Title: A combined sleep hygiene and mindfulness intervention to improve sleep and wellbeing during high-performance youth tennis tournaments

Submission Type: Original investigation

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Running head: Sleep hygiene and junior tennis tournaments

Abstract word count: 228

Text only word count: 3810

Number of Figures: 1

Number of Tables: 5

Abstract

Purpose: To investigate the effects of combined sleep hygiene recommendations and mindfulness on actigraphy-based sleep parameters, perceptual wellbeing, anxiety and match outcomes during high-performance junior tennis tournaments. ***Methods:*** In a randomized crossover design, 17 high-performance junior tennis players completed baseline, control and intervention conditions across three separate weeks. Baseline consisted of unassisted, habitual sleep during a regular training week and control was unassisted sleep during a tournament week. Players attended a sleep education workshop and completed a nightly sleep hygiene protocol during a tournament week for the intervention. Analysis was performed on weekly means and on the night prior to the first match of the tournament (T-1). ***Results:*** Significant differences were observed for increased time in bed, total sleep time and an earlier bedtime ($P<0.05$) across the intervention week. These parameters also significantly improved on T-1 of the intervention. A moderate effect size ($P>0.05$, $d>1.00$) was evident for decreased worry on T-1 of the intervention. Small effect sizes were also evident for improved mood, cognitive anxiety and sleep rating were evident across the intervention week. Match performance outcomes remained unchanged ($P>0.05$). ***Conclusions:*** Sleep hygiene interventions increase the sleep duration of high-performance junior tennis players in tournament settings, including the night prior to the tournament's first match. Effects on perceptual wellbeing and anxiety are unclear, though small trends suggest improved mood, despite no effect on generic match performance outcomes.

Keywords: tennis, sleep hygiene, competition, wellbeing, anxiety

Introduction

Sleep is considered important for optimal athletic preparation and post-exercise recovery. However, evidence suggests that athletes experience poor sleep quantity and quality[1], particularly individual[1] and junior athletes[2] and on nights preceding important competitions[3,4]. In turn, high-level junior (14-18-years) tennis players are exposed to condensed training schedules and tournament fixtures, which requires a considered approach to preparation and recovery[5]. Accordingly, high-level junior tennis players encompass these at-risk cohorts and situations, and strategies to alleviate truncated sleep behaviour are of interest to practitioners and researchers.

Susceptibility to poor sleep quantity and quality is often attributed to the contextual challenges faced as being both an adolescent (period characterised by an array of psychological and physical changes, including a natural phase delay in circadian timing leading to later bedtimes) and an athlete (e.g. competition stress and anxiety)[6]. Of importance are the effects a tournament may have on players' sleep. High-level junior tennis tournaments have congested schedules resulting in players competing in up to three matches per day with heightened physical and cognitive demands[7], which may degrade sleep quantity and quality[8]. Furthermore, with a majority of tournaments being played away from home and athletes staying in unfamiliar environments, there is greater risk for poor sleep quality[8]. Further, the psychological and emotional toll of a competitive match is elevated in comparison to training, with greater somatic and cognitive anxiety states present on the nights prior to competition[9]. Moreover, tennis players' emotions can vary, dependent on the outcomes of their matches[6], thus tournaments with multiple matches will greatly impact ones stress and anxiety, typified by emotional outbursts becoming more prominent as tournaments progress[10]. However, if an athlete is able to achieve adequate sleep, they may be more likely to improve the regulation and response to stress[11]. Since heightened stress can reduce sleep duration[12], approaches to improve the sleep of junior tennis players in tournament settings are warranted.

