and tournaments ($p<0.05$; $d=0.98$ $d=3.41$ respectively). Tournament stroke-rates were also significantly greater than simulated match-play ($p<0.05$; $d=1.22$). Within tournaments, stroke-rates were similar in both matches won (13 ± 3.4 $str \cdot min^{-1}$) and matches lost (16 ± 6.2 $str \cdot min^{-1}$) ($p=0.98$; $d=0.63$), as well as when playing a seeded opponent (17 ± 8.2 $str \cdot min^{-1}$) compared to non-seeded opponents (13 ± 4.2 $str \cdot min^{-1}$) ($p=0.95$; $d=0.60$). The work-rest durations of simulated match-play demonstrated large effects for less work (i.e., time in play) compared to tournament matches ($p=0.29$; $d=1.37$), and significantly less rest (i.e., stoppages) in simulated match-play than tournaments ($p<0.05$; $d=3.00$). Within tournament matches, work-rest durations of matches won (29.6 ± 10.6 mins work; 51.7 ± 16.1 min rest) and lost (27.8 ± 14.3 mins work; 50.2 ± 17.3 mins rest) were similar ($p>0.05$; $d<0.80$). Furthermore, there was a large effect observed for greater rest durations during matches against seeded (25.0±11.1 mins work; 44.7±10.4 mins rest) than non-seeded opponents (31.7±14.6 mins work; 54.4±20.3 mins rest) ($p>0.05$; $d=0.85$).

***** Table 1 near here *****

In a more detailed analysis of stroke characteristics, the absolute number of winners was similar between both simulated match-play and tournament match-play ($p=0.92$; $d=0.41$). However, relative for duration (Table 1), there was a large effect for more winners hit during simulated match-play than tournaments ($p>0.05$; $d=0.90$). Similarly, there were no differences observed between winners hit during tournament matches won (11±4.9 total; 0.4±0.3 w·min^{-1}) or lost (13±6.9 total; 0.5±0.3 w·min^{-1}) ($p>0.05$; $d<0.80$). There was also no difference in absolute winners hit during matches played against seeded (12±6.8 total; 0.5±0.3 w·min^{-1}) and non-seeded opponents (12±5.0 total; 0.5±0.3 w·min^{-1}) ($p>0.05$; $d<0.80$). Absolute and relative serve counts (se·min^{-1}) of simulated match-play (46±12.5 total; 2.6±1.3 se·min^{-1}) and tournament play (90±16.6 total; 3.4±0.8 se·min^{-1}) was increased during tournament matches compared to simulated match-play ($p<0.05$, $d=4.28$; $p=0.26$, $d=1.03$ respectively). While, absolute serve volume was similar between matches won (88±15.8 total; 3.2±0.9 se·min^{-1}) and lost (93±27.4 total; 3.7±1.2 se·min^{-1}), as well as between seeded opponents (80±13.6 total; 3.6±1.3 se·min^{-1}) and non-seeded opponents (96±27.5 total; 3.4±1.0 se·min^{-1}) ($p>0.05$; $d<0.80$). Finally, error-rates (er·min^{-1}) were significantly lower in training drills and simulated match-play than in tournament matches ($p<0.05$; $d>1.00$), whilst errors were similar between drill sessions and simulated match-play ($p>0.05$; $d<0.80$). Within tournament matches, there were no significant differences in error-rates ($p>0.05$; $d<0.80$) between matches won (1.7±0.6 er·min^{-1}) and lost (1.8±0.7 er·min^{-1}), or against seeded (1.7±0.7 er·min^{-1}) and non-seeded opponents (1.7±0.5 er·min^{-1}).

