Sleep and mood of elite basketball referees during international competitions

Cullen, T., Clarke, N. D. & Vaquera, A.

DOI 10.1007/s11332-022-00977-2
ISSN 1824-7490
ESSN 1825-1234

Publisher: Springer

Sleep and mood of elite basketball referees during international competitions

Submission Type: Original Investigation

Authors: *Tom Cullen*[1], *Neil D Clarke*[1], *Alejandro Vaquera*[2,3]

[1] Centre for Sport Exercise and Life Sciences, Coventry University, Priory Street, Coventry, UK.

[2] Faculty of Sports Science, University of Leon, León, Spain.

[3] Institute of Sport & Exercise Science, University of Worcester, Henwick Grove, Worcester, UK.

Corresponding author:

Dr Tom Cullen

Centre for Sport, Exercise and Life Sciences

Coventry University

Priory Street, Coventry, UK, CV1 5FB

Email: ad0189@coventry.ac.uk

https://orcid.org/0000-0002-9058-6716

Co-author email addresses:

Neil D Clarke: ab1633@coventry.ac.uk

Alejandro Vaquera: avaqj@unileon.es

Running Head: Sleep habits in elite basketball referees

Keywords: Sleep; officials; referee; basketball; tournament

Abstract

Purpose: The current study aimed to characterise the sleep habits of elite basketball referees during international competitions. **Methods:** Sixty-five elite basketball referees (international experience: 6 ± 3 years) provided actigraph derived sleep data and daily mood scores during an international competition. Referees were also asked to provide reasons for nights of poor sleep. **Results:** Referee's actual sleep time was 6:23 ± 1:07 (h:mm), with 70% sleeping less than 7 hr. Sleep onset and offset got later as the tournament progressed, but with minimal impact on actual sleep time. Sleep onset was later following evening games than on Rest Days (50 mins, $P=0.05$) and after Day Games (64 mins, $P<0.001$), while sleep offset was not different, resulting in shorter actual sleep times following Evening Games than Rest Days (-36 mins, $P=0.027$) and Day Games (-47 mins, $P<0.001$). Subjective mood status was not affected by tournament stage or game timing. The most common factors identified by referees as leading to poor sleep were 'jet lag' and Evening Games (both 16%). **Conclusion:** These results highlight poor sleep habits of elite sporting officials during the most important international sporting events. Poor sleep was exacerbated in evening fixtures due to increased arousal and a curtailed opportunity for sleep rather than competitive anxiety as is often the case with athletes. Future studies should build upon our findings by investigating potential countermeasures to the issues we have identified.

Keywords: Sleep; officials; referee; basketball; tournament

Introduction

International sporting competitions are the pinnacle of any sport and match officials are a important component of these events, as even minor errors in refereeing decisions have the potential to impact competition outcomes. The sports science support provided to many elite sports officials is becoming increasingly professional; as with athletes, they must meet minimal standards of aerobic fitness, are provided with personalised training programmes by professional strength and conditioning coaches all of which is underpinned by a growing understanding of the demands placed upon them during matches [1], [2]. However, there is minimal research focussing on the additional stressors encountered during international competitions. In contrast, there is a wealth of research on this topic describing the stressors experienced by athletes themselves with potential issues including; travel fatigue [3], jet lag [4], fatigue from repeated exertion (training or games) [5], and impaired sleep [6]. It is currently unknown which of these issues, if any, are experienced by sporting officials during international competitions. This represents a potential fruitful area to improve our understanding of the stressors encountered by sporting officials and then subsequently direct future interventions to mitigate performance detriments as is common with athletes [7].

