Methods of Monitoring Training Loads in Junior Tennis Players

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Abstract

High training volumes and injury risk with junior tennis players has gained much attention. In recent years, the ideas of monitoring training volume to provide guidance to coaches has been an area of interest to support the potential reduction in injury rates. In tennis several internal and external methods have been used to determine training loads. Often these methods vary in cost, ease, accuracy and reliability. As such this review provides information on training monitoring for junior tennis players using methods including heart rate (HR), heart rate variability (HRV), wellness questionnaires, rating of perceived exertion (RPE), global positioning systems (GPS), physical testing and wearable technologies.

Keywords: tennis, junior, children, training monitoring, workload, internal objective, internal subjective, external objective, external subjective.

To reach a high level of performance junior tennis players require a large training volume to develop technical, tactical, physical and mental disciplines (1,2). Training workloads of up to 15-20 hours per week have been reported (3). Junior Davis Cup players have been shown to train for an additional 8 hours per week in comparison to regional counterparts (4).

Injury occurrence in youth sports is highly multifactorial, however, an increase in training load and intensity has been identified as strong risk factors that may lead to injury (5 6). This is acknowledged in junior tennis with poorly managed training loads potentially leading to an increased risk of injury for young players (2,7). Overuse injuries are the most reported health problem with the knee, back/spine and shoulder region being areas of high injury incidence (2). Additionally, previous injury has been shown as a factor leading to lost practice and competitive time emphasising the need for effective rehabilitation and training monitoring to guide appropriate progression (8). However, training loads have been reported to be lower than competition loads suggesting that junior players may not be fully prepared to cope with the demands during extended tournament periods (9). Much discussion exists around how prepared athletes are for the demands of their sport and that high training load alone may not be the influencing factor leading to injury (10,11). It is in fact a lack of adaptation to exercise prescription and programming that may be considered the cause (11). Furthermore, despite it being well acknowledged that large variations exist with adolescent growth spurts young athletes may be at greater risk of overuse and traumatic injuries either just before, during or after times of peak height velocity (PHV) providing additional challenges to monitoring training volumes (12,13,14).

***Insert Table 1 near here ***

The implementation of a systematic training load monitoring system is believed to be critical in high-performance and developmental sport settings due to its relationship with injury (15). Training loads of athletes in tennis can either be recorded by internal or external measurements (16) (Table 1). Internal methods are considered the relative biological demands physically or psychologically during exercise. These may include the monitoring of heart rate (HR), oxygen consumption (VO_2), blood lactate levels, rating of perceived exertion (RPE), wellness questionnaires and psychological inventories (17). External training load are independent of internal response stressors with examples such as GPS data, training frequency and number of repetitions of movements (18, 19). It is recommended that both internal and external monitoring are used collaboratively to understand athlete stress during exercise. Not only does this allows an understanding of the difference perceptual and physiological responses to training between athletes, but also give an understanding of how an individual athlete is performing based on fatigue and additional stressors (10,11).

Monitoring internal and external training loads of youth athletes have been of great interest in recent years (12 17,18,19, 20). Therefore, the aim of this paper is to review internal and external load monitoring methods for junior tennis players (under 18 years of age) (21). This will provide guidance and assessments coaches and practitioners can implement to monitor training loads and maximise performance opportunities whilst reducing injury risk.

Internal Training Load Monitoring

HR and blood lactate concentration (LA) are common markers used to reflects the physiological response to stress during tennis training and competition (22,23,24,25). There are multiple studies that considers HR and LA for adult players on a variety of surfaces (26,27,28). Considerations have also been made with junior tennis players in relation to match play and on court drills (29,30,31)