Discussion

An important component of the prescription of TL's is to ensure that athletes are exposed to match-like demands within training. As with other sports, tennis uses on-court training drills and simulated match-play for such preparation, generally alternating training at, above or below match intensities . However, currently no literature has *concurrently* compared the demands of common training drills, simulated match-play and tournaments within a homogenous group. Accordingly, the current findings indicate that both session duration and RPE during training tends to be lower than those typical of tournament play. A comparison of work–rest durations also revealed simulated match-play to be less intensive (i.e., less work, less recovery). Furthermore, training sessions elicited less mental exertion than both simulated match-play and tournaments. From a technical standpoint, tournament stroke-rates exceeded those in training and in simulated match-play, whilst greater (relative and absolute) serve loads were observed during tournaments than in simulated match-play. It should be noted though that within the timeframe of the current data collection there were no injuries reported from the playing group. Consequently, it is clear that the physical and technical TLs of training drills and simulated match-play warrant ongoing scrutiny to assist with the prevention of "over-training" or "under-training", therein ensuring that the long-term consequences of poor training intensity are avoided.

As abovementioned, training drills were selected specifically due to the associated physical demands demonstrated in previous studies.[2] As such, the authors are confident any bias towards technical foci during training was minimized. In any case, the present RPE responses in simulated match-play (6±0.9 au) and in tournaments (6±0.8 au) were not dissimilar to previous discrete investigations.[1-3,7,14,25,26] However, simulated match-play and tournament match-play RPE exceeded training drill RPE's (5±0.8 au). Previously, after examination of training sessions, we suggested RPE is greatest in those drills that most closely mimic match "worse case scenarios" or extreme time pressure situations (i.e., recovery/defensive drills; 6.5±1.8 au).[2] To provide clearer context, we have also previously shown that closed technical drills are characterised by low RPE's (4.6±1.9 au).[2] Prior to these studies, Reid et al.[3] describe discrete, work-rest ratio driven, "conditioning" drills (i.e., suicide, 7.6±1.1 au; and Big X, 7.6±1.0 au) of much greater RPE. As to be expected, it was also found that drill duration (i.e., 30s vs. 60s) was pivotal in the distinction of RPE for drills, a concept relevant to the interpretation of all training drill analyses.[3] Thus, prescription of sessions to mimic tournament demands must not only take into consideration the RPE of drills, but also the duration of drills and work-rest ratios involved.

Notwithstanding the body of work that has reported internal load in competitive match-play and invitational tournaments, few researchers have specifically explored the RPE's of athletes following completion of tournament matches in which international junior or senior ranking points are in dispute. Indeed, the work of Coutts et al.[14] represents a rare investigative foray in this regard, describing the RPE and session-TL of a top-level player from the 2008 Roland Garros. These researchers reported match RPE's ranging from 5 - 7 (au), with a weekly competition TL of 2908 (au), ~18% greater TL than during the final week of tournament preparation (2380 au).[14] However, caution is required in comparing between different developmental stages of players, as many other factors might influence overall perception of effort during this type of tournament play (i.e., prize money, media scrutiny, spectators), potentially increasing the RPE. Further it is unclear to what extent these influences may or may not affect the RPE's reported in tournaments where rankings are in dispute as compared to other competition/tournament formats. Nevertheless, in the current study, the RPE's reported in training could be interpreted to reflect a mismatch with tournament demands. As such, care should be taken to ensure that athletes are exposed to match-like physical intensities at some stage within preparatory training blocks.

Despite the abovementioned widespread use of perceptual load monitoring measures in tennis, mental exertion is an area that TL monitoring literature has seldom investigated - particularly in tennis. Admittedly, this may be confounded by the validity of the construct, yet its simplicity is instructive within high-performance junior tennis environments. Indeed, within the current investigation it is evident that a discrepancy exists between the perceived mental demands of training, simulated match-play and tournament match-play. Both simulated match-play and tournament matches required similar perceived mental intensity, which is considerably more than that of training. Previously, we have shown discrepancies between certain drill categories, with drills of greater focus (accuracy drills) and physical intensity (recovery/defensive drills) being characterized by significantly greater mental exertion than closed technical drills.[2] Keeping in mind the current investigation has controlled for intensity of training drills, it can be interpreted that in order for mental exertion to approximate tournament match-play, simulated competition or pressures (i.e., targets, time-pressure) must be incorporated in to training.