The structure of elite international basketball competitions requires referees to officiate multiple times over a series of days (i.e. fixture congestion) and it is possible that referees may experience accumulated fatigue or disrupted sleep in a similar fashion to players [8]. Furthermore, fixtures can take place at multiple times throughout the day and early evening, which can itself impact the performances of athletes and referees depending upon the chronotype of the individual [9]. Importantly there is a growing body of evidence showing that evening fixtures can have deleterious effects on sleep [10], [11], which appears to be primarily due to high post game arousal [12]. During the fixtures themselves, the demands placed upon officials in team sports are substantial; they must be sufficiently aerobically fit and agile to keep up with play while also making numerous complex subjective decisions in order to ensure games continue fairly and within the rules of the sport [1]. In order to do so, referees in elite basketball experience cardiovascular demands that are relatively similar to those experienced by the athletes [13]. This is important as it is well known that aerobic fitness, cognitive function and mood are negatively affected following poor sleep [14]–[16] in addition to being impacted by the circadian typology of the individual [9].

To date there is limited research that has assessed sleep or mood status of elite sports officials, and none focusing on officials during major international competitions. The aim of the current study was to characterise the sleep and mood status of elite basketball referees during major

international competitions and to identify factors which may have a negative impact. Based upon previous research on athletes it was hypothesised that the sleep of referees would be; 1) negatively affected by competition anxiety [12], and therefore be impaired as the tournament progressed and the importance of games increased, 2) be shorter following evening fixtures and 3) that poor sleep would be associated with impaired mood status and increased perceived fatigue.

Methods

Participants

The study comprised of 65 referees (47 males and 18 females; mean age 35 ± 5 years; height 180.3 ± 8.6 cm, weight 79.1 ± 10.5 kgs; BMI 24.2 ± 1.8) who volunteered to take part in the study while officiating in International Basketball Federation (FIBA) major international competitions. Referees were recruited from all 5 of the continents of which FIBA is comprised (Asia, Africa, Americas, Europe and Oceania), representing a total 55 different countries of origin.

All referees were internationally licensed officials with a mean international experience of 6 ± 3 years (range: 1 - 14 years). FIBA Referee Department prescribed a specific training regime in the 12 weeks immediately before the competitions and had to reach a minimum physical fitness standard in order to officiate. This training regime consisted of a mixture of endurance training, speed training, strength training and official games.

Prior to commencement of the study, all referees were adequately informed about the purposes of the study, completed a general health pre-screening questionnaire, and provided written informed consent. Referees were excluded from the study if they were taking any medications that could influence their sleep. All procedures were conducted in accordance with approval of the Human Ethics committee of León University that conformed with the Code of Ethics of the World Medical Association (Declaration of Helsinki, 2013).

Methodology

Referees were nominated to officiate by FIBA in the 2018 Men's U17 World Cup in Argentina (22 referees), 2018 Women's U17 World Cup in Belgium (21 referees) and the 2018 Women's Senior World Cup in Spain (22 referees). For each tournament, referees flew to the tournament destination 3 days prior to the tournament starting and data were collected from 10 consecutive days; one day of the 'pre-competition clinic' (described as Tournament day -1) and the entire

9 days of the tournament (Tournament Days 1-9). Each night participants wore a Polar M430 running watch to calculate sleep characteristics. M430 running watch (Polar Electro Oy, Kempele, Finland) which uses accelerometery to estimate a number of sleep related variables. The derived variables included sleep onset (the time participant fell asleep), sleep offset (the time that the participant woke up), total sleep time (the time between sleep onset and sleep offset), actual sleep percentage (the percentage of time in bed that was spent asleep), actual sleep time (total amount of sleep obtained, accounting for interruptions in sleep), subjective sleep quality (a 1-5 scale of how well they felt they slept, very poorly - poorly – okay - well - very well). With the exception of subjective sleep quality, which is entered manually upon wakening, all data are derived using Polar's proprietary algorithm. This device has been validated against the gold standard sleep measurement technique of polysomnography and while it was shown to have acceptable accuracy for research, the Polar algorithm does slightly underestimate total sleep time in comparison to polysomnography, but less so than other accelerometers routinely used in free livening research studies [17].