Due to the simplicity of implementation and the lack of resources required[13], sleep hygiene (SH) may be an appropriate strategy for junior athletes to enhance their sleep during competition. SH interventions are typified by education and modification of night-time behaviours to improve sleep quantity and quality[13,14]. Commonly used protocols include restricted exposure to light and technology prior to sleeping and manipulation of the sleep environment (temperature and noise) [13]. In addition, mindfulness has been used to enhance relaxation states[15] and improve sleep onset latency[16]. Despite the present benefits of SH to general populations[17], the effect of these interventions in athletes is mixed. For instance, in acute settings, football players have shown to obtain over 1.5 h more sleep after a late-night match compared to controls; however, the restoration of physical performance was unchanged[18]. Comparatively, extended sleep (2 h) has shown to significantly improve sprint performance of basketball players[19] and serving accuracy of tennis players[20]. Ongoing sleep education may be beneficial as it has shown to have psychological benefits such as increased subjective performance, sleep quality[21], perceived fatigue and vigour[22]. Collectively, although SH education shows acute benefits (i.e. increased sleep duration) for adult athletic populations[14,23], the conflicting evidence of its effect on performance, wellbeing and anxiety requires further investigation, particularly in junior athletes. Therefore, the aim of this study was to investigate the effects of a week-long combined SH and mindfulness intervention during competitive tournaments on objective measures of sleep, perceptual wellbeing and performance in high-performance junior tennis players.

Methods

Subjects

Seventeen high-level junior tennis players (male n=10, female n=7; age=15.4 ± 1.1; height=171.5 ± 11.2 cm; mass=60.7 ± 10.2 kg) participated in the study. The players were Tennis Australia (TA) scholarship athletes (Australian ranking, male=218 ± 119; female=205 ± 129) from two state-based National Academies (Sydney and Adelaide). All players and parents/guardians were provided with detailed information about the study. All available scholarship athletes were invited to volunteer, however inclusion criteria required athletes to participate in at least two tournament weeks and a baseline week within the study timeframe. Players were not screened for sleep disorders, but none had reported sleep-related issues from TA medical staff in the preceding six months. If players were eligible for the study timeframe, and wished to volunteer, informed consent was obtained from both parents and the participants, and ethical approval from the institutional ethics committee was granted (ETH19-3391).

Design

Two groups completed baseline (BASE), control (CON) and intervention (INT) conditions in a randomised crossover design (Figure 1). BASE observation was within the home environment during a regular training week (4-5 training days per week, 2-3 sessions per day, typically between 08:00–09:30 and 15:00–19:00) whilst CON (unassisted, normative sleep behaviour) and INT were during two separate tournament weeks. INT consisted of a “sleep education” workshop prior to the tournament, and a nightly SH and mindfulness routine implemented within one of

the tournament weeks. The tournaments were of Junior ITF (G4-G5) level played on hardcourt over six days between April and September 2019. Objective sleep parameters were collected with wristwatch actigraphy and combined with subjective sleep diaries each night within each seven-day period. Perceptual wellbeing questionnaire responses were collected upon awakening each morning and the Competitive State Anxiety Inventory-2 (CSAI2[24]) was completed on night 1 of BASE and the night prior to the tournament (T-1), as well as night two and five throughout CON and INT. The Athlete Sleep Screening Questionnaire (ASSQ[25]) was completed on night one of each condition and the reduced-Morningness-Eveningness questionnaire (rMEQ[26]) was completed on night one of BASE only. These three questionnaires are typically used to provide a snapshot (i.e. weekly) of the players' condition as opposed to daily use. Tournament match results were recorded during CON and INT.
(Insert Figure 1 near here)

Methodology

Tri-axial accelerometer actigraphy devices (Actigraph wGT3x-BT, ActiGraph Corporation, Pensacola, FL, USA) were set for players' height, body mass, date of birth and non-dominant wrist to provide estimates of sleep quantity and quality and worn from 30 min prior to going to bed until waking. Actigraphy monitors have shown acceptable agreement rates (81-91%) to polysomnography (PSG) in elite adult athletes and are deemed a valid method to monitor sleep in athletic populations[27,28]. In addition, actigraphy holds advantages in youth populations due to their cost effective and non-intrusive nature[27,28]. Devices were set at a sampling frequency of 60Hz with a 60s epoch[27]. Following each week of monitoring, data was downloaded using the manufacturer's proprietary software (Actilife, Actigraph Corporation, Penasacola, FL, USA). With the assistance of a subjective diary, bedtimes (BT) and waketimes (WT) were entered into the sleep analysis section of the software using the Sadeh algorithm[29]. Weekly averages for sleep parameters as well as values of the night prior to the first match of the tournament (T-1) were analysed due to evidence that sleep quantity and quality can be truncated prior to important competitions[3]. In addition, as tournament weeks vary dependent on player results, T-1 represents a standardized pre-first match night.