Given that the selection of drills was chosen due to their prominent physical intensity rather than technical focus, the present findings identify a somewhat perplexing disparity between stroke-rates of training sessions (7±1.0 strokes·min^{-1}), simulated match-play (10±5.1 strokes·min^{-1}) and tournament matches (14±3.6 strokes·min^{-1}). Despite similar durations observed between simulated and tournament matches, a reduced amount of work completed in simulated match-play compared to tournament matches. This was despite greater rest periods during tournaments - further highlighting a disconnect in the intended training prescription from a physical perspective. The authors admit however, that such disparity may be due to the technical/tactical focus or development during simulated match-play (i.e., tactical patterns, or stroke technique) within the corresponding training block. Alternatively, the observed increased winner rate during simulated match-play sessions may indicate more aggressive mindsets during these sessions. This is according to the similar ratings of mental exertion perhaps corresponding to alternative pressures during tournament matches (i.e., match outcome/consequences). Nevertheless, with such disparity between simulated match-play and tournaments, it is advisable that high-intensity drills be implemented within close proximity to simulated match-play to compliment or elevate simulated match-play demands. Previously reported tournament demands have been noted to reach 0.81±0.04 strokes·sec^{-1} for men and 0.76±0.03 strokes·sec^{-1} for women for matches during the Australian Open in 1997–1999.[27] Such discrepancies highlight the difference in elite tournament match intensity and that of the current developing player cohort (0.23 strokes·sec^{-1}).

In certain situations, increased error rates within matches may increase match durations, alter the work-rest ratio, and affect the mental state of players.[28] As such, error rates become of interest to coaches when preparing players for competition demands. The present findings suggest that tournament matches result in greater error rates than both training and simulated match-play. The authors postulate that such elevated error rates in simulated match-play and tournaments may be due to increases in mental exertion compared to drills. Anxiety of players is perhaps increased in simulated and competitive situations where opposition or situational pressure (i.e., increased strokes rates, physical demand, or importance of result) hinders an athlete’s ability to perform well. Earlier, descriptive analysis of training drills have identified that drills of technical focus and extreme physical (end range) requirements induced higher error rates.[2] Furthermore, a recent tennis investigation has identified increased somatic and cognitive state anxiety, and lower self-confidence pre-competition on match-day compared to training-day.[29] Moreover, following matches, somatic and cognitive anxiety (with associated with consequence of failure), were still elevated compared to training-days.[29] Therefore, during simulated match and training sessions in which error-ameliorating practice is desired, the effect that both physical *and* mental exertion have on error rates should be acknowledged. Additionally, to effectively prepare athletes for the mental demands of competition, there appears limited alternative other than through tournament matches. Having acknowledged this however, a limitation of the current investigation is the lack of obtainable context under which matches were played i.e. environmental conditions, opposition, and ranking-points needed/on offer. Accordingly, it should be acknowledged that these factors might also affect both physical effort and mental perception of the on-court demands.

Noteworthy is that the above findings are certainly subject to the constraints of individual matches and sessions. Accordingly, a secondary aim was to compare the technical and perceptual TL's between tournament matches won and lost, as well as against seeded and non-seeded opponents. The findings highlight that TL's of matches won are of greater RPE than matches lost, notwithstanding similar mental perception, and, match durations. Furthermore, similar stroke and work rates in matches lost were apparent. A recent tennis investigation observed greater post match salivary cortisol response and anxiety in losers than winners, while winners reported higher self-confidence.[29] As such, the authors suggest that a final positive (or potentially positive) outcome may provide a buffering effect on the mental stress experienced by junior high-performance athletes. While no other literature has investigated the discrepancies in TL between tennis matches won and lost, it is conceivable that developing high performance players are perhaps more "invested" physically for matches where a winning outcome is possible, or perceive matches won as more taxing as they produced a winning performance - despite no difference in external TL. Internal TL measures comparing seeded and non-seeded matches also found no key differences, however a moderate effect suggests potentially greater mental exertion was required during matches against seeded opponents. Furthermore, stroke-rate, winners and serves indicate limited differences between match types (despite a relatively low sample size). In summary, it appears that neither training drills nor simulated match-play equals the duration, perceptual or technical TL of tournament matches.