Upon awakening referees also completed a shortened modified version of the profile of mood states questionnaire in order to assess their subjective wellbeing and mood status [18]. Participants provided a score on a 1-5 scale in the following categories: tension, miserable, angry, lively, fatigue, confusion. Questionnaires of this type have been shown to be reliable and valid for assessing mood and fatigue in team sport [19]. Referees were also asked to provide a brief explanation for any reasons why they had experienced a particularly poor night's sleep. Each referee subsequently entered their sleep and mood states data into an online Google document (Google Forms, Google, CA, USA).

Statistical Analyses

Prior to analysis data were visually inspected to identify any outliers and to check the homogeneity of responses. Data met the assumptions required for the chosen statistical models. Sleep and mood data were analysed using linear mixed effects models. Tournament Day (-1 to 9) and the time of each game (Rest Day, Day Game, Evening) were coded and entered as fixed effects, while referee identities were entered as random effects. In order to identify the location of any significant effects, pairwise comparisons were conduction with a Bonferroni correction factor. To assist with assessing the practical significance of the findings, mean difference (with 95% confidence intervals) and corresponding effect sizes (Cohen's d) have been calculated. Pearson correlation was used to assess the relationship between objective sleep measures. Participants explanations for particularly poor sleep were analysed according to

content and categorised into themes. These themes were then coded and reported as a percentage of the total number times explanations were provided in order to demonstrate the frequency of each theme. All data are presented as mean ± 95% confidence interval unless otherwise stated and statistical significance was set at $p<0.05$. Statistical analysis was performed using SPSS version 25 (IBM Corp. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.)

Results

Sleep and mood throughout the tournament

A total of 524 cases were analysed from a potential total of 585 cases (65 referees, measurements taken on 9 occasions) representing 10.5% missing data due to non-compliance from participants or equipment malfunctioning. On average referee's actual sleep time was 6:23 ± 01:07 (h:mm), falling asleep at 00:46 ± 01:43 (hh:mm), and waking up at 07:37 ± 01:16 (hh:mm). When accounting for all nights slept throughout the entire tournament, 70% slept less than the minimum recommended sleep duration of at least 7 hr [20]. Actual sleep percentage was 93 ± 0.3 %, while subjective sleep quality was and 3.6 ± 0.8 (AU). Sleep and mood variables for each day of the tournament and one day of the pre-tournament preparation phase are presented in Figure 1 and Table 1 respectively. Sleep time, actual sleep time, sleep onset and sleep offset were affected by tournament day, but there were no further effects on sleep or mood variables. Sleep time and actual sleep time showed an identical pattern throughout subsequent analysis, and therefore for ease of comprehension, only actual sleep time will be described in more detail below.

Insert Figure 1 Here

Insert Table 1 Here

Actual sleep time was significantly longer on day 6 of the tournament compared to days 5 (P= 0.003, mean difference= 54 mins, 95% CI= 10 to 100 mins, ES=0.79), day 8 (P= 0.006, mean difference= 53 mins, 95% CI= 7 to 97 mins, ES=0.75) and day 9 (P= 0.045, mean difference= 46 mins, 95% CI= 0 to 92 mins, ES=0.67). Sleep onset time was significantly earlier on day -1 than day 3 (P= 0.013 mean difference= -96 mins, 95% CI= -9 to -182 mins, ES=1.31), day 5 (P= 0.038, mean difference= -86 mins, 95% CI= -1 to -171 mins, ES=0.66), day 7 (P<0.001,

mean difference= -86 mins, 95% CI= -23 to -142 mins, ES=0.56), day 8 (P= 0.0026, mean difference= -82 mins, 95% CI= -4 to -160 mins, ES=0.81) and day 9 (P<0.001, mean difference= -119 mins, 95% CI= -42 to -197 mins, ES=1.25). Sleep onset on day 1 was also earlier than on day 9 (P=0.008, mean difference= -76 mins, 95% CI= -9 to -141 mins, ES=0.88). Subjective sleep quality was significantly lower on day 2 than on day 4 (P=0.012, mean difference= -0.7, 95% CI= -0.1 to – 1.3 mins, ES=0.91) and day 6 (P=0.019, mean difference= -0.6, 95% CI= -0.1 to -1.1 mins, ES=0.71).