Player wellbeing data was obtained from the TA database (Athlete Management System) for which players answered a daily questionnaire (immediately upon waking) on a mobile application using VAS scales between 1-10. Subjective sleep quality was assessed using a VAS scale, with (1 =very bad/very restless – 10 =no disturbances) as part of TA athlete monitoring. The CSAI2 was used to assess feelings of anxiety and confidence. The CSAI2 has been shown to be a valid and reliable measure of cognitive and somatic anxiety as well as self-confidence among a broad range of athletes (i.e. age, gender, sport), yet provided the length (27 questions) of it, is suggested not to be utilised daily[24]. Furthermore, the ASSQ was used to determine the level of difficulty athletes have in achieving sleep, for which the scoring system shows good agreement (81% for moderate-severe; 93% for none-mild) with sleep medicine physicians diagnosis[25]. Participants who were categorised as 'severe' in the ASSQ aligned with physician recommendations of requiring follow-up treatment[25]. The rMEQ, which provides an accurate prediction of chronology preferences in the general population [26], was used for descriptive purpose.

Match data, including duration, and results (i.e. games won, and games lost) were collated during each tournament from tournament organisers, while athletes provided a subjective rating of their performance on a VAS (1 =very poor – 10 =best you've played) scale following each match. Previous research suggests that sleep extension[20] and sleep restriction[30] may effect tennis-specific performance, though stroke or matchplay level analyses were not available.

Athletes were given no instruction as to how they should sleep while they were based in their home environment during a regular training week (BASE). Players completed the CSAI-2, ASSQ and rMEQ questionnaires once only on night one. Athletes were given no instruction as to how they should sleep during the tournament (CON). The CSAI-2 was completed on T-1 and nights two and five of the tournament. ASSQ was completed once only on T-1. Match results were collected daily.

Players were presented with a "sleep education" workshop (approx. 40 min) by the lead investigator three days prior to the tournament (INT). This presentation highlighted evidence of poor sleep in athletic populations, potential causes of poor sleeping and the ensuing effects (positive and negative) on performance (athletic, academic and general health), examples of high-profile athletes who support the importance of sleep and a SH routine to improve their bedtime habits. Following this presentation in the days leading up to the tournament, players' familiarised themselves with the SH protocol. Players were then instructed to follow the SH protocol information package each night throughout the tournament. The SH protocol consisted of the following; no consumption of caffeine or other stimulants after 15:00, at 20:00, a reminder was sent to the group to prepare their bedroom (cool – 18-21ºC or as comfortable; dark – blinds/curtains drawn; and quiet – remove any noisy objects if possible) and start thinking about commencing the 'power-down' hour; by 20:30 athletes were to have commenced their 'power-down' hour (reduce exposure to light, limit use of technology and minimise physical activity). Athletes were instructed to be in bed by 21:30 with their actigraphy watch on. Once in bed athletes were instructed to start listening to a mindfulness recording focusing on breathing and body awareness (12 min) with their eye mask on. The recording (Body Scan for Sleep: Saturating the Body with the Breathe, Breathworks CIC, Manchester, United Kingdom), used nightly, has been previously shown to improve sleep onset latency of adolescents when used immediately prior to sleep[16]. Finally, by 21:45 (or immediately after, if not during, the recording) athletes were instructed to attempt to fall asleep.

