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Abstract

Purpose: To investigate the discrepancy between coach and athlete perceptions of internal load and notational analysis of external load in elite junior tennis. ***Methods:*** Fourteen elite junior tennis players and 6 international coaches were recruited. Ratings of perceived exertion (RPE) were recorded for individual drills and whole sessions, along with a rating of mental exertion, coach rating of intended session exertion, and athlete heart rate (HR). Further, total stroke count and unforced error count were notated using video coding following each session, alongside coach and athlete estimations of shots and errors made. Finally, regression analyses explained the variance in the criterion variables of athlete and coach RPE. ***Results:*** Repeated measures analyses of variance and interclass correlation coefficients revealed that coaches significantly ($p<0.01$) underestimated athlete session-RPE, with only moderate correlation ($r=0.59$) demonstrated between coach and athlete. However, athlete drill-RPE ($p=0.14$; $r= 0.71$) and mental exertion ($p=0.44$; $r= 0.68$) were comparable and substantially correlated. No significant differences in estimated stroke count were evident between athlete-coach ($p=0.21$), athlete-notational analysis ($p=0.06$), or coach-notational analysis comparison ($p=0.49$). Coaches estimated significantly greater unforced errors than either athletes or notational analysis ($p<0.01$). Regression analyses found that 54.5% of variance in coach RPE was explained by intended session exertion and coach drill-RPE, while drill-RPE and peak HR explained 45.3% of the variance in athlete session-RPE. ***Conclusion:*** Coaches misinterpreted session-RPE but not drill-RPE, whilst inaccurately monitoring error counts. Improved understanding of external and internal load monitoring may assist coach-athlete relationships in individual sports like tennis to avoid maladaptive training.

Key Words – Training load; Periodisation; Perception; Long Term Athlete Development; Overtraining

Introduction

The quantification of training load is important for monitoring and successfully prescribing periodised training programs for elite level athletes.[1,2] Appropriate and informed manipulation of training load is important in tennis given the limited training time resulting from busy international competition schedules.[3] Consequently, when opportunities arise for intensive training periods, coaches must ensure optimal loads and recovery are prescribed for forthcoming competition. Effective manipulation of training loads requires that coaches have an understanding of the athletes' response to load, recovery and ensuing adaptation.[4,5] Common descriptors of training load include external load (i.e., the training stimulus), and internal load (i.e., athlete response to a stimulus).[6] Currently, tennis lacks evidence-based tools for training load monitoring, potentially leaving tennis athletes at risk of maladaptation to training.

Alongside physical testing, external load measures are commonly used within many sports to assess training outcomes.[5] Generally, coaches prescribe by external load (i.e., a distance to run or velocity to maintain).[6] Global positioning satellite systems (GPS), accelerometry and movement tracking systems are considered appropriate tools in the analysis and prescription of external load.[4,6] Australian football (AFL), hockey and soccer research suggests that the aforementioned motion-analysis systems offer valid and reliable measures of distance and velocity in both training and match play.[7-9] However, whilst team sports have access to multiple appropriate external load measures, there is an absence of similar, suitable, reliable or valid technology in tennis.[10] Consequently, tennis currently relies on session count, duration, and stroke analysis (i.e., stroke volume and errors) to objectively measure external tennis load.[11,12] Internal load measures such as heart rate (HR), oxygen consumption (VO_2), lactate, salivary and blood markers of stress, and rating of perceived exertion (RPE) are suggested to be of prominence. However, the nature of tennis means measures of HR, VO_2 and lactate are often complicated by travel, portability, or reluctance from athletes.[4,12,13] As such, RPE is broadly acknowledged as one of the most suitable methods of monitoring load in tennis.[6,13,14]

To precisely prescribe training loads and interpret athlete responses in tennis, it is important to establish the level of agreement between the RPE's of the coach and athlete. Research comparing these perceptions in other sports however, reports mixed results. For example, Viveiros et al.[15] found that judo coaches underestimated the session RPE reported by athletes. This contrasts with empirical work in athletics, where session RPE's were generally well matched with the prescribed intensity from coaches; albeit with some discrepancy in perceived load for sessions of varying intensity.[16] More specifically, it was observed that athletes trained with internal loads greater than intended on easy days, and lighter than intended on heavy days.[16] Such discrepancies have the potential to cause maladaptation to training[17], while inappropriate manipulation of training loads can result in highly monotonous training and non-functional over-reaching.[16] Moreover, in technically demanding sports such as tennis, the contrary (i.e., under-loading) is not desirable for long-term athlete development.[18]