Sleep offset was significantly later on day 3 than day -1 (P= 0.001, mean difference= 87 mins, 95% CI= 21 to 153 mins, ES=1.78), day 1 (P= 0.003, mean difference= 64 mins, 95% CI= 11 to 117 mins, ES=1.31) and day 2 (P= 0.013 mean difference= 50 mins, 95% CI= 5 to 97 mins, ES=1.05). Sleep offset was significantly later on day 6 than on day -1 (P< 0.001, mean difference= 96 mins, 95% CI= 27 to 166 mins, ES=1.95), day 1 (P= 0.001, mean difference= 73 mins, 95% CI= 17 to 130 mins, ES=1.48), day 2 (P= 0.005, mean difference= 60 mins, 95% CI= 9 to 91 mins, ES=1.22) and day 5 (P= 0.025 mean difference= 54 mins, 95% CI= 3 to 105 mins, ES=1.08). Sleep offset was also significantly later on day 9 than on day -1 (P<0.001, mean difference= 82 mins, 95% CI= 22 to 143 mins, ES=1.69) and day 1 (P= 0.002, mean difference= 60 mins, 95% CI= 11 to 108 mins, ES=1.22).

The Influence of Match Timing

Sleep and mood variables were categorised and calculated according to whether referees officiated on games and they did not officiate on a game that day (Rest Day) officiated on a game that took place during the day (11:00-18:00) and when officiating on a game that took place during the evening (20:00 start time). The corresponding sleep and mood variables for each time of match are summarised in table 2. When referees were not officiating that day, 49% achieved less than the minimum recommended sleep duration of at least 7 hr [20]. This number was similar following officiating a Day Game (52%) but substantially higher following Evening Games (86%).

Sleep onset was significantly later following an Evening Game than Rest Days (P= 0.05, mean difference= 50 mins, 95% CI= 1 to 101 mins, ES=0.85) and Day Games (P< 0.001, mean difference= 64 mins, 95% CI= 30 to 100 mins, ES=0.89). Time in bed was significantly shorter following Evening games than on Rest Days (P= 0.043, mean difference= -42 mins, 95% CI= -1 to -81 mins, ES=0.6) and Day Games (P< 0.001, mean difference= -58 mins, 95% CI= -30 to -84 mins, ES=0.86). Actual sleep time was similarly affected, with actual sleep time being significantly less following Evening Games than Rest Days (P= 0.027, mean difference= -36

mins, 95% CI= -3 to -70 mins, ES=0.74) and Day Games (P< 0.001, mean difference= -47 mins, 95% CI= -24 to -70 mins, ES=0.75). In contrast, subjective sleep quality was higher following Day Games than Rest Days (P= 0.008, mean difference= 0.38, 95% CI= 0.08 to 0.69, ES=0.51) and Evening Games (P=0.02, mean difference= 0.3, 95% CI= 0.03 to 0.56 mins, ES=0.38). No effects were detected for sleep offset and actual sleep percentage.

Insert Table 2 & 3 Here

Reasons for poor Sleep

Referees provided a brief explanation of why they slept poorly, these responses were categorised according to themes and have been displayed as a percentage of the total number (Table 5). The most common reasons for instances of particularly poor sleep were 'waking up too early' (16.4%), 'jet lag' (14.9 %) and having refereed in a 'Late Game' earlier described as an Evening Game (14.9%). All responses identifying jet lag as the reason for poor sleep occurred in the first half of the tournament, with 70% occurring on the first day (day -1). In contrast, there was no clear pattern to the timing of any other response themes.