The CSAI-2 was completed on T-1 and nights two and five of the tournament. ASSQ was completed once only on T-1. Match results were collected daily. Communication with athletes was through an instant messaging application (WhatsApp, WhatsApp Inc., Mountain View, California, United States)) which allows the sender to see who has viewed the message/attachment and when they viewed it. This was monitored each night by researchers in conjunction with parents, along with a nightly checklist to ensure adherence to the protocol. All participants completed the checklists and adhered to the protocol.

Statistical Analysis

Descriptive statistics are presented for all variables as mean ± SD. A repeated measure analysis of variance (ANOVA) was performed to determine differences in sleep parameters, wellbeing and performance between conditions (BAS, CON and INT). Greenhouse-Geisser corrections were applied where significance was observed in Mauchly's Test of Sphericity. Pairwise comparisons were used to locate differences where main effects were evident. Significance was set at $P<0.05$. Statistical analysis was performed in Statistical Package for the Social Sciences (IBM SPSS Statistics for Macintosh, Version 25.0. Armonk, NY). In addition, effect sizes (ES) (Cohen's D, 95% confidence intervals) were calculated on a customised Microsoft Excel spreadsheet (Microsoft, Redmond, USA)[31] to determine the magnitude of effect of the conditions. ES were interpreted as <0.2, trivial; 0.2-0.6, small; 0.6 – 1.2, moderate; 1.2 – 2.0, large; >2.0, very large[31].

Results

Objective sleep parameters

All mean weekly sleep parameters for BASE, CON and INT are presented in Table 1. A significant increase in TBT was evident for INT compared to BASE ($P=0.02$, $d=0.74$) and CON ($P<0.01$, $d=0.98$), along with significant increases in TST for INT compared to both BASE ($P<0.01$, $d=0.68$) and CON ($P<0.01$, d=0.90). Small ES were observed for a shorter TIB (P=1.00, d=-0.24) and TST (P=1.00, d=-0.22) for CON compared to BASE. BT was significantly earlier during INT than both BASE (P<0.01, d=-0.75) and CON (P<0.01, d=-0.69). Small and moderate ES were evident for shorter SOL in INT compared to CON (P=1.00, d=-0.37) and BASE (P=0.24, d=-0.66). The remaining sleep parameters (WT, SE, WASO, WE and WED) were not significantly different (P>0.05) with trivial or small ES (d=0.10-0.60) between conditions.

(Insert table 1 near here)

Table 2 shows the sleep parameters on the night prior to the beginning of each tournament. A significant difference and moderate ES existed for increased TST (+0.72 ± 0.78 h) for INT T-1 to CON T-1(P=0.01, d=0.98). BT for INT T-1 was significantly earlier than CON T-1 (P<0.01, d=-0.88). TIB was significantly longer and had a large ES for INT T-1 (P=0.01, d=1.66), with athletes achieving 1.03 ± 0.82 h additional time in bed compared to CON T-1.

(Insert table 2 near here)

Perceptual wellbeing

Perceptual wellbeing measures for all conditions are presented in Table 3. There was a significant difference and moderate ES (P<0.01, d=-0.72) for increased feelings of worry in CON compared to BASE, with a similar ES (P=0.30, d=-0.76) for INT to BASE. A significant difference was observed for lower levels of confidence in CON compared to BASE (P=0.03, d=-0.65), along with a small ES (P=1.00, d=-0.50) for INT respectively. In addition, cognitive anxiety levels in CON moderately increased from BASE (P=1.00, d=0.51) and showed a small decrease in INT from CON (P=1.00, d=-0.21). Sleep rating demonstrated small ES for an increase from BASE (P=0.95, d=0.32) and CON (P=0.51, d=0.25) to INT. ASSQ responses across BASE, CON and INT all scored in the ‘severe’ category for difficulty in sleeping and did not differ (P>0.05) between conditions. Mean rMEQ scores were 16.88 ± 3.43, classifying the group as a neutral chronotype. Remaining wellbeing measures (fatigue, mood, hunger and somatic anxiety) showed no significant differences (P>0.05), with trivial (d<0.20) or small (d=0.20-0.60) ES between conditions.