Practical Applications

Current comparison of training drills, simulated match-play and tournament matches reveals that the demands placed on tennis players in training are not necessarily of sufficient physical requirement to prepare for tournament match-play. Coaches should be aware of reduced internal (RPE) and technical (stroke-rate) demands in training to ensure appropriate stimuli, aiming for preparations to be as similar as possible to competition. Specifically, stroke-rates during tournaments exceeded those observed in training and simulated match-play sessions. Additionally, coaches should be mindful that even the most physically demanding training sessions and simulated match-play were of lower RPE than tournament matches. With mental exertion in training also lower than both simulated match-play and tournaments, it appears that tournament match-play is currently difficult to replicate during training. Given the disagreement of internal and external TLs between training drills, simulated match-play and tournament match-play, periodization of training needs to be clearly driven towards the demands of competition at their stage of development.

Conclusions

Session durations and RPE during training and simulated match-play do not match that of tournament matches. Similarly, mental exertion in training was not comparable to simulated or tournament match-play. From a technical standpoint, stroke-rates during tournament matches exceed those of both training and simulated match-play, suggesting again that training and simulated match-play intensity is mismatched. Furthermore, match specific measures of the serve (relative and absolute) demonstrate greater incidence during tournament matches than simulated match-play. Likely due to the increased stroke volume, tournament error rates are also far greater than that of simulated match-play, which is greater again than training sessions. Despite greater stroke counts during tournament play, comparison of work – rest durations reveal that simulated match-play to be less intensive (i.e., less work, less recovery). Secondary analysis suggests TLs of matches won are perceived as requiring greater physical exertion, notwithstanding similar mental perception. Of note, through an attempt to present an ecologically valid and concurrent comparison between of training and competition, our analysis was limited to a small cohort of players and . Nonetheless, it appears that both training drills and simulated match-play do not match the perceptual or external TLs of tournament matches. Coaches should be aware of the disparity in TL and aim to adequately prepare athletes for tournament requirements.

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References

1. Murphy A, Duffield R, Kellett A, Reid M. Comparison of athlete-coach perceptions of internal and external load markers for elite junior tennis training. *Int J Sports Physiol Perform.* 2013;9(1):751-756.
2. Murphy A, Duffield R, Kellett A, Reid M. A Descriptive Analysis of Internal and External Loads for Elite-Level Tennis Drills. *Int J Sports Physiol Perform.* 2014;9(1):863-870.
3. Reid M, Duffield R, Dawson B, Baker J, Crespo M. Quantification of the physiological and performance characteristics of on-court tennis drills. *Brit J Sport Med.* 2008;42(2):146-151.
4. Bekraoui N, Fargeas-Gluck M-A, Léger L. Oxygen uptake and heart rate response of 6 standardized tennis drills. *Appl Physiol Nutr Metab.* 2012;37(5):982-989.
5. Ford P, De Ste Croix M, Lloyd R, et al. The long-term athlete development model: physiological evidence and application. *J Sports Sci.* 2011;29(4):389-402.
6. Reid M, Quinlan G, Kearney S, Jones D. Planning and periodization for the elite junior tennis player. *Strength Cond J.* 2009;31(4):69-76.
7. Fernandez-Fernandez J, Mendez-Villanueva A, Fernandez-Garcia B, Terrados N. Match activity and physiological responses during a junior female singles tennis tournament. *Brit J Sport Med.* 2007;41(11):711-716.
8. Torres-Luque G, Cabello-Manrique D, Hernández-García R, Garatachea N. An analysis of competition in young tennis players. *Eur J Sport Sci.* 2011;11(1):39-43.
9. King T, Jenkins D, Gabbett T. A time motion analysis of professional rugby league match-play. *J Sports Sci.* 2009;27(3):213 - 219.
10. Gabbett TJ. Science of rugby league football: a review. *J Sports Sci.* 2005;23(9):961-976.
11. Reid M, Duffield R. The development of fatigue during match-play tennis. *Brit J Sport Med.* 2014;48(Suppl 1):i7-i11.
12. Mendez-Villanueva A, Fernandez-Fernandez J, Bishop D. Exercise-induced homeostatic perturbations provoked by singles tennis match play with reference to development of fatigue. *Brit J Sport Med.* 2007;41(11):717-722.
13. Hornery DJ, Farrow D, Mujika I, Young W. An integrated physiological and performance profile of professional tennis. *Brit J Sport Med.* 2007;41(8):531-536.
14. Coutts AJ, Gomes RV, Viveiros L, Aoki MS. Monitoring training loads in elite tennis. *Rev Bras Cineantropom Desempenho Hum.* 2010;12(3):217-220.
15. Gomes RV, Coutts AJ, Viveiros L, Aoki MS. Physiological demands of match-play in elite tennis: A case study. *Eur J Sport Sci.* 2011;11(2):105-109.
16. Mendez-Villanueva A, Fernandez-Fernandez J, Bishop D, Fernandez-Garcia B, Terrados N. Activity patterns, blood lactate concentrations and ratings of perceived exertion during a professional singles tennis tournament. *Brit J Sport Med.* 2007;41(5):296-300.