With the above backdrop in mind, the present paper aims to determine the magnitude of discrepancy between coach and athlete perceptions of internal, (i.e., RPE and mental exertion) and external load (i.e., stroke count) in on-court training. Coach and athlete perceptions of external load compared to objective notational analysis will be further pursued to assess the sensitivity or veracity of their ratings. Finally, for discrepancies that do exist, regression analysis will be used to determine what constitutes both an athlete and coaches concept of RPE. In light of previous coach-athlete RPE comparisons in relevant literature,[15] we hypothesise that coaches will underestimate measures of athlete internal load, whilst demonstrating a greater understanding of stroke and error rates than athletes.

Methods

Subjects

Fourteen elite-level junior tennis players, who train permanently as scholarship holders (>2 y), were recruited from a national tennis development program. Players routinely trained 2-3 sessions per day, completing 98±20 matches for the year. The cohort had the following characteristics; gender: 8 male, 6 female, age: 15±1.2 y, mass: 60±14.2 kg, stature: 167±10.8 cm, Australian junior ranking: 7±4, and ITF junior ranking 91±72. Six qualified coaches with whom the players worked (>6 months), were also recruited for the study. Coaches reported 10±3 y of elite level coaching experience, and completion of Tennis Australia's highest level coaching qualification. Coaches and athletes were familiarised with HR, RPE, mental exertion, and stroke and error rates during a 4-week training block prior to commencement of data collection. Players possessed an intimate prior familiarity with each drill. The University Ethics in Human Research Committee approved all experimentation, with consent given by participants, parents/guardians and Tennis Australia.

Design

A total of 285 drills were included for analysis, with a mean duration of 24.6±19.0 mins. Athletes completed 21±3 sessions with a mean on-court duration of 71.8±10.9 min for sessions included in data collection. This study involved intermittent collection of training loads over a 16-week hard court training period. Training weeks were determined by the absence of competitive match play. Data were only collected from sessions that involved ≥2 athletes. We examined both internal and external load measures during ecologically valid training sessions, matched for duration and training focus. Coaches reported the following themes or training foci: 2 on 1 drills, accuracy (target hitting), pre-determined pattern drills, closed technical drills, and defensive drills. Mean training load (TL) for respective sessions was calculated as a function of training volume and intensity, by multiplication of session-RPE and session duration in minutes.[5,6] Training duration, stroke count and error rate were used to measure external load based on post-session observational notation from video footage.

Methodology

All training sessions were filmed using a digital video camera (DSR-PDX10P, Sony, Japan) positioned 10-m above and 6-m behind one baseline. The recorded footage was downloaded and later notated to establish total stroke count, stroke rate, and unforced error counts. A trained analyst (Coefficient of Variation <2%) performed notational analysis using customised software (The Tennis Analyst, V4.05.284, Fair Play, Australia). Coaches and athletes were asked to individually estimate the exact number of shots and errors that characterised each individual drill within each session. Coaches and athletes responded privately during recovery periods between drills, allowing sessions to continue uninterrupted.

Prior to each training session, coaches reported a rating of intended session exertion (Borg CR-10)[19] which was later compared to their post session perception of the athletes' RPE. Athletes were fitted with individual HR monitors, (Suunto Memory Belts, Suunto Oy, Vantaa, Finland) to record HR at 1s intervals for the entirety of each session. HR was downloaded after the session to calculate mean and peak heart rate for each drill (Suunto Training Manager, Suunto Oy, Vantaa, Finland). Immediately following the completion of individual drills, athletes provided a RPE (Borg CR-10)[19] and mental exertion evaluation (0-10 Likert scale).[20] Mental exertion rating (0-10) was used to establish a holistic rating of mental intensity perceived throughout drills. Athletes provided a single rating based on descriptions of mental demand (i.e., “How much mental and perceptual activity was required?” “Was the task easy or demanding, simple or complex, exacting or forgiving?”).[20] All ratings were provided privately to ensure no predisposition of internal load perception between coach and athlete. Finally, post session RPE was independently collected from the athlete and the coach (for the athlete) 30 minutes after the completion of the session.

