Significant energy deficit and suboptimal sleep during a junior academy tennis training camp

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ABSTRACT

***Purpose**:* To assess the training load, energy expenditure, dietary intake, and sleep quality and quantity of junior tennis players during a tennis training camp. ***Methods**:* Ten junior academy tennis players (14±1 years) completed a 6-day camp with daily morning and afternoon training. Players wore accelerometer watches to measure activity energy expenditure and sleep. Global positioning system units were worn to monitor external training load (distance covered, max. velocity, PlayerLoad^{TM}). Dietary intake was obtained from a food diary and supplementary food photography. ***Results**:* Players covered significantly more distance and had higher PlayerLoad^{TM} during morning sessions than afternoon sessions (5370±505m vs 4726±697m, $p<0.005$, d=3.2; 725±109a.u. vs 588±96a.u., $p<0.005$, d=4.0). Players also ran further (5624±897m vs 4933±343m, $p<0.05$, d=1.0) and reached higher max velocities (5.17±0.44m·s^{-1} vs 4.94±0.39m·s^{-1}, $p<0.05$, d=0.3) during simulated match play compared to drill sessions. Mean daily energy expenditure was 3959±630kcal. Mean energy intake was 2526±183kcal, resulting in mean energy deficits of 1433±683kcal. Players obtained an average of 6.9±0.8 hours sleep and recorded 28±7 nightly awakenings. ***Conclusions**:* Junior academy tennis players failed to achieve energy balance and recorded sub-optimal sleep quantity and quality throughout the training camp.

***Key words**:* tennis, nutrition, energy, sleep, performance

Introduction

At an early age, tennis players often exceed 15—20 hours of training per week (26). In preparation for tournaments, players are exposed to high training loads, and often undergo high-intensity training camps (16). Training camps are typically characterised by an increase in load and volume, and a reduction in rest and recovery time (22). If recovery is insufficient and other non-training stressors are present, this may lead to maladaptive responses such as overtraining syndrome, and increase the risk of injury (11,18).

Balancing training stress with appropriate recovery is integral to achieving optimal athletic performance, with nutrition and sleep critical components of recovery (6,31). Nutrition has a direct influence on optimising energy stores, reducing fatigue and the risk of injury, enhancing recovery, and improving health status (31). Supporting young athletes to meet energy needs, with sufficient energy availability for growth and physiological development should be a primary focus for practitioners (5). Failing to meet these needs can increase players' susceptibility to Relative Energy Deficiency in Sports (RED-S) syndrome; which can have a negative impact on, *inter alia,* metabolism, menstrual function, bone health, immunity, protein synthesis, and cardiovascular and psychological health (20).

Optimised sleep quality and quantity may attenuate the physiological fatigue associated with high training volumes and improve recovery and performance (8). Following periods of heightened physiological and psychological stress (such as training camps), subsequent sleep loss may compromise neurocognitive and physiological performance (10). Insufficient sleep or experimentally modelled sleep restriction negatively affects indices of performance (speed and endurance), cognitive function (attention and memory) and physical health (illness and injury risk) (30). Despite a lack of sleep research during training camps, reductions in sleep efficiency have been observed in Australian Rules Football players (24), associated with a change in sleep environment. An inability to meet sleep duration recommendations (8—10 hours per night) (13) has been reported amongst junior rowers (15) and basketball players (16) during training camps, with no evidence of sleep monitoring or the implementation of sleep hygiene practices.

There is no research on the junior tennis player during a training camp. Therefore, this study aimed to investigate: 1) external training load; 2) energy expenditure, energy intake, and energy balance and 3) sleep quality and quantity, during a junior academy tennis training camp.

Methods

Subjects

Twelve junior tennis players participated in an 8-day training camp in La Manga, Spain. All players were part of a high-performance tennis academy, regularly competing at regional to national level. Due to injury, two players failed to partake in enough training sessions (45 % and 55 % respectively) and were excluded from the study, leaving a sample size of 10 (age 14 ± 1 years; height 164 ± 5 cm, weight 54 ± 8.5 kg). All participants gave informed consent. Where participants were < 18 years, parental/guardian consent was sought. All data collection was completed in accordance with the declaration of Helsinki and an institutional ethics committee granted ethical approval (SREP/2018/018).

Experimental design

The 8-day training camp consisted of two 2-hour tennis training sessions on clay courts (drill and simulated match play [SMP] training), and one 1-hour strength and conditioning session each day bar one (see supplementary materials, training camp timetable for breakdown of daily content). On this occasion, players had down time in which they had the option to partake in non-prescribed activity following morning training. Due to travel delays resulting in reduced training on day 1 and a subsequent amendment to the training schedule on day 8, days 1 and 8 were excluded from the study. The first day was used to familiarise participants with equipment and data collection methods.

