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A Sleep Analysis of Elite Female Soccer Players During a Competition Week

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Abstract

Purpose: (1) To compare the sleep of female players from a professional soccer team to non-athlete controls across an in-season week and (2) to compare the sleep of core and fringe players from the same team on the night after a match to training nights.

Methods: Using an observational design, 18 professional female soccer players and 18 female non-athlete controls were monitored for their sleep via wristwatch actigraphy across one week. Independent sample *t*-tests and Mann Whitney U tests were performed to compare sleep between groups whilst an ANOVA compared sleep on training nights to the night after a match.

Results: Soccer players had significantly greater sleep duration than non-athlete controls (+38 min; P = 0.009; d: 0.92), which may have resulted from an earlier bedtime (-00:31 h: min; P = 0.047; d: 0.70). The soccer players also had less intraindividual variation in bedtime than non-athletes (-00:08 h: min; P = 0.023; r: 0.38). Despite this, sleep onset latency was significantly longer within soccer players (+8 min; P = 0.032; d: 0.78). On the night after a match, sleep duration of core players was significantly lower than on training nights (-49 min; P = 0.010; d: 0.77). In fringe players, there was no significant difference between nights for any sleep characteristic.

Conclusions: During the in-season period, sleep duration of professional female soccer players is greater than non-athlete controls. However, the night after a match challenges the sleep of players with more match involvement and warrant priority of sleep hygiene strategies.

Keywords: wristwatch actigraphy, team sports, training, in-season, recovery

Introduction

Sleep is considered the single best recovery strategy available for elite athletes following training and competition.[1] This is attributed to the bodily processes that occur during sleep thought to serve physical and psychological restoration.[2] Individuals are recommended to sleep at least 7h per night with 85% or more sleep efficiency (time asleep as a percentage of time in bed [sleep quality]).[3,4] During the competitive soccer season, however, sleep may be impacted by numerous factors such as scheduling, training stress, arousal and travel.[5] For example, a recent investigation of different match situations (i.e. home, away, day and night) revealed that sleep duration (5:49 h: min) and sleep efficiency (79 %) were lower on matchdays compared to training days (6:36 h: min and 85% for sleep duration and sleep efficiency respectively) in players from a professional men's Portuguese team.[6] There has also been no alteration to sleep after a match (i.e. day and night) and evening high intensity training compared with a rest day in male youth soccer players[7,8], though the sleep duration in these studies was highly variable (5.7–7.5 h). Such findings coupled with other studies in semi-professional and professional players showing a reduction in sleep duration after home, away and night-time fixtures (4.5-6 h)[9-11] highlight that although matchdays tend to impact sleep more, male soccer players may not meet current sleep guidelines during the season.

Data concerning the sleep of female soccer players during the competitive season is somewhat more limited. Sleep duration was lower following night-time training sessions (21:00 h) than on rest day nights (7:17 vs. 7:51 h: min) in players from a semi-professional female Portuguese team.[12] This was corroborated in a follow up study, as sleep duration after night-time training was markedly lower (7:09 h: min) compared to matchdays (i.e. home and away matches; 8:44 h: min) and rest days (8:35 h: min), also in semi-professional female players.[13] This was despite sleep efficiency falling within guidelines on all days (88-91 %).[13] Other than after night-time training, these findings may indicate female soccer players attain optimal sleep during the soccer season. That said, the players in the aforementioned studies were not full-time and thus, would not have the same schedule or training load as professional players. Besides, in the study by Costa et al[13], it is unknown if matchday sleep would have differed from training nights according to players match involvement. Fullagar et al[10] showed that male soccer players who started a night match had a smaller reduction in sleep efficiency from pre-match days than non-players (-3.9 vs. -20.7 %). Consequently, it may be appropriate to compare the sleep characteristics of professional female players between training and matchday nights based on playing time.