(Insert table 3 near here)

Wellbeing measures prior to the beginning of the tournament are presented in Table 4. No significant differences (P>0.05) and small-trivial ES were observed between conditions. However, a moderate ES (P=0.20, d=1.01) was evident for a decrease in feelings of worry for INT T-1 compared to CON T-1.

(Insert table 4 near here)

Performance

Table 5 shows the performance measures recorded during CON and INT tournament conditions. No significant differences were observed (P>0.05), with small ES observed for an increase in the amount of games lost (P=1.00, d=-0.29), decrease in subjective performance (P=1.00, d=0.36) and an increase in match duration (P=1.00, d=-0.30) in INT compared to CON. No significant differences (P>0.05) were observed for performance measures between conditions for the first main draw match (M1) of each tournament in INT and CON. Small ES (d=0.20–0.60) for match duration and trivial (d<0.20) ES for games won, games lost and player rating were evident.

(Insert table 5 near here)

Discussion

This study shows that a combined SH and mindfulness intervention can improve sleep quantity in high-performance junior tennis players during tournaments, particularly on the night before a tournament/first match. Specifically, a single sleep education workshop and nightly routine led to significant improvements in weekly objective actigraphy parameters (TIB, TST and BT), as well as the night preceding the tournament. In addition, there were small-moderate effects for decreased feelings of worry and increased confidence in the SH condition compared to CON on the night preceding the tournament. Despite no changes to general match outcome characteristics, the present findings suggest that acute SH and mindfulness is effective to improve sleep and potentially perceptual wellbeing and anxiety in tournament settings.

The primary finding of our study was that SH and mindfulness practices increased sleep duration during a week-long tournament. Similar weekly increases in sleep duration following SH education have been previously shown for elite netballers (+22 min)[14] and rugby league players (+20 min)[23] and highlights sleep education and hygiene can effectively adjust acute sleep behaviour in athletic populations. Sleep as a recovery strategy is of particular importance during a tournament when athletes are required to elicit daily physical and cognitive demands, as well as constantly increase arousal levels and often be aggressive in their technical play[6]. By creating a conducive environment for sleep (e.g. limiting light exposure) and adjusting night-time behaviours (e.g. mindfulness and preparedness for sleep)[13], the transition to a physical and cognitive homeostasis may be better achieved. It should also be noted the mean sleep durations in each condition were still lower than recommended for adolescents[2]. Since the present study has shown SH to improve sleep in tournament settings, combined with the fact that high-performing junior tennis players compete in 18-25 tournaments or 125-150 matches per year[5,9], the implementation of sleep education and protocols is recommended for these players' during tournament routines.

Similar to the findings of increased sleep over the week, there were significant improvements in TIB, TST and BT on the night preceding the first match while using SH. These results concur with Fullagar, Skorski, Duffield, Meyer [18], who found comparable results (+99 min) following the use of an acute SH protocol with highly-trained soccer players after a late-night match. Additionally, tennis players have been shown to be able to achieve 60 min additional sleep time on a single night following repeated on-court training when utilising a SH protocol[32]. The initial benefit to sleep duration in our study, as well as previous research, may be attributed to the correction of poor in-tournament SH behaviours as indicated by the ASSQ scores. Since sleep quantity and quality is generally poorer on the night prior to a competition[3], the findings in our study suggest that acute SH and midnfulness may offer a practical solution to alleviating the acute risks to sleep duration that come on the night before a tournament commences.

Interestingly, the improved sleep quantity in our study was accompanied by moderate decreases in worry on the morning of the first match. Gymnasts have previously displayed comparable results prior to competition where greater sleep quality was associated with lower levels of precompetitive stress[11]. However, it should be acknowledged that the improvements noted in our study were smaller than that of Silva, Paiva [11]; potentially given sleep efficiency and subjective sleep quality remained unchanged, thus sleep quality may be a stronger determinant of mood than sleep duration[13]. Nonetheless, any advantage in reducing stress prior to a tournament should be explored further, such as the inclusion of additional mindfulness and meditation education and practice which has shown initial benefit for adolescents with sleep problems and anxiety[16].