Statistical Analysis

Data are reported as mean ± SD and within-individual mean range (mean minimum - mean maximum), unless otherwise specified. As gender was mixed, and age varied within the cohort, within-individual statistical procedures were used to alleviate any potential gender or age bias.[2,21] The within-individual correlations between coach, athlete and notational analysis (RPE, mental exertion, stroke and error count) were analysed using interclass correlation coefficient (ICC). The following criteria were adopted to interpret the magnitude of the correlations: <0 poor agreement, 0-0.2 slight agreement, 0.21-0.4 fair agreement, 0.41-0.6 moderate agreement, 0.61-0.8 substantial agreement and 0.81-1 almost perfect agreement.[22] Ratio measures for 95% limits of agreement (CI) were calculated and expressed within Figures 1 and 2. Differences in coach, athlete and notational data were assessed using a one-way ANOVA with Tukey HSD post hoc comparisons. Stepwise multiple regression analyses were used to explain the variance in criterion variables of coach and athlete session RPE. Predictor variables included; drill duration, RPE, HR, mental exertion, stroke and error count measures, according to the corresponding coach or athlete analyses. Partial correlations, standardised coefficients, and level of significance for coach and athlete predictors of session RPE were also reported. Collinearity tolerance statistics ascertained correlations between predictor variables, whereby associations <0.10 were considered beyond an acceptable tolerance level and were removed from the model. All data analysis was conducted using PASW statistic software package (PASW, Version 17, Chicago, USA). Statistical significance was set at p<0.05.

Results

Coaches significantly (p<0.01) underestimated athlete session RPE (Table 1). Further, within-individual coach and athlete comparisons of session RPE (Figure 1) were only moderately correlated (r=0.59). Coach rating of intended session exertion was similar in magnitude and strongly correlated to coach post-session RPE (p=0.63, 0.79 ICC) but significantly greater than athlete post-session RPE (p<0.01). In contrast, coach drill RPE was comparable and strongly correlated (p=0.14, Table 1; r=0.71, Figure 1) with athlete drill RPE. Similar agreement existed between rating of drill mental exertion reported by the coach and athlete (p=0.44, Table 1; r=0.68;Figure 1).

*** Table 1 near here ***

*** Figure 1 near here ***

Across all drills, stroke rate was calculated as 0.12 strokes·sec^{-1}. No significant differences in stroke count were evident between athlete-coach (p=0.21), athlete-notational analysis (p=0.06), or coach-notational (p=0.49) comparisons (Table 1). Substantial correlations were evident between athlete perception and notated stroke counts (r=0.63), as well as athlete and coach perceptions of stroke count (r=0.67) (Figure 2). However, coach perception only showed moderate agreement with notational analysis (r=0.56; Figure 2).

There was no significant difference (Table 1), and substantial correlation (Figure 2), between athlete perception and notational count of unforced errors (p=0.24; r=0.61). However, coaches reported significantly greater unforced errors than either athletes (p<0.01) or the notated count (p<0.01) (Table 1). Further, unforced error count as perceived by the coach was only moderately correlated with the athletes' perception of the same variable or notational analysis (r=0.54 and 0.51, respectively).

*** Figure 2 near here ***

Table 2 summarises the results of the stepwise multiple regression analysis, where 54.5% of the adjusted variance in coach RPE could be explained by the coach's rating of intended session exertion and coach drill RPE (Y = 1.37 + 0.51 coach predicted RPE + 0.25 coach drill RPE) [Adjusted $R^2 = 0.55$; $F_{2, 273} = 163.71$; p<0.001]. The collinearity of this equation was acceptable for both variables with tolerance levels at 0.907. Meanwhile, 45.3% of the adjusted variance in athlete session RPE could be explained by drill RPE and peak HR (Y = 9.60 + 0.53 drill RPE – 0.37 peak HR) [Adjusted $R^2 = 0.45$; $F_{2, 50} = 20.73$; p<0.001]. Collinearity statistics were acceptable for both variables with tolerance levels at 0.996.

*** Table 2 near here ***

Discussion

The purpose of this study was to assess the level of agreement between coach and athlete perception of internal load as well as their agreement with notational analysis of external load during tennis training. Further, where discrepancies in internal and external load existed, regression analyses explained the variance in the criterion variables of athlete and coach RPE. The results showed significant incongruity between coach and athlete session RPE. Yet, within training sessions, substantial correlations were demonstrated between coaches and athletes for RPE and mental exertion of individual drills. Good agreement was also found between coach, athlete and notational analysis of stroke counts within drills. However, coaches report significantly greater unforced errors than both athletes and a notated count. Finally, regression analyses revealed the variables that best predicted post-session coach RPE to be the rating of intended session exertion and individual drill RPE; drill RPE and peak HR were the greatest determinants of session RPE as reported by the athletes.