There is also no study comparing the sleep characteristics of female soccer players with a non-athlete, control group. Elite athletes are thought to have a greater sleep need than their non-athlete counterparts due to the physical demands associated with training and competition.[14] Within soccer players, studies employing objective measures of sleep have produced conflicting findings on the comparison with non-athletes.[15,16] This may be explained by the length of study, as Whitworth-Turner et al[16] is the only investigation to have monitored sleep over consecutive nights, thereby capturing the variation in scheduled activities. In this study, male youth soccer players had a longer sleep duration (486 vs. 422 min), but a lower sleep efficiency than non-athletes (93 vs. 96 %), as measured using a wireless system. These findings are in accordance with suggestions that elite athletes may have reduced sleep quality compared with non-athlete controls.[17,18] It would therefore seem important to first compare professional female soccer players and non-athlete controls to provide an insight into the sleep differences between these two populations. The primary aim of this study was to compare the sleep characteristics of female players from a professional soccer team to non-athlete controls across an in-season training week. Additionally, as it is unclear whether matchday alters sleep in professional female players, a secondary aim was to compare the sleep of core and fringe players on the night after a match to training nights. This type of analysis could further the understanding of how professional female soccer players sleep during the season and where their sleep may be challenged.

Methods

Subjects

Eighteen female soccer players (age = 23.2±4.5yrs) and 18 female non-athlete controls (age = 24.9±2.8yrs) were recruited. The soccer players were contracted to a professional team in England (competing in the FA Women's Super League, the top tier of English women's football) and had playing experience of 6.7±4.7yrs. In the group, there were two goalkeepers, five defenders, six midfielders and five forwards. The non-athlete controls were full time university students and physically active. Inclusion criteria consisted of the following: 18-40 years of age; non-smoker for at least six months; not a night-shift worker and not engaged in competitive sport. None of the participants were using sleep aids (e.g. medication) nor had they travelled across different time zones in the month prior to participation. Before the study commenced, written informed consent was obtained and participants filled in the morningness-eveningness questionnaire for the assessment of their chronotype.[19] The mean score for soccer players and non-athletes was 58±6 (intermediate) and 59±8 (moderate morning) respectively. This study was granted ethical approval from the Local University research ethics committee.

Design

Using an observational, descriptive study design, sleep characteristics were monitored across a week via wristwatch actigraphy. Actigraphy was implemented as this has shown to have a good overall agreement with polysomnography (gold standard measurement of sleep) and is considered a valid alternative in field settings (90-91 %).[20] Female soccer players were monitored across one of four in-season weeks (early to mid-season) that had similar training and matchday schedules. This was important to prevent differences in sleep characteristics between soccer players induced by the timing of training and competition in relation to the amount of days that were recorded. Accordingly, from Tuesday to Saturday, players trained and rested to prepare for matchday on Sunday, whilst on Monday they either rested or participated in activities to aid post-match recovery (Table 1). All training sessions were scheduled by the coaching staff at the club and the team played two home and two away matches (travelled night before and on the day) across the four-week period. The non-athlete controls were monitored during a week where they participated in their habitual routines, consisting of typical lecture and study days. Rest days (i.e. days with no set schedule) were excluded from data analysis in both groups. This was conducted to avoid unwanted variation associated with non-work activities[21] and this approach has previously been used within soccer players.[16] In addition, participants filled in a diary for the quantification of their internal training load. Across the monitoring period, participants were encouraged not to alter their sleep behaviour and they followed their usual dietary intake, which included caffeinated products.

INSERT TABLE 1 HERE

Methodology

Sleep Assessment

To monitor sleep characteristics, an actiwatch (Actiwatch 4, Cambridge Technology Ltd, UK) was provided and set to an epoch length of 1 min at a medium sensitivity.[22] On each night, participants were asked to wear the actiwatch on their non-dominant wrist at least 30 min before they retired to bed and then press the marker button upon their bedtime (lights out). The marker button was used again the following morning to indicate their final awakening time (lights on) before they were instructed to fill in the Consensus Sleep Diary[23] within an hour of getting out of bed. The Consensus Sleep Diary asks questions relating to bedtime, sleep onset latency, number of awakenings, final awakening time, get up time and sleep quality. Using the actiwatch markers and the information from the Consensus Sleep Diary; bedtime, sleep onset, final awakening time and get up time were determined so that sleep behaviour could be automatically calculated using the appropriate actiwatch software (Actiwatch activity and sleep analysis version 5.24, Cambridge Neurotechnology Ltd, UK). From the actiwatch analysis, the following characteristics were chosen to describe sleep: time in bed (min), bedtime (h: min), time of final awakening (h: min), sleep onset latency (min), sleep duration (min), sleep efficiency (%) and wake after sleep onset (min) (Table 2).