Players and support staff (including the lead investigator) stayed together in self-catered villas for the duration of the camp. Players stayed in shared rooms, accommodating up to three players in each room (two rooms of three and three rooms of two). Breakfasts and lunches were catered by the support staff, with evening meals selected from a set menu at the same restaurant. Players were responsible for any additional food and fluid consumption outside of these set meals. All meals were eaten together. A nightly curfew of 22:00 was imposed, players had to be in bed with lights off by this time.

Procedures

Energy Expenditure: ActiGraph GT9X Link (ActiGraph, Pensacola, FL) accelerometer watches were worn continuously (on the player's non-dominant wrist) throughout the camp to measure individualised activity energy expenditure. ActiGraph is the most studied accelerometer in children and adolescents with extensive evidence for good reproducibility, validity and feasibility in this population (32). Subsequently, total daily energy expenditure (TDEE) was estimated using the following equation: resting metabolic rate (RMR) + activity energy expenditure + dietary induced thermogenesis (DIT). Resting metabolic rate was calculated using the Schofield-HW equation (females; 8.365*BW [kg] + 4.65*Height (cm) + 200; males: 16.25*BW [kg] + 1.372*Height (cm) + 515.5) (29), a valid measure within 10-18 year olds (2). Dietary induced thermogenesis was set at 10% of the total amount of energy ingested over the 24-hour period; a representative value for healthy individuals consuming a mixed diet (33).

Sleep: Sleep patterns were monitored using the ActiGraph GT9x devices. After visual inspection of the data sleep outcomes including time in bed, sleep onset latency, total sleep time, number of awakenings, wake after sleep onset (WASO), and sleep efficiency were generated using the validated Sadeh algorithm (27). Actigraphy is deemed a valid means of estimating sleep in clinical, field and workplace settings (Martin 2011). There is good agreement between actigraphy and polysomnogrphy for sleep latency, total sleep time and sleep efficiency (intraclass correlation coefficient [ICC] > 0.80 respectively) moderate agreement for WASO (ICC = 0.73) and weak agreement for number of awakenings (ICC < 0.42) (1).

Training Load: During tennis sessions, a portable accelerometer (Kionix KX94, Kionix, Ithaca, New York, USA), housed inside a GPS unit (OptimEye S5, Catapult Innovations, Scoresby, Australia) measured distance covered, max velocity and PlayerLoad™ at a sampling frequency of 100 Hz. Participants were assigned the same unit for each training session, as the Catapult OptimEye S5 device has been shown to possess high intra-unit reliability (CV from 0.01%—<3.0%) (21). A tight-fitted neoprene garment was worn to secure the device, housed in-between the scapulae to limit movement artefacts. See Figure 1 for full breakdown of trial day procedures.

INSERT FIGURE 1 HERE

Energy intake was recorded using hand-written food diaries. Participants were asked to provide as much detail as possible, including the brand names of the food/drink, and time of consumption. Where possible, participants were asked to quantify the portion of the foods and fluids consumed, referring to the weight/volume provided on food packages, or using standardised household measures, or providing the number of items of a predetermined size. The lead investigator was present during breakfast, lunch and dinner and took notes and photos of food consumption, including leftovers.

Food diary data were analysed using Nutritics software (3.74 professional edition, Nutritics Ltd., Dublin, Ireland). Total energy intake was inclusive of all foods and fluids consumed at breakfast, lunch, dinner, and snacks throughout the day. All analyses were carried out by a single trained researcher so that potential variation of data interpretation was minimized. To assess intra-tester reliability, JF selected a 20% sample of dietary intake records and analysed the data on three separate occasions. Reliability analyses were carried out via IBM SPSS statistical software (v23.0 for windows, IBM corporation, Armonk, NY, USA) for total energy and macronutrient intakes with intraclass correlation coefficients of >0.969 established for all variables. A further reliability analysis was conducted (inter-researcher reliability); LDC individually assessed energy intake data of two players selected at random. No significant difference was observed (as determined by one-way ANOVA) for energy, carbohydrate, protein or fat intake ($p>0.05$).

