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

3

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5

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12

13 **ABSTRACT**

14 **Purpose:** To assess the training load, energy expenditure, dietary intake, and sleep quality
15 and quantity of junior tennis players during a tennis training camp. **Methods:** Ten junior
16 academy tennis players (14±1 years) completed a 6-day camp with daily morning and
17 afternoon training. Players wore accelerometer watches to measure activity energy
18 expenditure and sleep. Global positioning system units were worn to monitor external
19 training load (distance covered, max. velocity, PlayerLoad™). Dietary intake was
20 obtained from a food diary and supplementary food photography. **Results:** Players
21 covered significantly more distance and had higher PlayerLoad™ during morning sessions
22 than afternoon sessions (5370±505m vs 4726±697m, p<0.005, d=3.2; 725±109a.u. vs
23 588±96a.u., p<0.005, d=4.0). Players also ran further (5624±897m vs 4933±343m,
24 p<0.05, d=1.0) and reached higher max velocities (5.17±0.44m·s⁻¹ vs 4.94±0.39m·s⁻¹,
25 p<0.05, d=0.3) during simulated match play compared to drill sessions. Mean daily energy
26 expenditure was 3959±630kcal. Mean energy intake was 2526±183kcal, resulting in mean
27 energy deficits of 1433±683kcal. Players obtained an average of 6.9±0.8 hours sleep and
28 recorded 28±7 nightly awakenings. **Conclusions:** Junior academy tennis players failed to
29 achieve energy balance and recorded sub-optimal sleep quantity and quality throughout
30 the training camp.

31

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

33

34

35

36 **Introduction**

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

43

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

54

55 Optimised sleep quality and quantity may attenuate the physiological fatigue associated
56 with high training volumes and improve recovery and performance (8). Following periods
57 of heightened physiological and psychological stress (such as training camps), subsequent
58 sleep loss may compromise neurocognitive and physiological performance (10).
59 Insufficient sleep or experimentally modelled sleep restriction negatively affects indices of
60 performance (speed and endurance), cognitive function (attention and memory) and

61 physical health (illness and injury risk) (30). Despite a lack of sleep research during
62 training camps, reductions in sleep efficiency have been observed in Australian Rules
63 Football players (24), associated with a change in sleep environment. An inability to meet
64 sleep duration recommendations (8—10 hours per night) (13) has been reported amongst
65 junior rowers (15) and basketball players (16) during training camps, with no evidence of
66 sleep monitoring or the implementation of sleep hygiene practices.

67

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

72

73 **Methods**

74 *Subjects*

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

84

85 *Experimental design*

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

94

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

102

103 *Procedures*

104 Energy Expenditure: ActiGraph GT9X Link (ActiGraph, Pensacola, FL) accelerometer
105 watches were worn continuously (on the player's non-dominant wrist) throughout the
106 camp to measure individualised activity energy expenditure. ActiGraph is the most studied
107 accelerometer in children and adolescents with extensive evidence for good
108 reproducibility, validity and feasibility in this population (32). Subsequently, total daily
109 energy expenditure (TDEE) was estimated using the following equation: resting metabolic
110 rate (RMR) + activity energy expenditure + dietary induced thermogenesis (DIT). Resting

111 metabolic rate was calculated using the Schofield-HW equation (females; $8.365 \cdot BW$ [kg]
112 $+ 4.65 \cdot \text{Height (cm)} + 200$; males: $16.25 \cdot BW$ [kg] $+ 1.372 \cdot \text{Height (cm)} + 515.5$) (29), a
113 valid measure within 10-18 year olds (2). Dietary induced thermogenesis was set at 10%
114 of the total amount of energy ingested over the 24-hour period; a representative value for
115 healthy individuals consuming a mixed diet (33).