Analysis of internal load measures demonstrated that coaches significantly underestimate athlete RPE for the overall training session. Further, only a moderate relationship existed between coach and athlete session RPE, highlighting a potential disconnect in the perception of session load. Indeed, previous literature has highlighted this discrepancy between coach and athlete RPE in athletics, judo and swimming.[15-17] We also found coach rating of intended session exertion to be significantly lower than athlete RPE, suggesting a misconception of athlete state following the previous session's load. This is consistent with the work of Foster et al.[16] and Wallace et al.[17], whom reported differences between planned sessions by coaches and the ensuing athlete loads in running and swimming respectively. These studies also highlighted that coach and athlete perceptions were comparable for moderate intensity sessions, however high and low intensity sessions produced significant discrepancies.[16,17] Although our investigation did not distinguish between intended hard and easy sessions, the poor relationship between athlete session RPE and both coach intended and post-session RPE suggests the potential for similar incongruence in tennis. Interestingly, athletes in these sports have been reported to train harder than intended on coach-designated recovery days and easier than intended on hard days.[16,17] Our findings highlight similar incongruity in coach-athlete training perception for global tennis sessions, perhaps increasing the risk of maladaptive training.

In a novel finding from the present study, coaches and athletes report comparable RPE's for individual drills. To our knowledge, no previous research has explored differences in coach-athlete perceptual load within a session. Due to the nature of tennis sessions, whereby a session may be comprised of multiple drills, it is important that coaches are aware of the loading subtleties of drills throughout the session. The current findings suggest the coaching cohort were able to detect these subtle differences in athlete RPE within specific drills. However, as highlighted above, session RPE was significantly underestimated, suggesting that coaches display a poorer understanding of the accumulating effect of training loads of the drills over an entire training session. As such, this poses a potential issue in understanding athlete response to full training loads, not only within a session, but also potentially over multiple sessions within training blocks. Thus, the current findings emphasise the importance of coach awareness of athlete RPE, rather than sole reliance on coach perception.

Interestingly, there also existed substantial correlation between coaches and athletes for ratings of mental exertion. These data also suggest that coaches are able to interpret athlete mental exertion more accurately than RPE. Whilst conceptually measuring different components, Minganti et al.[23] reported no differences between perceptions of mental and physical fatigue in springboard and platform diving. Meanwhile, Marcora et al.[24] report that mental stress can limit exercise tolerance, as evidenced through higher RPE rather than cardiorespiratory and musculoenergetic mechanisms. Thus, as the technical demand increases during an open skilled, highly complex sport such as tennis, the discrepancy between physical and mental measures of exertion may increase. Further, as coaches show a greater level of accuracy in appreciating mental exertion than RPE, coaches may use signs of mental effort to assist determine session load tolerance in open skilled sports such as tennis. Yet, whilst it seems coach perception of drill mental exertion is of greater accuracy than drill RPE, the efficacy of mental exertion as a load-monitoring tool is yet to be thoroughly investigated in elite sports, including tennis. Further, it should be acknowledged that there is a lack of validated tools to measure mental exertion within exercise, however Visual Analogue Scales and Likert scales- such as the one used in the current study- are commonplace within literature.[25,26]

Stroke count comparisons between coach perception, athlete perception and notational analysis were comparable. Analysis of stroke count perception shows substantial correlation between athletes and both coaches and notational analysis. However, coach estimates presented only moderate correlation with notational analysis. Previous swimming data report that athletes are able to comply with coach prescribed swim distances, suggesting that no additional monitoring of external load in training is warranted.[27] Similarly, the high-level of awareness of external load (i.e., stroke volume) from tennis athletes in this study suggests that prescription of external load in un-supervised practice may be appropriate, so long as athletes are well educated on the required intensity. A secondary finding indicates that shot rates during drills were 0.12 $strokes \cdot sec^{-1}$, seemingly lower than previously reported drill and match play stroke rates.[28,29] Reid et al.[29] describe four common training drills - designed to induce heavy physiological stress - reporting stroke rates between 0.13-0.40sec^{-1}, while O'Donoghue et al.[28] reported similarly inflated stroke rates (0.81±0.04sec^{-1} for men and