Statistical Analysis

All parametric data is reported as mean ± SD. Statistical analysis was completed using SPSS. Normality of data was assessed using the Shapiro–Wilks test, with $p>0.05$ used as the threshold for normal distribution. Multiple one-way repeated measures ANOVAs were performed to compare energy intake, energy expenditure, and indices of sleep during the training camp. Assumptions of sphericity were assessed using Mauchly's test, with Greenhouse-Geisser correction applied if sphericity was violated. Where significant differences were present, post hoc analysis (Bonferroni) was conducted to locate specific differences. Pearson's correlation coefficients were calculated to determine if there were relationships between energy balance and indices of sleep. Paired samples t-tests were also conducted to calculate differences between energy intake and energy expenditure. Further paired samples t-tests were conducted to investigated whether time (AM v PM) and type (drill vs SMP) of training session influenced distance covered, PlayerLoad™, max velocity and energy expenditure. Effect size analyses (Cohen's *d*) were conducted to determine the magnitude of effect. An effect size was classified as trivial (<0.20), small (0.20—0.49), moderate (0.50—0.79), or large (>0.80).

Results

Training Demands

Participants covered a mean distance of 4787 ± 517m, reached 5.1 ± 0.3m·s^{-1} in max velocity and recorded a PlayerLoad^{TM} of 643 ± 92a.u. during the training week. Significantly higher distance covered and PlayerLoad^{TM} were recorded during morning sessions than afternoon sessions (5370 ± 505 vs 4726 ± 697m, $p<0.005$, d=3.2: 725 ± 109a.u. vs 588 ± 96a.u., $p<0.005$, d=4.0). No difference in max velocity was found between morning and afternoon sessions (5.21 ± 0.69 vs 5.26 ± 0.32m·s^{-1}, $p>0.05$).

Participants ran further (5624 ± 897 vs 4933 ± 343m, $p<0.05$, d=1.0) and produced higher max velocity outputs (5.17 ± 0.44 vs 4.94 ± 0.39$m \cdot s^{-1}$, $p<0.05$, d=0.3) during SMP training than drill training sessions. No significant difference was found between SMP training and drill training sessions for PlayerLoad^{TM} (718 ± 146 vs 695 ± 95a.u., $p>0.05$).

Energy Expenditure

No differences in daily activity energy expenditures were reported for full training days (2217 ± 176kcal). Activity energy expenditure on day four (no afternoon training) was significantly lower than all other days (<339—463kcal·day; $p<0.05$, d>0.6). Players expended significantly more energy in the morning sessions than the afternoon sessions (419 ± 90 vs 409 ± 85kcal, $p<0.05$, d=0.1), yet no difference was found between types of sessions (drill training vs SMP; 410 ± 86 vs 422 ± 95kcal, $p>0.05$, d=0.1). With the inclusion of RMR values and DIT, estimated daily energy expenditure resulted in a mean of 3959 ± 630kcal (range; 2611—5251kcal·day).

Energy intake

Mean energy intake was significantly lower than mean energy expenditure, with players consuming 2526 ± 183kcal and expending an estimated 3959 ± 630kcal ($p<0.001$). Mean energy deficits were 1433 ± 683kcal, with some individuals reporting deficits >2000kcal·day; Figure 2). Players consumed significantly less calories at breakfast (567 ± 136kcal) compared with lunch and dinner (932 ± 159kcal and 1018 ± 167kcal respectively; $p<0.005$), and players opted not to eat personal snacks during 40% of the opportunities to do so. Relative total daily macronutrient intake was 6 ± 1.3 $g \cdot kg \cdot BM^{-1}$ for carbohydrates; 2.1 ± 0.4$g \cdot kg \cdot BM^{-1}$ for protein and 0.6 ± 0.2$g \cdot kg \cdot BM^{-1}$ for fat.

INSERT FIGURE 2 HERE

Sleep

On average, players went to bed at 22:10 and obtained 6.9h of sleep per night. Fragmented sleep patterns were reported throughout the week, with time spent awake after initial sleep onset (WASO) averaging 78 mins per night, and average number of awakenings in excess of 23 on all nights. Full characteristics of players' sleep are presented in Table 1.

INSERT TABLE 1 HERE

There were no statistically significant correlations between energy balance and total sleep time ($r = .057$, $p > 0.05$) and sleep efficiency ($r = .37$, $p > 0.05$).

Discussion

The main findings of this study were a) that players reported insufficient energy intake resulting in negative energy balance and b) sub-optimal total sleep time and disturbed sleep patterns were observed. These findings indicate concerns regarding performance optimisation, recovery and readiness, and susceptibility to injury/illness and conditions associated with RED-S.