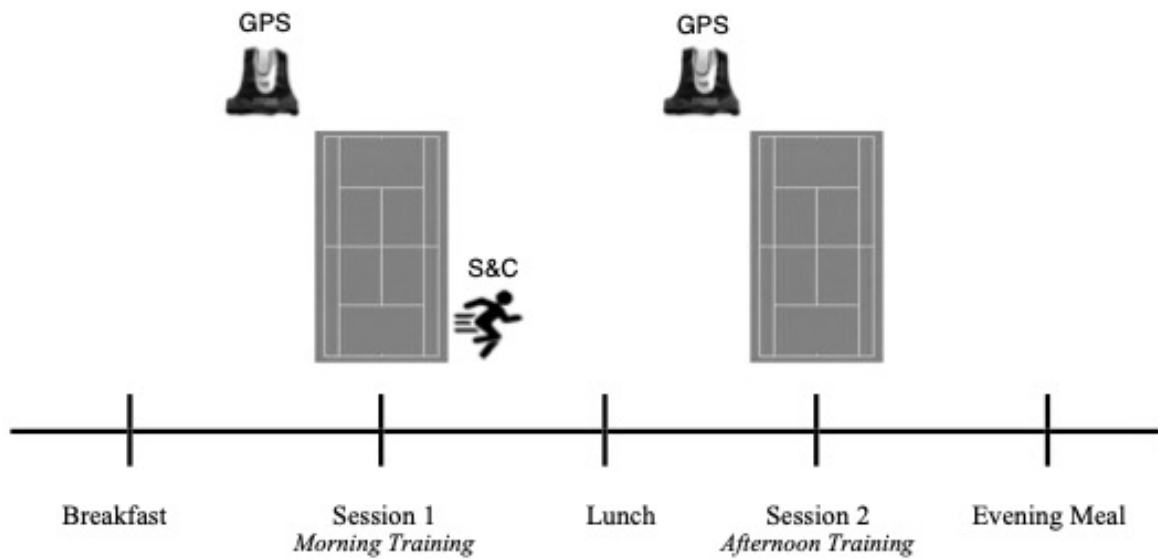
116

117 Sleep: Sleep patterns were monitored using the ActiGraph GT9x devices. After visual
118 inspection of the data sleep outcomes including time in bed, sleep onset latency, total sleep
119 time, number of awakenings, wake after sleep onset (WASO), and sleep efficiency were
120 generated using the validated Sadeh algorithm (27). Actigraphy is deemed a valid means
121 of estimating sleep in clinical, field and workplace settings (Martin 2011). There is good
122 agreement between actigraphy and polysomnography for sleep latency, total sleep time and
123 sleep efficiency (intraclass correlation coefficient [ICC] > 0.80 respectively) moderate
124 agreement for WASO (ICC = 0.73) and weak agreement for number of awakenings (ICC
125 < 0.42) (1).

126

127 Training Load: During tennis sessions, a portable accelerometer (Kionix KX94, Kionix,
128 Ithaca, New York, USA), housed inside a GPS unit (OptimEye S5, Catapult Innovations,
129 Scoresby, Australia) measured distance covered, max velocity and PlayerLoad™ at a
130 sampling frequency of 100 Hz. Participants were assigned the same unit for each training
131 session, as the Catapult OptimEye S5 device has been shown to possess high intra-unit
132 reliability (CV from 0.01%— $< 3.0\%$) (21). A tight-fitted neoprene garment was worn to
133 secure the device, housed in-between the scapulae to limit movement artefacts. See Figure
134 1 for full breakdown of trial day procedures.

135



136
137
138
139
140

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.

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

148

149 Food diary data were analysed using Nutritics software (3.74 professional edition,
150 Nutritics Ltd., Dublin, Ireland). Total energy intake was inclusive of all foods and fluids
151 consumed at breakfast, lunch, dinner, and snacks throughout the day. All analyses were
152 carried out by a single trained researcher so that potential variation of data interpretation
153 was minimized. To assess intra-tester reliability, JF selected a 20% sample of dietary
154 intake records and analysed the data on three separate occasions. Reliability analyses were

155 carried out via IBM SPSS statistical software (v23.0 for windows, IBM corporation,
156 Armonk, NY, USA) for total energy and macronutrient intakes with intraclass correlation
157 coefficients of >0.969 established for all variables. A further reliability analysis was
158 conducted (inter-researcher reliability); LDC individually assessed energy intake data of
159 two players selected at random. No significant difference was observed (as determined by
160 one-way ANOVA) for energy, carbohydrate, protein or fat intake ($p>0.05$).