$0.76 \pm 0.03 sec^{-1}$ for women) for match play at the Australian Open in 1997–1999. To the authors' knowledge, no previous study has compared coach-athlete perception of external load measures in tennis. However, issues with coaching strategies and the perception of external load (stroke count) have previously been raised.[29] Reid et al.[29] discuss the problematic lack of quantitatively driven training sessions within tennis environments; describing current methods as intuitive, perhaps failing to provide for optimal physiological and developmental improvement. Therefore, it would appear to stand to reason that coach awareness of external load prescription may be vital for athlete preparation and development. In a similar vein, athletes travelling unaccompanied by a coach, or during periods of self-practice should also be sensitive to their external load to best maintain physical condition and skill levels.

These results are also the first to show coach overestimation of errors within tennis training drills. Coaches estimated significantly more errors during drills than both athletes and notational analysis. Interestingly, athletes show no difference in the estimation of errors compared to a notated count. At present, no coaching research has compared estimations of errors made between coach, athlete and post session notation for any sport. However, coaches' progress or regress drills depending on errors made and the ability of an athlete to handle a task.[30] While the present study did not directly investigate the relationship between unforced errors and physical or mental exertion, previous research suggests that with an increase in drill duration and intensity more variable ball placement, reduced precision and lower consistency in shot outcomes becomes evident.[29] Potential misunderstanding of drill outcomes may alter the design, selection and progression of drills; therefore emphasising the importance of coaches being aware of error rates to ensure appropriate drill feedback and learning.

Similar to previous research, the current study has shown discrepancies in coach and athlete perception of internal and external load.[15-17] Whilst awareness of deviations in coach-athlete perceived load are key, understanding the internal and external load variables that explain variance in session RPE is arguably more important. In rugby league, Lovell et al.[21] have shown a combination of load and intensity measures best explain the variance in session RPE. That is, distance covered, impacts, body load and training impulse accounted for 62.4% of the variance in session training load (duration x RPE), while 35.2% of variance in session RPE was explained through $\%HR_{peak}$, impacts/min, m/min and body load/min.[21] Our data show that 54.5% of variance in coach session RPE could be explained using drill RPE combined with the pre-session rating of intended session exertion. As such, this suggests that the combination of drill RPE and predetermined session RPE explain the variance in coach session RPE better than any other measures. Meanwhile, 45.3% of variance in athlete session RPE could be explained by measures of drill RPE and peak HR. Therefore, it would seem that internal load markers explain more of the variance in athlete session RPE than external load measures, though the limitations in providing accurate measures of external load are acknowledged. These data highlight the complexity of load perception in tennis, and whilst knowledge of the variables that explain session RPE is valuable, they may be unique to this elite tennis setting. Consequently, care should be taken when attempting to apply these interpretations to other tennis settings.

Practical Applications

Owing to the extensive travel and competition schedules of tennis players, planning and periodisation are important in maximising the value of training time. External and internal load monitoring allows for optimal planning during preparation phases, however coaches must also correctly understand the load experienced by athletes.[16,17] With a clearer understanding of athlete load, training may be structured to elicit greater gains and reduce injury and illness risk.[31] Although our results demonstrate incongruity between coach, athlete and notational analysis of load within an elite junior tennis environment, this mismatch may be alleviated with continued athlete education or proactive communication between athletes and coaches. Future research in tennis load monitoring should attempt to differentiate load discrepancies for low, moderate and high intensity sessions, as well as develop other suitable methods of external load measurement.

Conclusion

Coach perception of individual drill RPE does not differ from that of athletes. However, it would appear that coaches misinterpret the accumulating effect of drill load over an entire training session, demonstrated through their lower perceptions of session RPE. It was further evident that coaches were better equipped to interpret the mental exertion required for individual drills than physical exertion. Stroke count demonstrated discrepancies between notational analysis and the perception of coaches and athletes, with these two groups overestimating total stroke count. Finally, it was observed that coach perception of session RPE may be primarily informed by drill RPE and a rating of intended session exertion, while a significant amount of the variance in athlete session RPE was explained through drill RPE and peak HR. Overall, these findings provide coaches with a practical, evidence based insight into the monitoring of load across typical tennis training sessions. Appropriate load quantification and coach-athlete communication is vital to best use this information and to avoid maladaptive responses to training.

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