Increased feelings of worry and decreased self-confidence in addition to a moderate increase in cognitive anxiety in tournament settings compared to baseline were observed. This concurs with previous research suggesting tournaments elicit increased feelings of anxiety and worry[33]. Indeed, individual athletes commonly report nervousness and anxiety prior to competition as the key reason for poor and disrupted sleep[3,4]. Interestingly, despite the continual protocol throughout the week, our study only observed small and trivial improvements in perceptual wellbeing. Reasons for the lack of an effect on perceptual measures may have been due to participants losing at some point during the week, resulting in less pressure and competitive anxiety for the remainder of the week when competing in consolation matches. Given that emotions are linked with match performance and outcomes in junior tennis players[6], collectively, this suggests that tournament results may have a greater impact on wellbeing than sleep.

No significant differences were observed for generic match outcomes in the present study. These results concur with previous research, with Fullagar, Skorski, Duffield, Meyer [18] reporting no improvement in jump or intermittent running performance, blood-based variables nor psychological recovery among soccer players despite improved sleep duration. In contrast, there is evidence that longer TST (i.e. sleep extension) may improve physical and cognitive performance[13]. For instance, sleep extension protocols resulted in improved serving accuracy for tennis players[20], significantly greater physical, cognitive and sport-specific performance among college basketball players [19] and reaction time of rugby players[34]. Despite this promising initial evidence, these studies were set in controlled training environments, and as such lack ecological validity to tournaments. Indeed, tournament settings are vastly different and thus performance may be predominantly affected by other factors unique to competition. Future research may focus on associations with sleep behaviour and more granular movement, technical and tactical measures within tennis.

Provided this was a field-based study, there are limitations that must be acknowledged. The study had a limited sample size due to the already constrained population (i.e. high-performance junior tennis players) and selection of players that met the inclusion criteria (i.e. playing at particular tournaments). Actigraphy was used in place of PSG to monitor sleep as it's a non-invasive and portable device. Given the use of two strategies within our study (i.e. mindfulness to compliment SH), it is difficult to discern if either particular method had a greater effect on the outcome measures. With tournaments occurring away from home, as usual, players/parents were required to organise their own accommodation (e.g. hotels), resulting in non-standardised sleep environments which may impact how the intervention was implemented. However, this limitation also leads to ecological validity of such an intervention being able to be implemented in real scenarios. Furthermore, specific enforcement of the intervention (i.e. researchers/staff checking bedrooms) was deemed unacceptable given the age of the players (under 18). The performance measures used in the study may not have been as susceptible to changes in sleep compared to serve accuracy or groundstroke errors, however these metrics were not available. Furthermore, match load and the time of day matches took place were unable to be controlled given it was an official tournament setting. Finally, due to the nature of the intervention, blinding of participants and assessors was not possible.

Practical Applications

The findings of this study can be applied in the field by coaching and performance staff within tennis academies to benefit high-performance junior players:

- SH education, protocols and mindfulness increase the sleep duration of high-performance junior tennis players, thus may be used during tournaments to improve sleep behaviour.
- Coaches and players should, in particular, consider such protocols prior to the first match, when anxiety and stress are typically greater, to alleviate feelings of worry and anxiety and increase self-confidence.
- The education session may be utilised to promote positive sleep behaviours and healthy bedtime routines.

Conclusion

The current investigation is the first to show that a combined SH and mindfulness intervention including a single education session and nightly protocol can have a positive effect on actigraphy based sleep indices and perceptual wellbeing, including anxiety during a tournament. Furthermore, the intervention was of particular benefit on the night preceding the tournament in potentially alleviating feelings of worry and increasing sleep duration. Future research should look to investigate effects on tennis-specific performance outcomes (e.g. serve accuracy and groundstroke errors) during the tournaments when utilising such protocols, whilst also looking to obtain participant feedback. In addition, a chronic approach with long term follow ups to SH among junior athletes should be explored, to assess whether ongoing education is more beneficial.