161

162 *Statistical Analysis*

163 All parametric data is reported as mean \pm SD. Statistical analysis was completed using
164 SPSS. Normality of data was assessed using the Shapiro–Wilks test, with $p>0.05$ used as
165 the threshold for normal distribution. Multiple one-way repeated measures ANOVAs were
166 performed to compare energy intake, energy expenditure, and indices of sleep during the
167 training camp. Assumptions of sphericity were assessed using Mauchly’s test, with
168 Greenhouse-Geisser correction applied if sphericity was violated. Where significant
169 differences were present, post hoc analysis (Bonferroni) was conducted to locate specific
170 differences. Pearson’s correlation coefficients were calculated to determine if there were
171 relationships between energy balance and indices of sleep. Paired samples t-tests were also
172 conducted to calculate differences between energy intake and energy expenditure. Further
173 paired samples t-tests were conducted to investigate whether time (AM v PM) and type
174 (drill vs SMP) of training session influenced distance covered, PlayerLoad™, max
175 velocity and energy expenditure. Effect size analyses (Cohen’s d) were conducted to
176 determine the magnitude of effect. An effect size was classified as trivial (<0.20), small
177 (0.20 — 0.49), moderate (0.50 — 0.79), or large (>0.80).

178

179 **Results**

180 *Training Demands*

181 Participants covered a mean distance of $4787 \pm 517\text{m}$, reached $5.1 \pm 0.3\text{m}\cdot\text{s}^{-1}$ in max
182 velocity and recorded a PlayerLoadTM of $643 \pm 92\text{a.u.}$ during the training week.
183 Significantly higher distance covered and PlayerLoadTM were recorded during morning
184 sessions than afternoon sessions (5370 ± 505 vs $4726 \pm 697\text{m}$, $p<0.005$, $d=3.2$: $725 \pm$
185 109a.u. vs $588 \pm 96\text{a.u.}$, $p<0.005$, $d=4.0$). No difference in max velocity was found
186 between morning and afternoon sessions (5.21 ± 0.69 vs $5.26 \pm 0.32\text{m}\cdot\text{s}^{-1}$, $p>0.05$).