INSERT TABLE 2 HERE

Quantification of Training Load

After exercise, the duration and session rating of perceived exertion (sRPE) were recorded in the diary to calculate internal training load (CR10 scale).[24] The soccer players were asked to fill in the diary within an hour of finishing each training session and as soon as possible after a match to account for post-match activities. The non-athlete controls were asked to fill in the diary on days when they performed exercise and was also to be completed within an hour after their sessions. From this information, daily training load (arbitrary units [AU]) was calculated for both groups by multiplying the session duration in minutes by the sRPE.[24]

Statistical Analysis

Statistical Package for the Social Sciences (SPSS v26) was used for data analysis. To compare average sleep between soccer players and non-athletes, the mean of the characteristics across five nights was calculated for each individual. The data of both groups were then assessed for normality using the Shapiro-Wilk statistic and independent sample *t*-tests were conducted to assess group differences. When assessing the average daily training load between groups, the same process was used. Intraindividual variation of sleep characteristics was also calculated for groups across five nights by obtaining the mean of individual standard deviations.[25,26] For intraindividual sleep characteristics that met normality (i.e. time in bed), independent sample *t*-tests were performed, but for those that violated normality (i.e. bedtime, time of final awakening, sleep duration, sleep efficiency, sleep onset latency and wake after sleep onset), the Mann Whitney U test was chosen. A Linear Mixed Model ANOVA was used to assess if sleep on training nights and the night after a match differed within core (involved in ≥60 minutes of a match) and fringe (unused substitute or involved in ≤45 minutes of a match) players. The average of the characteristics from training days was calculated for each player and assessed against the night after a match. Within the models, type of night (i.e. training or match) was inputted as the fixed effect and individual player identification was included as the random effect. Data are presented as mean±standard deviation, mean difference and 95% confidence intervals (CI) or the median and interquartile range (IQR) for the reporting of non-parametric tests. Cohens *d* was calculated for effect size where normality was met and was subsequently assessed using the following thresholds: < 0.20 = trivial effect; 0.20-0.60 = small effect; > 0.60-1.20 = moderate effect; > 1.20-2.00 = large effect; > 2.00-4.00 = very large and > 4.00 = extremely large effect.[27] In circumstances where normality was not displayed, the *r* (uses z score from Mann Whitney U test) was used for effect size.[28] The *r* was interpreted from Cohen's criteria, where: 0.1 = small effect; 0.3 = moderate effect and 0.5 = large effect.[29] Statistical significance was set at level $P<0.05$.

Results

Soccer Players vs. Non-Athlete Controls

The soccer players had a significantly greater daily training load compared with non-athlete controls (738±169 vs. 364±167 AU; $P < 0.001$; *d*: 2.23 [very large]; 95% CI: 260-488 AU). Average sleep characteristics for soccer players and non-athletes are shown in Table 3. Soccer players spent significantly more time in bed than non-athlete controls (+55 min; $P = 0.001$; *d*: 1.22 [large effect]). Bedtime was significantly earlier in soccer players (-00:31 h: min; $P = 0.047$; *d*: 0.70 [moderate effect]) but final awakening was similar between groups ($P = 0.167$; *d*: 0.47 [small effect]). Soccer players had significantly greater sleep duration than non-athlete controls (+38 min; $P = 0.009$; *d*: 0.92 [moderate effect]). Sleep onset latency of soccer players was also significantly longer than non-athlete controls (+8 min; $P = 0.032$; *d*: 0.78 [moderate effect]). There were no significant differences between groups for sleep efficiency ($P = 0.362$; *d*: 0.39 [small effect]) and wake after sleep onset ($P = 0.733$; *d*: 0.14 [trivial effect]).