17. Mendez-Villanueva A, Fernandez-Fernandez J, Bishop D, Fernandez-Garcia B. Ratings of perceived exertion-lactate association during actual singles tennis match play. *J Strength Cond Res.* 2010;24(1):165-170.
18. Fernandez-Fernandez J, Sanz-Rivas D, Fernandez-Garcia B, Mendez-Villanueva A. Match activity and physiological load during a clay-court tennis tournament in elite female players. *J Sports Sci.* 2008;26(14):1589-1595.
19. Reid M, Duffield R, Minett G, Sibte N, Murphy A, Baker J. Physiological, perceptual and technical responses to on-court tennis training on hard and clay courts. *J Strength Cond Res.* 2013;27(6):1487-1495.
20. Johnson CD, McHugh MP, Wood T, Kibler WB. Performance demands of professional male tennis players. *Brit J Sport Med.* 2006;40(8):696-699.
21. Borg G. Subjective aspects of physical and mental load. *Ergonomics.* 1978;21(3):215-220.
22. Hart SG. NASA-task load index (NASA-TLX); 20 years later. Paper presented at: Proceedings of the Human Factors and Ergonomics Society Annual Meeting; October, 2006; Santa Monica: HFES.
23. Eston R, Williams J. Exercise intensity and perceived exertion in adolescent boys. *Brit J Sport Med.* 1986;20(1):27-30.
24. Christensen JE, Christensen CE. Statistical power analysis of health, physical education, and recreation research. *Res Q.* 1977;48(1):204-208.
25. Novas AMP, Rowbottom DG, Jenkins D. A practical method of estimating energy expenditure during tennis play. *J Sci Med Sport.* 2003;6(1):11.
26. Girard O, Lattier G, Micallef JP, Millet GP. Changes in exercise characteristics, maximal voluntary contraction, and explosive strength during prolonged tennis playing. *Brit J Sport Med.* 2006;40(6):521-526.
27. O'Donoghue P, Ingram B. A notational analysis of elite tennis strategy. *J Sports Sci.* 2001;19(2):107-115.
28. Duffield R, Murphy A, Kellett A, Reid M. Recovery From Repeated On-Court Tennis Sessions: Combining Cold Water Immersion, Compression and Sleep Recovery Interventions. *Int J Sports Physiol Perform.* 2013;9(1):273-282.
29. Fernandez-Fernandez J, Boullosa D, Sanz-Rivas D, Abreu L, Filaire E, Mendez-Villanueva A. Psychophysiological Stress Responses during Training and Competition in Young Female Competitive Tennis Players. *International journal of sports medicine.* 2014(EFirst).