Acknowledgements

Tennis Australia provided funding for equipment (eye masks) which contributed to the development of this manuscript. The authors report no conflicts of interest. The authors sincerely appreciate the time and participation given by the players. The coaches and performance staff must also be thanked for their assistance and support of the project.

References

1. Lastella M, Roach GD, Halson SL, Sargent C. Sleep/wake behaviours of elite athletes from individual and team sports. *European Journal of Sport Science.* 2015;15(2):94-100.

2. Copenhaver EA, Diamond AB. The Value of Sleep on Athletic Performance, Injury, and Recovery in the Young Athlete. *Pediatr Ann.* 2017;46(3):E106-E111.
3. Juliff LE, Halson SL, Peiffer JJ. Understanding sleep disturbance in athletes prior to important competitions. *J Sci Med Sport.* 2015;18(1):13-18.
4. Erlacher D, Ehrlenspiel F, Adegbesan OA, Galal El-Din H. Sleep habits in German athletes before important competitions or games. *J Sports Sci.* 2011;29(8):859-866.
5. Reid MP, Quinlan G, Kearney S, Jones D. Planning and Periodization for the Elite Junior Tennis Player. *Strength and Conditioning Journal.* 2009;31(4):69-76.
6. Lewis FR, Knight CJ, Mellalieu SD. Emotional experiences in youth tennis. *Psychol Sport Exerc.* 2017;29:69-83.
7. Maraga N, Duffield R, Gescheit D, Perri T, Reid M. Playing not once, not twice but three times in a day: the effect of fatigue on performance in junior tennis players. *International Journal of Performance Analysis in Sport.* 2018;18(1):104-114.
8. Roberts SSH, Teo WP, Warmington SA. Effects of training and competition on the sleep of elite athletes: a systematic review and meta-analysis. *Br J Sports Med.* 2019;53(8):513-522.
9. Fernandez-Fernandez J, Boullosa DA, Sanz-Rivas D, Abreu L, Filaire E, Mendez-Villanueva A. Psychophysiological stress responses during training and competition in young female competitive tennis players. *Int J Sports Med.* 2015;36(1):22-28.
10. Gescheit DT, Duffield R, Skein M, Brydon N, Cormack SJ, Reid M. Effects of consecutive days of match play on technical performance in tennis. *J Sports Sci.* 2017;35(20):1988-1994.
11. Silva M, Paiva T. Sleep, precompetitive stress and achievements in young performance athletes. *Sleep Med.* 2013;14:e269.
12. Dumortier J, Mariman A, Boone J, et al. Sleep, training load and performance in elite female gymnasts. *European Journal of Sport Science.* 2018;18(2):151-161.
13. Bonnar D, Bartel K, Kakoschke N, Lang C. Sleep Interventions Designed to Improve Athletic Performance and Recovery: A Systematic Review of Current Approaches. *Sports Med.* 2018;48(3):683-703.
14. O'Donnell S, Driller MW. Sleep-hygiene Education improves Sleep Indices in Elite Female Athletes. *International journal of exercise science.* 2017;10(4):522-530.