Mean HR for match play has been recorded at 143 ±16 to 166 ± 15 b·min^{-1} with higher average HR found during service game, whilst mean LA levels have been reported to be 2.0 ± 0.8 mmol/l (29,30). Based on the training drills a range of mean HR and LA have been documented with recovery defensive and higher stroke number exercises being the most demanding for players (30,31). Monitoring internal loads of common tennis drills provides information on more effective ways to train junior players. This may include simulating demands of points play, overreaching for physiological adaptation, deload weeks or emphasis on tactical and technical development Furthermore practitioner may use this information to blend effective high intensity interval training (HITT), repeat sprint drills and sport specific drills (32,33). Despite players often disliking HR monitors due to feelings of discomfort when playing, using them at agreed times to monitor intensity and training load during certain drills seems appropriate to monitor both the training load and level of intensity. Despite the benefits of using within training HR and LA monitoring, analysis cannot be made before training and thus limits the opportunity to determine how 'ready' an athlete is to train (34).

Measuring heart rate variability (HRV) provides an attractive, cost effective and simple measurement that can be recorded pre participation (35). Monitoring HRV is a non-invasive method measuring the variability between each heartbeat considering cardiovascular autonomic control (36). A recent review concluded that the use of portable devices such as using apps and heart rate monitors to determine HRV provide an acceptable accuracy based on the practicality at rest (36). Monitoring HRV with other youth athletes has been shown to be a helpful tool to monitor training load (37). Combined with other psychometric and non-invasive performance markers HRV may provide a time effective method to determine the readiness to train of a junior tennis player. This is an area requiring greater research in junior tennis.

Despite much focus in recent years on the use of technology to monitor objective measures of athlete wellbeing, subjective measures continue to demonstrate a close relationship with training induced changes in athletes (38). A host of subjective monitoring tools can be utilised including the Profile of Mood State (POMS), Recovery Stress Questionnaire for Athletes (RESTQ-S), Daily Analysis of Life Demand of Athlete (DALDA) and the Multi Component Training Distress Scale (MTDS) (38,39). Through the measurement of POMS players who have demonstrated lower mood disturbances, reduced anxiety levels and increased self-confidence have been more successful in competition (40). Furthermore, mental exertion has been monitored when comparing a range of tennis drills, simulated match play and tournament competition (30). Although acknowledged it may lack construct validity mental exertion is related to the intensity of drills. Exercises that focus on recovery and defensive drills have a high correlation between RPE and mental exertion (30).

However, the practicality of using questionnaires can often be time consuming for both coaches and athletes with the importance of meaningful data being crucial. Therefore, it is recommended that monitoring tools such as POMS, RESTQ-S, DALDA or MTDS are used a weekly basis to gather information, with short form wellness questionnaires being used on a more regular basis (38, 41). This may include a daily check before training using questions based around levels of soreness, feelings of fatigue, mood, sleep quality and duration (Hill and Rogerson, 2018). Training diaries or the use of online training monitoring systems can help record subjective measures (42).

Further internal subjective measures may include daily or session rating of perceived exertion (RPE). This provides players and coaches an efficient monitoring tool of individual exercises (43). RPE is broadly acknowledged as one of the most suitable methods of monitoring training load in tennis, whilst also being shown to be a reliable measure of intensity within strength and conditioning training (43,44,45). This is likely to provide a more holistic understanding of a junior players program. In settings where multiple coaches work with players ensuring the types or categories of drills that elicit the desired RPEs is important. Coaches may classify drills differently based on their interpretation of the desired outcome or goal of the drill, and thus could be creating training loads that were not intended or planned for. Comprehending which exercises correlate to higher and lower player RPEs will enhance the coaching team's overall effectiveness of selecting the appropriate drills according to the training load needs of the player. When junior players were asked to report the intensity of certain drills RPE were highest for recovery/defensive drills (6.5 ± 1.8 au), followed by open-pattern drills (5.9 ± 1.6 au) and point play (5.8 ± 1.5 au) (30). It was reported that different types of drills provided different internal loads linked to physical, tactical, technical and mental development (Figure 1). Case studies have previously reported match play RPEs of up to 8 au in elite tennis players (ranking < 120 ATP), increasing from 3 to 8 au throughout a four-set match (46). Furthermore, weekly training loads (2380 au) and tournament week loads (2908 au) have also shown to vary (47). Although this intensity reported has obvious age and expertise difference, the importance of well-planned training and effective monitoring is essential. Considerations can be made that at appropriate times based on maturation carefully controlled higher volumes in training are necessary to help players tolerate higher loads during tournaments. However, it is essential that a balance is found to allow adequate recovery and that poorly managed volumes are avoided potentially leading to an increase in injury risk.