Intraindividual variation of sleep variables for both groups are also in Table 3. Soccer players had significantly less intraindividual variation in bedtime compared with non-athlete controls (-00:08 h: min; $P = 0.023$; *r*: 0.38 [moderate effect]). A marginal non-significant difference between groups was shown for intraindividual variation of final awakening ($P = 0.050$; *r*: 0.33 [moderate effect]). There were no significant differences between groups for intraindividual variation of time in bed ($P = 0.226$; *d*: 0.44 [small effect]), sleep duration ($P = 0.496$; *r*: 0.11 [small effect]), sleep efficiency ($P = 0.649$; *r*: 0.08 [trivial effect]), sleep onset latency ($P = 0.178$; *r*: 0.23 [small effect]) and wake after sleep onset ($P = 0.326$; *r*: 0.16 [small effect]).

INSERT TABLE 3 HERE

Night After Match vs. Training Nights

The time played by core and fringe players on matchday was 84±11 min and 14±18 min respectively. All core players started whilst one fringe player started, and three others were used as substitutes. Table 4 displays sleep characteristics of these groups on the night after a match and on training nights.

In core players, bedtime was significantly later on the night after a match compared with training nights (+00:37 h: min; $P = 0.032$; *d*: 0.76 [moderate effect]) but there was no significant difference for final awakening ($P = 0.359$; *d*: 0.37 [small effect]). Sleep duration was significantly lower on the night after a match compared with training nights (-49 min; $P = 0.010$; *d*: 0.77 [moderate effect]). There were marginal non-significant differences for time in bed ($P = 0.069$; *d*: 0.68 [moderate effect]), sleep efficiency ($P = 0.069$; *d*: 0.60 [small effect]) and wake after sleep onset ($P = 0.059$; *d*: 0.54 [small effect]). A small non-significant difference was observed for sleep onset latency ($P = 0.208$; *d*: 0.45). In fringe players, there was no significant difference for any of the sleep characteristics between the night after a match and training nights ($P>0.05$, $d<0.60$).

INSERT TABLE 4 HERE

Discussion

The aims of the current study were (1) to compare the sleep characteristics of female players from a professional soccer team to non-athlete controls (2) to compare the sleep of core and fringe players on the night after a match to training nights. In comparison to non-athlete controls, the soccer players displayed a greater sleep duration, which was likely a result of an earlier bedtime. Despite this, the soccer players had a longer sleep onset latency compared with non-athlete controls. On the night after a match, bedtime was later and sleep duration was lower within core players compared with training nights, whilst there was no alteration to the sleep of fringe players. These findings may suggest sleep duration of professional female soccer players is greater than non-athletes but that matchday challenges the sleep of players with more match involvement.

Sleep Comparison Between Soccer Players and Non-Athlete Controls

This is the first study to compare the sleep characteristics of female soccer players with non-athlete controls during the competitive season. In line with a previous investigation that described the sleep of male youth soccer players and non-athletes[16], the female soccer players slept more than the non-athlete controls. Additionally, the soccer players sleep time was similar to that of other elite female athletes monitored during multiple training days (7.2-7.6 h).[30] The greater sleep duration observed within the soccer players was likely facilitated by an earlier bedtime compared with non-athletes. After the completion of a training day, the soccer players did not have any scheduled work commitments that may have delayed their time to bed. In contrast, the bedtime of the non-athlete controls may have been constrained by independent study activities in the evening (i.e. writing, reading and revision) or late-night socialising. The timing of these activities are a frequent cause of poor sleep and sleepiness in students, and the use of psycho-active stimulants may have added effects.[31] In the current study, this notion is also supported by the disruption to bedtime within non-athletes, as indicated by greater intraindividual variability of this measure compared with soccer players. Thus, by having fewer commitments in the late evening, it is possible professional female soccer players may be able to increase sleep duration during the season.

Despite more time asleep, the female soccer players had a longer sleep onset latency accompanied by a moderate effect size compared with non-athlete controls, which suggests the soccer players had more difficulty falling asleep. It was also observed that the sleep onset latency of the soccer players was within the range of 20-30min deemed long in duration.[32] The difference in time to sleep onset with the non-athlete controls was comparable to values reported in previous studies (+10-13 min).[16,18] Our findings may be attributed to excessive electronic device use by players prior to bedtime, as this behaviour has been linked to delayed sleep onset within senior athletes.[33] With some of the female soccer players living together, it is also possible that noise outside of bedrooms or pre-bedtime arousal may have led to the difficulty in falling asleep. The longer sleep onset latency, however, was not associated with a lower sleep efficiency as found within Olympic athletes and male youth soccer players.[16,18] Indeed, the female soccer players had a similar sleep efficiency to the non-athlete controls. Irrespective of this, it seems there may be a need to develop individual strategies to improve the sleep onset latency of professional female soccer players.