During training camps and periods of increased training load and volume, the development of adequate nutritional plans to maintain energy balance is imperative (5,31). Adequate dietary intake is important for optimal growth and maturation, maintaining health and well-being, reducing the risk of illness and injury, stimulating training adaptations and promoting performance (12). This is particularly pertinent in an adolescent population, with even greater strain on the body during puberty and periods of intense growth (19). The present study saw players participate in over 28 hours of training, averaging ~4.7 hours per day and often spending their down time physically exerting themselves (e.g., swimming or playing football after dinner). This resulted in mean TDEE in excess of 3900kcal (range 2611—5251kcal), and activity energy expenditures in excess of 2200kcal·day (range 1081—3076kcal), emphasising the importance of sufficient dietary intake to support such demands.

Albeit limited to very few studies, negative energy balance has been widely reported in a junior tennis population (3,14,34). Coelho et al. (3) reported 54% of players consuming less than 1800kcal·day (1715 ± 321kcal), which is considered the minimum energy necessary to maintain positive energy balance (31). Juzwiak et al. (14) observed calorie deficits ranging from 532—1709kcal in 32% of their sample, and Yli-Piipari (34) reported deficits between 268—921kcal, with sub-optimal carbohydrate intake also reported (<5g·kg·BM^{-1}·day) as a key contributor towards failure to meet energy balance. Our findings corroborate those from previous research. Players failed to meet energy balance, with individual deficits in excess of 2000kcal·day regularly reported (mean deficits 1433 ± 683kcal·day). Sub-optimal carbohydrate intakes were also reported, with players averaging 1.5g·kg·BM^{-1} carbohydrates prior to morning training and overall daily intakes of 6g·kg·BM^{-1} compared to recommendations of 1-4g·kg·BM^{-1} and 6-10g·kg·BM^{-1} respectively (12,31). Least calories were consumed at breakfast (~550kcal) prior to the longest training period (3 hours), compared to lunch and dinner (~1000kcal respectively), indicating a lack of nutrition planning or meal consideration, raising concerns regarding energy availability to support performance and recovery (31), whilst also posing the longer-term threat of RED-S in this population (20).

The insufficient energy intake reported in the present study may have been attributed to the ‘one-size fits all’ approach adopted during the training camp. Players were given three meals a day, often with limited choice and availability, and were advised to consume their own personal snacks ad libitum. Consequently, snacking was utilised infrequently, with players opting to consume foods outside of the three meals on only 60% of the opportunities available. A distinct lack of energy/carbohydrate intake during training was also reported, illustrating sub-optimal nutritional practices to support performance during periods of sustained high intensity activity, or sessions >1 hour in duration. It is evident that players were unable to manage their intake effectively, suggesting that a more prescriptive approach to nutrition may be warranted when working with this age group. Coaches and support staff must plan and cater for the increased training load and energy expenditure, with increased food provision during training camps and periods of heightened training load and volume. It is also recommended to consider intra-training nutrition strategies such as isotonic drinks and carbohydrate rich snacks, whilst also enhancing the energy density of foods consumed at mealtimes to improve within-day energy balance (31). Nutrition education may be required for those working with young athletes to ensure all parties (including parents) are equipped to adequately support athletes and protect them from issues associated with RED-S (20).

Sleep quality and quantity are crucial psychological and physiological contributors to recovery in athletes (10), with those whom attain <8 hours sleep per night 1.7 times more likely to gain an injury than those who meet recommended sleep guidelines (9). General guidelines state that adolescents should attain between 8—10 hours per night in order to facilitate physiological restoration and recovery, memory consolidation and neuroendocrine function (23). Within athletes, there may be an increased overall requirement for sleep, associated with the frequent exposure to high intensity training and competition and increased recovery need (16).

Previous research during training camps has reported sub-optimal total sleep time amongst elite adolescent basketball players (7.2 ± 1.0hrs per night) (16) and elite junior rowers (6.8 ± 0.3hrs week 1; 6.9 ± 0.3hrs week 2) (15). Similarly, sub-optimal sleep quantity was reported in the present study with players averaging <7 hours per night. Poor sleep quality was also reported with high levels of fragmentation (Table 1), including WASO in excess of 60 minutes per night, and sleep efficiency below the normal range of 85% (25). It is important to note that unfamiliar environments such as hotel rooms and new accommodation may reduce sleep quality. When athletes encounter disruptions to their environments, normal sleep-wake cycles can become desynchronised (8). This may have contributed to the poor sleep habits reported in the present study, with players sharing rooms in a new sleep environment.