*** Insert Figure 1 near here ***

One method in which this can be recorded is through the acute chronic workload ratio (ACWR) (5,48). ACWR is a value that depicts the current workload (acute) of the day/week in comparison to a rolling, often monthly (chronic) average workload amount. Despite much debate about average ACWR of $\geq$ 1.5 leading to the likelihood of increased injury risk it has been acknowledged that there is no 'magic number' (5). Ultimately a balanced approach of training with well-planned alterations in acute training variables seems to be an appropriate suggestion, however evidence within both junior and professional tennis is needed to support.

External Load Monitoring

External training loads are objective measures that can be recorded during training or competition independent to internal measures (16). Often a combination of both external and internal loads are monitored, with the external training load influencing the psychophysiological internal response (49). External measures used within junior tennis include notational and motion analysis, the use of global positioning systems (GPS) and the monitoring of physical capacities such as counter movement jumps (CMJ) and 20m sprint scores (19, 30, 50, 51).

One of the most common external training loads used in junior tennis is the total number of hours played per week (52). International junior tennis players (15.6 ± 1.1 years of age) report a total of 22.7 ± 6.8 hours per week of training including physical conditioning (4). Furthermore, younger players (12-13 years of age) have reported between 11-15 hours of tennis training per week with some players reporting more than 25 hours during heavy weeks (2, 53). Despite the number of hours failing to provide an indication of intensity during training or competition, this basic measure may hold relevance in the context of injury reduction. Younger players with higher weekly volumes may be at an increased risk of medical withdrawal when performing more than 16 hours per week (53).

Charting and shot count measurements are common ways coaches obtain information about the number and type of shots players are performing. However, this can be time consuming impractical and inconsistent (54). Recently inertial measurement units (IMUs) using accelerometers, vibration and motion sensors have been researched in tennis (19, 54). Accuracy of IMUs predicting the total number and types of shot with speed of the ball has varied between 91-97% (19, 54). However, the accuracy of defining shot type and identifying contact point on the string bed continues to be poor with some sensors (55). Despite promise in wearable technology it is essential that the technology is non-invasive and does not alters the racket weight or balance to large effects. Future research needs to continue to enhance the accuracy of shot type alongside the types of spin a player may use.

Uncertainty continues to exist around the accuracy of GPS monitoring particularly with tennis being played indoors precluding the use of GPS (56, 57). It has been concluded that the use of GPS under report distances covered alongside mean and peak speeds (56). Despite this several studies have used GPS systems to monitor total distance covered, number of accelerations, deceleration movements, velocity of movements and distances covered at different speed zones (50, 58, 59, 60). Distance covered in the literature based on competitive match play varies from 3362 ± 869m to 4519.8 ±1604m (59, 60). Interestingly one study suggested that the distance covered per minute was greater in match play compared to training (50). However, this may be viewed with caution based on the training intentions of the coach during that period, the age and level of the individual. Under 12 male tennis players have demonstrated higher distance covered during training (4530.2 ± 505m) in comparison to competition (3227.8 ± 627m) where under 18 have shown higher distances during competition (3995.2 ± 1415m) in comparison to training (4519.8±1604m) (60). Further analysis of GPS data suggests a range of player loads (measured in arbitrary units) in both competition and training and adolescent players performing 59 ± 13 (2 to < $4/ms^2$) and 19 ± 18 accelerations (≥ $4/ms^2$) and 48 ± 17 (2 to > $4/ms^2$) and 5 ± 2 (≤ $4m/s^2$) (58). This emphasises the short high intensity, intermittent bursts associated with tennis (61).