Sleep Comparison Between Night After Match and Training Nights

Previous research has shown that sleep duration was lower following night-time training than on matchdays (i.e. home and away) within semi-professional female soccer players.[13] However, this study did not reflect the training schedule of professional soccer players and there was no consideration that matchday sleep may be dependent upon players match involvement. Within core players, we found that sleep duration was lower on the night after a match compared with training nights, whereas there was no alteration to the sleep of fringe players. These findings may suggest that sleep duration on the matchday night is lower compared to training nights within professional female soccer players that have more match involvement. This opposes Fullagar et al[10], where starting players from a men's national team had a smaller reduction in sleep efficiency after a night match compared with pre-match days than non-players. In the current study, sleep duration of core players on the night after a match was below the minimum 7h recommended to maintain optimal health and functioning.[3] This length of sleep may impact post-match recovery and subsequently, the training readiness of core players.[14] Taken together, these findings may provide a rationale to prioritise the sleep hygiene of core players over fringe players post-match.

Given the bedtime of core players was later on the night after a match, a delayed time to bed was likely responsible for the reduced sleep duration. Later bedtimes coupled with lower sleep durations are common among soccer players, more so after evening matches (i.e. late kick offs).[5,6,11] Of note, our data demonstrates that core players still retired to bed later and slept less on the night of an afternoon match (12-14:00 kick off). This broadly concurs with findings from Australian football, where the night after a match, regardless of the match start time, impacted bedtime and sleep duration compared with non-matchdays.[34] The reason for the later bedtime is unclear but is probably related to match factors as there was no alteration to the sleep of fringe players. It should also be mentioned more core players were involved in away matches, however, those that travelled the shortest (derby match) had the later bedtimes, indicating post-match travel was not influential. An obvious candidate from the match are the physical effects of playing (i.e. increased muscle damage)[2], though such mechanisms have not gained appraisal.[35] It is perhaps more plausible that the core players may have experienced a change in their mood (i.e. elation or tension) as a result of the match outcome that meant they adopted a later bedtime than usual. Male youth soccer players displayed poorer mood and sleep quality the day after losing a match but better mood and sleep quality after winning.[36] Nonetheless, further research is warranted to provide a better understanding of the factors that impact sleep following daytime matches in professional soccer players.

Limitations

Although the current study utilised female soccer players at the professional level, there are some limitations that should be considered. There was no controlling for the menstrual cycle, so habitual sleep may have been altered due to the participants being within different phases. It is acknowledged other factors (e.g. napping, psychology, electronic device use, nutrition, water immersion recovery strategies and sleep environment) were not monitored, which would have been useful to explain sleep differences. Due to monitor availability, not all players were assessed at the same time and thus, this may have increased variation in the sleep characteristics reported in this article. As the data was collected from one team during five days of the season, it may not reflect other teams or indeed, competitive schedules (i.e. two games per week). It is also unknown from our data if core and fringe players sleep is affected by match location and time. Future research should examine the sleep of professional female soccer players over a longer period during the season that incorporates more match situations.

Practical Applications

- Professional female soccer players may have greater sleep duration during the season than non-athlete controls due to earlier bedtimes. Practitioners could, therefore, highlight the importance of having control over bedtime to achieve more sleep.
- Despite a greater sleep duration, professional female soccer players may also have longer sleep onset latencies compared with non-athlete controls. Implementing individual sleep strategies may be useful to assist soccer players with falling asleep.
- On the night after a match, core but not fringe players may sleep less than on training nights. Practitioners could use this information to prioritise core players sleep following a match as reduced sleep duration may impact their recovery from the match itself.