187

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

192

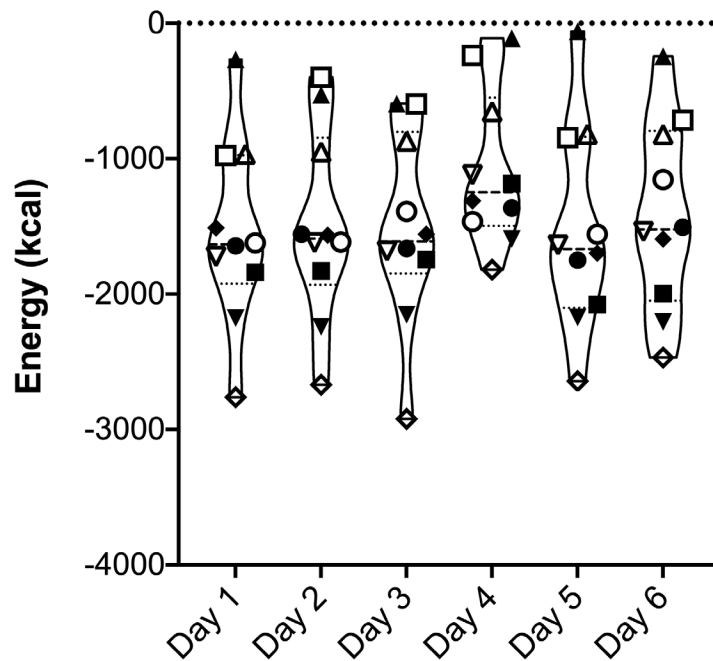
193 *Energy Expenditure*

194 No differences in daily activity energy expenditures were reported for full training days
195 ($2217 \pm 176\text{kcal}$). Activity energy expenditure on day four (no afternoon training) was
196 significantly lower than all other days ($<339\text{--}463\text{kcal}\cdot\text{day}$; $p<0.05$, $d>0.6$). Players
197 expended significantly more energy in the morning sessions than the afternoon sessions
198 (419 ± 90 vs $409 \pm 85\text{kcal}$, $p<0.05$, $d=0.1$), yet no difference was found between types of
199 sessions (drill training vs SMP; 410 ± 86 vs $422 \pm 95\text{kcal}$, $p>0.05$, $d=0.1$). With the
200 inclusion of RMR values and DIT, estimated daily energy expenditure resulted in a mean
201 of $3959 \pm 630\text{kcal}$ (range; $2611\text{--}5251\text{kcal}\cdot\text{day}$).

202

203 *Energy intake*

204 Mean energy intake was significantly lower than mean energy expenditure, with players
 205 consuming $2526 \pm 183\text{kcal}$ and expending an estimated $3959 \pm 630\text{kcal}$ ($p < 0.001$). Mean
 206 energy deficits were $1433 \pm 683\text{kcal}$, with some individuals reporting deficits
 207 $>2000\text{kcal/day}$; Figure 2). Players consumed significantly less calories at breakfast ($567 \pm$
 208 136kcal) compared with lunch and dinner ($932 \pm 159\text{kcal}$ and $1018 \pm 167\text{kcal}$
 209 respectively; $p < 0.005$), and players opted not to eat personal snacks during 40% of the
 210 opportunities to do so. Relative total daily macronutrient intake was $6 \pm 1.3 \text{g}\cdot\text{kg}\cdot\text{BM}^{-1}$ for
 211 carbohydrates; $2.1 \pm 0.4\text{g}\cdot\text{kg}\cdot\text{BM}^{-1}$ for protein and $0.6 \pm 0.2\text{g}\cdot\text{kg}\cdot\text{BM}^{-1}$ for fat.
 212



213
 214 **Figure 2:** Distribution of daily estimated energy balance; deficits shown via negative
 215 values. Lines indicative of the upper quartile, median and lower quartile values. Each
 216 datapoint (e.g., ■) represents an individual's estimated energy balance for each day. Note.
 217 Day 4 = no afternoon tennis training.
 218

219 *Sleep*

220 On average, players went to bed at 22:10 and obtained 6.9h of sleep per night. Fragmented
 221 sleep patterns were reported throughout the week, with time spent awake after initial sleep

222 onset (WASO) averaging 78 mins per night, and average number of awakenings in excess
 223 of 23 on all nights. Full characteristics of players' sleep are presented in Table 1.

224

225 **Table 1.** Training week sleep data.

226

	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

227 Mean ± SD. Note. SOL = Sleep Onset Latency; duration of time from turning the light off to falling
 228 asleep. Awakenings: the number of different awakening episodes. WASO = Wake After Sleep Onset;
 229 periods of wakefulness after defined sleep onset. Efficiency: the sleep duration expressed as a
 230 percentage of time asleep from bedtime to sleep end. * denotes significant difference between night 2
 231 and all other nights. [^] denotes significant difference between night 2 and nights 1, 3 and 5. [#] denotes
 232 significant difference between night 2 and nights 3 and 4. ^a denotes significant difference between night
 233 3 and night 4.