When sleep quantity and quality may be impacted, implementing sleep hygiene strategies is recommended (17). Sleep hygiene is described as practicing behaviours that facilitate sleep and avoiding behaviours that interfere with sleep; with use of mobile phones and television key disturbances in adolescents (8). Sleep hygiene practices reduce sleep irregularity, improve sleep quality, and improve sleep onset latency (the length of time that it takes to accomplish the transition from full wakefulness to sleep) in an adolescent population (17). Although less is known in an athletic population, evidence suggests that adherence to sleep hygiene recommendations improves sleep quality, resulting in reductions in perceived soreness and fatigue in elite tennis players (6). Coaches and support staff have crucial roles in providing behavioural and performance related advice in relation to sleep. An increased focus on routine sleep assessment, with the development of educational sleep resources promoting sleep hygiene practices is recommended.

Despite the novelty and practical application of the current study, there are a number of limitations that must be acknowledged. Firstly, sample size; as the population was from a single squad of high-performance academy players, only small participant numbers were available. Secondly, dietary assessment; although food diary use has its inherent flaws (adherence and underreporting) (31), homogeneity of food intake was controlled with players living in self-catered villas managed by coaches and support staff. The squad and support staff frequented the same restaurant every night for dinner and the lead investigator was present during all meals. Lastly, despite reported limitations in GPS specificity for tennis (7) there are currently limited readily available validated methods available to measure distance and speed of movement for tennis, with total distance regularly highlighted as the most accurate measure of those reported within this population (26).

Conclusion

In summary, this is the first study to investigate the demands of a junior academy tennis training camp. Results indicate that players failed to meet energy requirements resulting in large energy deficits and sub-optimal sleep quantity and quality throughout. It is clear that a 'one size fits all' approach is insufficient for this population, and nutrition education of coaches/support staff may be warranted. It is also recommended to those supporting junior athletes during these periods to increase food quantity and quality, prioritising energy dense foods (particularly when fuelling opportunities are limited). Intra training nutrition strategies should also be embedded when players are exposed to training sessions >1 hour in duration. To combat the deleterious effects of poor sleep (particularly whilst players accustom themselves to new sleeping environments), effective sleep monitoring and sleep hygiene practices are required. Future research is also warranted to establish guidelines and aid coaches, support staff and players during periods of elevated training. This will support athlete development, prolonged sporting performance (4) and health status (28) and minimise the susceptibility to conditions linked to RED-S (20).

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Tables

Table 1. Training week sleep data.

	Bedtime (HH:MM)	Time in Bed (mins)	SOL (mins)	Total Sleep Time (mins)	No. of awakenings	WASO (mins)	Efficiency (%)
Camp Mean	22:10 ± 00:28	504 ± 42	9 ± 16	412 ± 46	28 ± 7	78 ± 40	82 ± 6
Night 1	21:56 ± 00:28	534 ± 32	2 ± 3	462 ± 57	26 ± 7	63 ± 38	86 ± 7
Night 2	22:27 ± 00:26	440 ± 41*	8 ± 14	362 ± 36^	23 ± 6[#]	66 ± 40	83 ± 7
Night 3	22:04 ± 00:17	534 ± 12	10 ± 18	444 ± 21	29 ± 5	77 ± 35	83 ± 5[a]
Night 4	22:19 ± 00:29	491 ± 30	13 ± 16	387 ± 21	30 ± 7	86 ± 40	79 ± 5
Night 5	22:09 ± 00:39	524 ± 33	11 ± 22	427 ± 25	30 ± 9	81 ± 37	82 ± 4
Night 6	22:07 ± 00:27	516 ± 22	11 ± 16	398 ± 43	31 ± 7	93 ± 49	79 ± 8

Mean ± SD. Note. SOL = Sleep Onset Latency; duration of time from turning the light off to falling asleep. Awakenings: the number of different awakening episodes. WASO = Wake After Sleep Onset; periods of wakefulness after defined sleep onset. Efficiency: the sleep duration expressed as a percentage of time asleep from bedtime to sleep end. * denotes significant difference between night 2 and all other nights. ^ denotes significant difference between night 2 and nights 1, 3 and 5. [#] denotes significant difference between night 2 and nights 3 and 4. [a] denotes significant difference between night 3 and night 4.

Figure Legends

Figure 1: Schematic of trial day procedures. GPS = Global Positioning System (*Catapult*); S&C = 1-hour strength and conditioning training immediately after morning tennis training. *Actigraph GT9X Link accelerometer watch worn throughout camp.

Figure 2: Distribution of daily estimated energy balance; deficits shown via negative values. Lines indicative of the upper quartile, median and lower quartile values. Each datapoint (e.g., ■) represents an individual's estimated energy balance for each day. Note. Day 4 = no afternoon tennis training.