Conclusion

In conclusion, sleep duration of professional female soccer players is greater than non-athlete controls. This is likely due to fewer evening commitments allowing for an earlier bedtime and highlights the importance of professional female soccer players having control of bedtime to achieve more sleep. However, the night after a match challenges the sleep of players with more match involvement and as such, they warrant priority of sleep hygiene strategies.

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Conflicts of Interest

The authors have no conflicts of interest to declare.

References

1. Halson SL. Nutrition, sleep and recovery. *Eur J Sport Sci*. 2008; 8(2): 119-126.
2. Fullagar H, Duffield R, Skorski S, Coutts AJ, Julian R, Meyer T. Sleep and recovery in team sport: current sleep-related issues facing professional team sport athletes. *Int J Sports Physiol Perform*. 2015; 10(8): 950-957.
3. Hirshkowitz M, Whiton K, Albert SM et al. National Sleep Foundation's sleep time duration recommendations: methodology and results summary. *Sleep Health*. 2015; 1(1): 40-43.
4. Ohayon M, Wickwire EM, Hirshkowitz M et al. National Sleep Foundation's sleep quality recommendations: first report. *Sleep Health*. 2017; 3(1): 6-19.
5. Nedelec M, Halson S, Abaidia AE, Ahmaidi S, Dupont G. Stress, sleep and recovery in elite soccer: a critical review of the literature. *Sports Med*. 2015; 45(10): 1387-1400.
6. Carrico S, Skorski S, Duffield R, Mendes B, Calvete F, Meyer T. Post-match sleeping behavior based on match scheduling over a season in elite football players. *Sci Med Football*. 2018; 2(1): 9-15.
7. Roach GD, Schmidt WF, Aughey RJ et al. The sleep of elite athletes at sea level and high altitude: a comparison of sea-level natives and high-altitude natives. *Br J Sports Med*. 2013; 47(supp 1): 114-120.
8. Robey E, Dawson B, Halson S, Gregson W, Goodman C, Eastwood P. Sleep quantity and quality in elite youth soccer players: a pilot study. *Eur J Sport Sci*. 2014; 14(5): 410-417.
9. Fowler P, Duffield R, Vaile J. Effects of domestic air travel on technical and tactical performance and recovery in soccer. *Int J Sports Physiol Perform*. 2014; 9(3): 378-386.
10. Fullagar H, Duffield R, Skorski S, White D, Bloomfield J, Kolling S, Meyer T. Sleep, travel, and recovery responses of national footballers during and after long-haul international air travel. *Int J Sports Physiol Perform*. 2016a; 11(1): 86-95.
11. 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*. 2016b; 33(5): 490-505.
12. Costa JA, Brito J, Nakamura FY, Oliveira EM, Costa OP, Rebelo AN. Does night training load affect sleep patterns and nocturnal cardiac autonomic activity in high-level female soccer players? *Int J Sports Physiol Perform*. 2019a; 14(6): 779-787.
13. Costa JA, Brito J, Nakamura FY, Figueiredo P, Oliveira E, Rebelo A. Sleep patterns and nocturnal cardiac autonomic activity in female athletes are affected by the timing of exercise and match location. *Chronobiol Int*. 2019b; 36(3): 360-373.
14. Davenne D. Sleep of athletes – problems and possible solutions. *Biol Rhythm Res*. 2009; 40(1): 45-52.
15. Brand S, Beck J, Gerber M, Hatzinger M, Holsboer-Trachsler E. Evidence of favorable sleep-EEG patterns in adolescent male vigorous football players compared to controls. *World J Biol Psychiatry*. 2010; 11(2 Pt 2): 465-475.
16. Whitworth-Turner C, Di Michele R, Muir I, Gregson W, Drust B. A comparison of sleep patterns in youth soccer players and non-athletes. *Sci Med Football*. 2017; 2(1): 3-8.
17. Bender AM, Van Dongen HPA, Samuels CH. Sleep quality and chronotype differences between elite athletes and non-athlete controls. *Clocks and Sleep*. 2019; 1(1): 3-12.
18. Leeder J, Glaister M, Pizzoferro K, Dawson J, Pedlar C. Sleep duration and quality in elite athletes measured using wristwatch actigraphy. *J Sports Sci*. 2012; 30(6): 541-545.
19. Horne JA, Ostberg O. A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. *Int J Chronobiol*. 1976; 4(2): 97-110.