15. Amutio A, Martínez-Taboada C, Hermosilla D, Delgado LC. Enhancing relaxation states and positive emotions in physicians through a mindfulness training program: A one-year study. *Psychol Health Med.* 2015;20(6):720-731.
16. Bartel K, Huang C, Maddock B, Williamson P, Gradisar M. Brief school-based interventions to assist adolescents' sleep-onset latency: Comparing mindfulness and constructive worry versus controls. *J Sleep Res.* 2018;27(3):e12668.
17. Irish LA, Kline CE, Gunn HE, Buysse DJ, Hall MH. The role of sleep hygiene in promoting public health: A review of empirical evidence. *Sleep Med Rev.* 2015;22:23-36.
18. Fullagar H, Skorski S, Duffield R, Meyer T. The effect of an acute sleep hygiene strategy following a late-night soccer match on recovery of players. *Chronobiol Int.* 2016;33(5):490-505.
19. Mah CD, Mah KE, Kezirian EJ, Dement WC. The Effects of Sleep Extension on the Athletic Performance of Collegiate Basketball Players. *Sleep.* 2011;34(7):943-950.
20. Schwartz J, Simon RD, Jr. Sleep extension improves serving accuracy: A study with college varsity tennis players. *Physiol Behav.* 2015;151:541-544.
21. Harada T, Wada K, Tsuji F, et al. Intervention study using a leaflet entitled 'three benefits of "go to bed early! get up early! and intake nutritionally rich breakfast!" a message for athletes' to improve the soccer performance of university soccer team. *Sleep Biol Rhythms.* 2016;14:S65-S74.
22. Van Ryswyk E, Weeks R, Bandick L, et al. A novel sleep optimisation programme to improve athletes' well-being and performance. *European Journal of Sport Science.* 2017;17(2):144-151.
23. Caia J, Scott TJ, Halson SL, Kelly VG. The influence of sleep hygiene education on sleep in professional rugby league athletes. *Sleep Health.* 2018;4(4):364-368.
24. Gabilondo JA, Rodríguez O, Moreno M, Galarraga S, Cecchini J. Validation of the competitive state anxiety inventory 2 (CSAI-2 re) through a web application. *Revista Internacional de Medicina y Ciencias de la Actividad Fisica y del Deporte.* 2012;12.
25. Bender AM, Lawson D, Werthner P, Samuels CH. The Clinical Validation of the Athlete Sleep Screening Questionnaire: an Instrument to Identify Athletes that Need Further Sleep Assessment. *Sports Medicine - Open.* 2018;4(1):23.
26. Montaruli A, Galasso L, Carandente F, Vitale JA, Roveda E, Caumo A. If the Morning-Evening

Questionnaire (MEQ) is able to predict the actigraphy-based acrophase, how does its reduced, five-item version (rMEQ) perform? *Chronobiol Int.* 2017;34(4):443-444.

27. Cellini N, McDevitt EA, Mednick SC, Buman MP. Free-living cross-comparison of two wearable monitors for sleep and physical activity in healthy young adults. *Physiol Behav.* 2016;157:79-86.

28. Sadeh A. The role and validity of actigraphy in sleep medicine: an update. *Sleep Med Rev.* 2011;15(4):259-267.

29. Sadeh A, Sharkey KM, Carskadon MA. Activity-based sleep-wake identification: an empirical test of methodological issues. *Sleep.* 1994;17(3):201-207.

30. Reyner LA, Horne JA. Sleep restriction and serving accuracy in performance tennis players, and effects of caffeine. *Physiol Behav.* 2013;120:93-96.

31. Hopkins WG. How to analyze a straightforward crossover trial www.newstats.org/xcrossover.xls. Published 2007. Accessed June 20, 2019.

32. Duffield R, Murphy A, Kellett A, Reid M. Recovery from repeated on-court tennis sessions: combining cold-water immersion, compression, and sleep recovery interventions. *Int J Sports Physiol Perform.* 2014;9(2):273-282.

33. Taylor L, Chrismas BC, Dascombe B, Chamari K, Fowler PM. The Importance of Monitoring Sleep within Adolescent Athletes: Athletic, Academic, and Health Considerations. *Front Physiol.* 2016;7:101.

34. Swinbourne R, Miller J, Smart D, Dulson DK, Gill N. The Effects of Sleep Extension on Sleep, Performance, Immunity and Physical Stress in Rugby Players. *Sports.* 2018;6(2).

Figure Captions

Figure 1: Diagrammatic representation of the study design.