234

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

237

238 **Discussion**

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

244

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

257

258 Albeit limited to very few studies, negative energy balance has been widely reported in a
259 junior tennis population (3,14,34). Coelho et al. (3) reported 54% of players consuming
260 less than 1800kcal·day (1715 ± 321 kcal), which is considered the minimum energy
261 necessary to maintain positive energy balance (31). Juzwiak et al. (14) observed calorie
262 deficits ranging from 532—1709kcal in 32% of their sample, and Yli-Piipari (34) reported
263 deficits between 268—921kcal, with sub-optimal carbohydrate intake also reported
264 ($<5\text{g}\cdot\text{kg}\cdot\text{BM}^{-1}\cdot\text{day}$) as a key contributor towards failure to meet energy balance. Our
265 findings corroborate those from previous research. Players failed to meet energy balance,
266 with individual deficits in excess of 2000kcal·day regularly reported (mean deficits $1433 \pm$
267 683 kcal·day). Sub-optimal carbohydrate intakes were also reported, with players averaging
268 $1.5\text{g}\cdot\text{kg}\cdot\text{BM}^{-1}$ carbohydrates prior to morning training and overall daily intakes of

269 6g·kg·BM⁻¹ compared to recommendations of 1-4g·kg·BM⁻¹ and 6-10g·kg·BM⁻¹
270 respectively (12,31). Least calories were consumed at breakfast (~550kcal) prior to the
271 longest training period (3 hours), compared to lunch and dinner (~1000kcal respectively),
272 indicating a lack of nutrition planning or meal consideration, raising concerns regarding
273 energy availability to support performance and recovery (31), whilst also posing the
274 longer-term threat of RED-S in this population (20).

275

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

294

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

303

304 Previous research during training camps has reported sub-optimal total sleep time amongst
305 elite adolescent basketball players (7.2 ± 1.0 hrs per night) (16) and elite junior rowers (6.8
306 ± 0.3 hrs week 1; 6.9 ± 0.3 hrs week 2) (15). Similarly, sub-optimal sleep quantity was
307 reported in the present study with players averaging <7 hours per night. Poor sleep quality
308 was also reported with high levels of fragmentation (Table 1), including WASO in excess
309 of 60 minutes per night, and sleep efficiency below the normal range of 85% (25). It is
310 important to note that unfamiliar environments such as hotel rooms and new
311 accommodation may reduce sleep quality. When athletes encounter disruptions to their
312 environments, normal sleep-wake cycles can become desynchronised (8). This may have
313 contributed to the poor sleep habits reported in the present study, with players sharing
314 rooms in a new sleep environment.

315

316 When sleep quantity and quality may be impacted, implementing sleep hygiene strategies
317 is recommended (17). Sleep hygiene is described as practicing behaviours that facilitate
318 sleep and avoiding behaviours that interfere with sleep; with use of mobile phones and

319 television key disturbances in adolescents (8). Sleep hygiene practices reduce sleep
320 irregularity, improve sleep quality, and improve sleep onset latency (the length of time
321 that it takes to accomplish the transition from full wakefulness to sleep) in an adolescent
322 population (17). Although less is known in an athletic population, evidence suggests that
323 adherence to sleep hygiene recommendations improves sleep quality, resulting in
324 reductions in perceived soreness and fatigue in elite tennis players (6). Coaches and
325 support staff have crucial roles in providing behavioural and performance related advice in
326 relation to sleep. An increased focus on routine sleep assessment, with the development of
327 educational sleep resources promoting sleep hygiene practices is recommended.

328

329 Despite the novelty and practical application of the current study, there are a number of
330 limitations that must be acknowledged. Firstly, sample size; as the population was from a
331 single squad of high-performance academy players, only small participant numbers were
332 available. Secondly, dietary assessment; although food diary use has its inherent flaws
333 (adherence and underreporting) (31), homogeneity of food intake was controlled with
334 players living in self-catered villas managed by coaches and support staff. The squad and
335 support staff frequented the same restaurant every night for dinner and the lead
336 investigator was present during all meals. Lastly, despite reported limitations in GPS
337 specificity for tennis (7) there are currently limited readily available validated methods
338 available to measure distance and speed of movement for tennis, with total distance
339 regularly highlighted as the most accurate measure of those reported within this population
340 (26).

341

342 **Conclusion**

343

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

358

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360 to carry out the investigations during the LaManga training camp and all participants who
361 completed the study.

362

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