20. Rupp TL, Balkin TJ. Comparison of Motionlogger Watch and Actiwatch actigraphs to polysomnography for sleep/wake estimation in healthy young adults. *Behav Res Methods*. 2011; 43(4): 1152-1160.
21. Wittmann M, Dinich J, Merrow M, Roenneberg T. Social jetlag: misalignment of biological and social time. *Chronobiol Int*. 2006; 23(1&2): 497-509.
22. Fuller KL, Juliff L, Gore CJ, Peiffer JJ, Halson SL. Software thresholds alter the bias of actigraphy for monitoring sleep in team-sport athletes. *J Sci Med Sport*. 2017; 20(8): 756-760.
23. Carney CE, Buysse DJ, Ancoli-Israel S, Edinger JD, Krystal AD, Lichstein KL, Morin, CM. The Consensus Sleep Diary: standardising prospective sleep self-monitoring. *Sleep*. 2012; 35(2): 287-302.
24. Foster C, Florhaug JA, Franklin J, Gottschall L, Hrovatin LA, Parker S, Doleshal P, Dodge C. A new approach to monitoring exercise training. *J Strength Cond Res*. 2001; 15(1): 109-115.
25. Caia JP, Halson SL, Scott TJ, Kelly VG. Intra-individual variability in the sleep of senior and junior rugby league athletes during the competitive season. *Chronobiol Int*. 2017; 34(9): 1239-1247.
26. Dillon HR, Lichstein KL, Dautovich ND, Taylor DJ, Riedel BW, Bush AJ. Variability in self-reported normal sleep across the adult age span. *J Gerontol B Psychol Sci Soc Sci*. 2015; 70(1): 46-56.
27. Hopkins W, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc*. 2009; 41(1): 3-13.
28. Fritz CO, Morris PE, Richler JJ. Effect size estimates: current use, calculations and interpretation. *J Exp Psychol Gen*. 2012; 141(1): 2-18.
29. Coolican H. *Research Methods and Statistics in Psychology*. London, UK: Hodder; 2009.
30. Lastella M, Roach GD, Vincent GE, Scanlan AT, Halson SL, Sargent C. The impact of training load on sleep during a 14-day training camp in elite, adolescent, female basketball players. *Int J Sports Physiol Perform*. 2020; 15(5): 724-730.
31. Hershner SD, Chervin RD. Causes and consequences of sleepiness among college students. *Nat Sci Sleep*. 2014; 6: 73-84.
32. McMahon DM, Burch JB, Wirth MD, Youngstedt SD, Hardin JW, Hurley TG, Blair SN, Hand GA, Shook RP, Drenowatz C, Burgess S, Hebert JR. Persistence of social jetlag and sleep disruption in healthy young adults. *Chronobiol Int*. 2018; 35(3): 312-328.
33. Jones MJ, Dawson B, Gucciardi DF, Eastwood PR, Miller J, Halson SL, Dunican IC, Peeling P. Evening electronic device use and sleep patterns in athletes. *J Sports Sci*. 2019; 37(8): 864-870.
34. Lalor BJ, Halson SL, Tran J, Kemp JG, Cormack SJ. No compromise of competition sleep compared with habitual sleep in elite Australian footballers. *Int J Sports Physiol Perform*. 2018; 13(1): 29-36.
35. Aloulou A, Duforez F, Bieuzen F, Nedelec M. The effect of night-time exercise on sleep architecture among well-trained male endurance runners. *J Sleep Res*. 2019; Dec 10: 1-12.
36. Abbott W, Brownlee TE, Harper LD, Naughton RJ, Clifford T. The independent effects of match location, match result and the quality of opposition on subjective wellbeing in under 23 soccer players: a case study. *Res Sports Med*. 2018; 26(3): 262-275.

Table 1. Female soccer players training schedule during the week of sleep monitoring.