The use of physical testing may also be able to provide external measures on an athlete’s readiness to train. Countermovement jump (CMJ) and sprint testing have both been considered as measures to determine athletes’ neuromuscular fatigue (62, 63). A recent meta-analysis concluded that a CMJ without arm swing measuring the average across multiple reps was a sensitive measure to track neuromuscular status (62). Furthermore, CMJ has been shown to be a more valid measure of fatigue post 24 hours in comparison to sprint based tests (63). The use of phone-based applications have been shown to be a valid and reliable measure of CMJ height therefore making this an attractive, inexpensive opportunity for coaches particularly due to the travel demands associated within tennis (64). Taking regular measurements and monitoring trends alongside additional subjective measures may provide coaches and players information on the readiness of the athlete to train. Limited research exists within junior tennis using physical measures to determine player’s readiness to train (65). Competing in two matches in one day have shown decrements in measures including CMJ height, sprint and agility tests (65).

The importance of establishing a level of agreement of training load between the coach and athlete is important (66). Junior players' coaches have been shown to significantly underestimate session RPE (5.5 ± 1.2 au) in comparison to players (6.2 ± 1.4 au) (43). Despite this both coach and players recorded similar RPE scores for individual drills (5.1 ± 1.7 to 5.4 ± 1.7 au) and mental exertion. Therefore, it is suggested that coaches have awareness of the accumulated effects of tennis drills on junior players (43). Further discrepancies exist within other sports regrading session RPE and recovery RPE as perceived by the coach and athlete (66, 67). Therefore, regular comparisons between coaches and players may be of benefit to understand and adapt effective training loads. Further research may also consider perceptions of load of additional practitioners such as the strength and conditioning coaches and parents.

Conclusion

Tennis requires multifaceted levels of training with junior players having the same challenges as on the professional tour such as regular travel, competing in a range of environments and participating on many surfaces. A key determinant of effective and sustainable monitoring requires features such as ease of use for players, coaches and parents with efficient result reporting that is clear and understandable alongside identification of meaningful changes (68). As this review shows tennis considers a host of internal and external methods of monitoring training loads and a combination of these approaches is likely to be the most effective.

It would seem sensible to suggest that junior players and coaches keep some form diary that allows a daily 'readiness' check to be monitored. Session RPE can be logged so that ACWR can be measured. Coaches, players and parents may also agree to provide perceptions of session RPE at certain intervals to make comparisons. Longer validated questionnaires such as POMS, RESTQ-S or DALDA may be used more sparingly. Measuring HR, HRV and CMJ using minimal equipment may also provide coaches with excellent tools to monitor intensity and potential levels of fatigue, however further research around HRV and using CMJ is warranted with junior tennis players. For HRV to be most effective would also require adherence from junior players to take measurements away from the coach. Certainly, the development of wearable technologies to measure the number and speed of shots provides valuable information to both coaches and players on workloads. This is likely to complement internal subjective monitoring such as wellness questionnaires and session RPE. However, accuracy needs to continue to improve determining the type of shots through this technology. This may also provide coaches with a greater depth of tactical analysis.

Although several techniques can be implemented with relative ease and cost effectiveness the question still needs to be answered as to what metrics are associated with increased injury

(52). Therefore, although recommendations can be made as to what methods can be used to monitor training loads the challenge exists to determine what metrics and/or levels of load are associated with risk. Longitudinal randomised controlled studies where load management is adjusted accordingly in comparisons to regular training methods will provide information. However, the individual and varied nature of the sport and the ethical considerations make this a challenging proposition.

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Table 1. Training monitoring methods for junior tennis players

Internal Measures	External Measures
Heart rate during training	Total number of hours
Heart rate variability (HRV)	Number of shots hit
Blood lactate	Number of type of shots hit
Wellness questionnaires	Speed of shot
Profile of Mood State (POMS)	Error rate
Recovery Stress Questionnaire for Athletes (RESTQ-S)	Total distance covered
Daily Analysis of Life Demand of Athlete (DALDA)	Number of accelerations
Multi Component Training Distress Scale (MTDS)	Arbitrary units load (au)
Mental exertion questionnaires	Countermovement jump (CMJ)
Daily wellness checks	Speed over 10m-20m
Daily rating of perceived exertion (RPE)	Coach RPE perception
Session RPE	
Drill activity RPE	

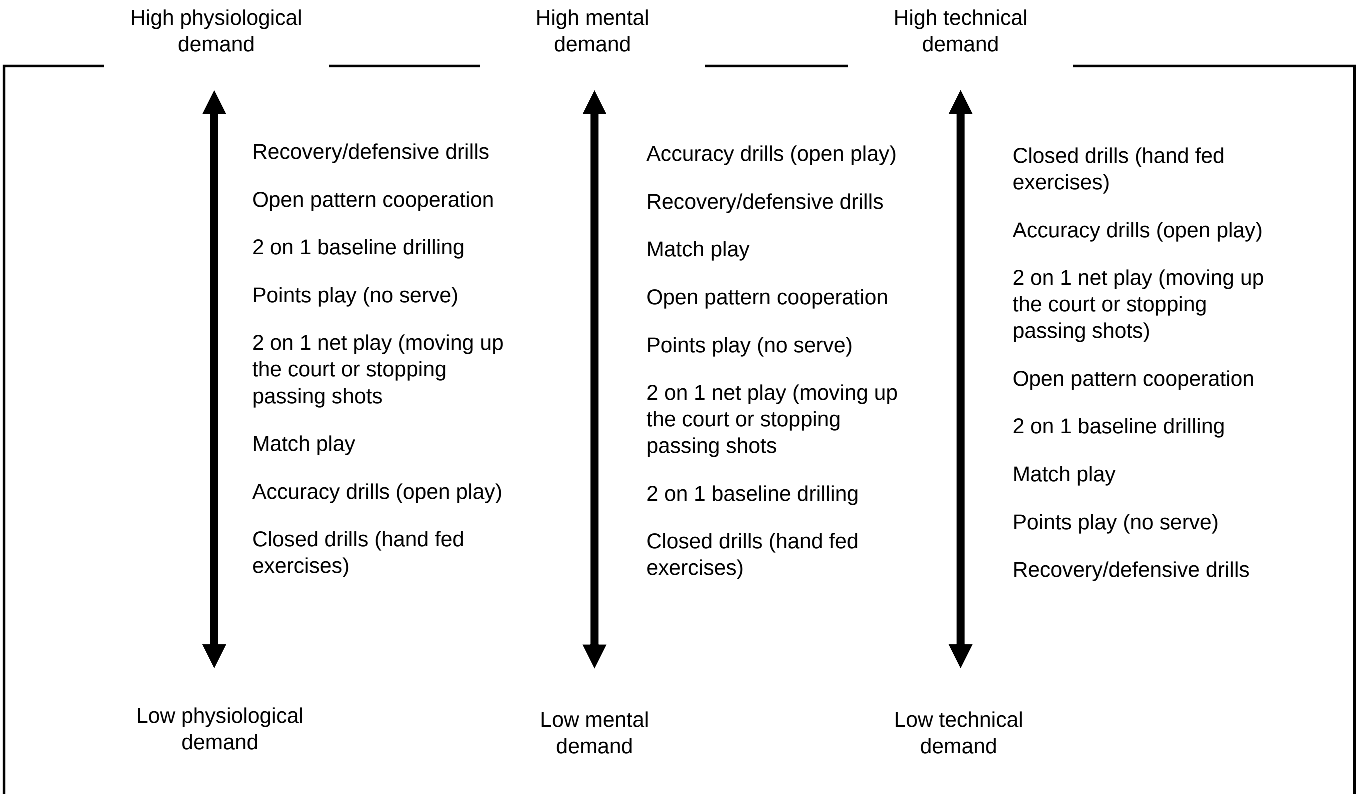

Figure 1. Drill demands based on internal loads, taken from Murphy et al. (30)