	Mon	Tue	Wed	Thurs	Fri	Sat	Sun
AM	Rest	S&C (10:00) Technical (11:00)	S&C (10:00) Technical (11:00)	Rest	S&C (10:00) Tactical (11:00)	Tactical (11:00)	
PM	Rest or recovery		S&C (14:30)	Rest	S&C (14:30)		Match (12-14:00 KO)

*Monday and Thursday were excluded from data collection as these were rest days. Abbreviations: AM = morning; PM = afternoon; S&C = strength and conditioning session; KO = kick off.

Table 2. Definitions of sleep variables taken from the wristwatch actigraphy analysis.

Sleep variable	Definition
Time in bed (min)	Time difference between bedtime and get up time
Bedtime (h: min)	Estimated clock time participant attempted to sleep
Time of final awakening (h: min)	Estimated clock time participant woke up for the final time
Sleep onset latency (min)	Time between bedtime and sleep onset
Sleep duration (min)	Time asleep between sleep onset and final awakening
Sleep efficiency (%)	Time asleep divided by time in bed multiplied by 100
Wake after sleep onset (min)	Time awake between sleep onset and final awakening

Table 3. Mean±SD or the median (IQR) where applicable, and effect size with 95% CI for comparisons of average sleep and intraindividual sleep variability in female soccer players vs. non-athlete controls.

	Soccer players	Non-athletes	ES (95% CI)
Average sleep			
Time in bed (min)	550±38*	495±51	1.22 (24-85)
Bedtime (h: min)	22:59±00:38*	23:30±00:51	0.70 (-01:01-00:00)
Time of final awakening (h: min)	07:49±00:31	07:31±00:46	0.47 (-00:08-00:45)
Sleep onset latency (min)	21±12*	13±8	0.78 (0-15)
Sleep duration (min)	456±43*	418±40	0.92 (10-67)
Sleep efficiency (%)	83.0±5.9	84.6±4.0	0.39 (-5.0-1.9)
Wake after sleep onset (min)	51±25	48±19	0.14 (-12-18)
Intraindividual sleep variability			
Time in bed (min)	43±20	54±29	0.44 (-27-6)
Bedtime (h: min)	00:29(00:12)*	00:37(00:30)	0.38 (-00:25--00:01)
Time of final awakening (h: min)	00:38(00:26)	00:50(00:36)	0.33 (-00:33-00:00)
Sleep onset latency (min)	10(12)	6(10)	0.23 (-2-9)
Sleep duration (min)	43(22)	42(38)	0.11 (-22-10)
Sleep efficiency (%)	4.0(1.9)	3.0(2.5)	0.08 (-1.0-1.7)
Wake after sleep onset (min)	14(12)	10(17)	0.16 (-4-9)

***Indicates** $P < 0.05$ compared to non-athlete controls.

Table 4. Mean±SD and effect size with 95% CI for comparisons of average sleep in core and fringe players on night after match vs. training nights (*n* = 10 core players and *n* = 8 fringe players).

	Night after match	Training nights	ES (95% CI)
Core players			
Time in bed (min)	517±81	557±37	0.68 (-85-6)
Bedtime (h: min)	23:26±01:03*	22:49±00:34	0.76 (00:01-01:12)
Time of final awakening (h: min)	07:31±00:49	07:44±00:21	0.37 (-00:45-00:19)
Sleep onset latency (min)	30±31	21±9	0.45 (-7-26)
Sleep duration (min)	414±70*	463±56	0.77 (-86--12)
Sleep efficiency (%)	80.0±5.3	82.9±5.1	0.60 (-6.3-0.5)
Wake after sleep onset (min)	40±17	50±20	0.54 (-20-1)
Fringe players			
Time in bed (min)	569±41	547±39	0.55 (-9-54)
Bedtime (h: min)	23:04±00:45	23:05±00:43	0.02 (-00:30-00:28)
Time of final awakening (h: min)	08:04±00:58	07:59±00:37	0.02 (-00:31-00:42)
Sleep onset latency (min)	16±15	20±12	0.30 (-12-6)
Sleep duration (min)	467±44	458±23	0.27 (-21-39)
Sleep efficiency (%)	82.6±10.0	84.2±6.7	0.12 (-5.4-2.1)
Wake after sleep onset (min)	55±29	54±35	0.03 (-18-22)

*****Indicates $P < 0.05$ compared to training nights.