Insert Table 4 Here

Discussion

This is the first study to report sleep habits of elite sports officials during international competitions. Throughout the entire tournament 70% of referees did not achieve the minimum recommended sleep duration of at least 7 hr [20]. As the tournament progressed referees went to bed later, but this was accompanied by waking up later, resulting in minimal change in total sleep time. Over the course of 3 international tournaments, the sleep of elite basketball referees was significantly shorter after officiating in evening games, which referees themselves identified as one of the most common reasons for why they had slept poorly. These findings highlight deficiencies in the sleep habits of elite sports officials during the most important international competitions and suggest that the underpinning reasons for this appear to be due to tournament organisation which curtailed the opportunity for sleep and increased arousal at bed time.

Our findings are in accordance with previous research on athletes which shows that evening fixtures result in significantly impaired sleep duration when compared to Rest Days and

fixtures taking place during the day [10]. Subjective sleep quality was also reduced following evening fixtures compared to daytime fixtures, while total sleep percentage was not impacted. As such, measures of sleep quality appear inconsistently impacted in this study and it is possible that the lowered perception of sleep quality was simply due to shortened duration rather than disrupted sleep per se. When comparing the size of these observed effects to those seen in athletes, the size of the effect appears much smaller; Sargent & Roach reported that athletes achieved 2.5 hrs less sleep per night following an evening game than a day game, while in the current study referees slept approximately 1 hr less. This reduced sleep time was manifested by a later sleep onset (50 min Vs Rest Day, 64 mins Vs Day Game), while sleep offset remained similar, suggesting that a later bedtime was not fully accounted for by simply sleeping in for longer which is the same pattern to that observed in athletes [10]. Potential explanations for this are that athletes experience relatively higher physical exertion than referees and vigorous physical activity prior to bedtime has been shown to increase bedtime heart rate, reduce bedtime heart rate variability and ultimately delay sleep onset [21]. Further, athletes experience significant post-match competitive arousal, which has been shown to be a major factor contributing to poor sleep following evening fixtures [12]. Yet, when asked to provide reasons for their poor sleep, referees reported a number of themes potentially aligned to post-game arousal (e.g. ‘nerves’, ‘struggled to fall asleep’, thinking about performance’) (Table 5). Suggesting that post game arousal could indeed have been a factor within the shorter sleep following evening fixtures, albeit likely less so than it is for athletes given the smaller magnitude of effect.

Contrary to our secondary hypothesis, psychological mood states were not altered as the tournament progressed and were not different following evening fixtures where sleep was shorter. Typically, impaired mood status and wellbeing are among the most commonly reported negative effects of poor sleep [14], [22], however there was no evidence of this in the referees following evening games. Unfortunately, it is not possible to say what other negative effects, if any, the referees may have been exposed to. While research on sporting officials is sparse, there is evidence that poor sleep can impair decision making, especially in circumstances where decisions involve complex scenarios, distractions and communication with other officials and players [23]. However, previous studies have shown that daytime napping can improve reaction time and cognitive function in the absence of changes in mood and wellbeing following poor sleep [24] and this should be encouraged in referees experiencing shortened or poor quality sleep. Napping was not assessed as part of the current study due to the fact that napping is not common practice in this cohort of officials due to the busy daily schedule during competitions.

However, it should be considered in future studies, especially if schedules are adjusted to allow regular naps for those who have slept poorly.

The inclusion of the referee's own explanations for their 'reasons for poor sleep' is novel and provides insights into the complexities of sleep disruption during competition and provides targets for potential interventions. Jet lag was acutely evident early in the tournament with 70% of responses identifying jet lag as the primary reason for poor sleep occurring on the first day (3 days after flying). This also corresponded with referees going to bed earlier in the first 2 days (Fig 1), which would correspond to 3- and 4-days post travel. It is highly likely sleep would have been more significantly impacted on days 1 and 2 post travel, had these been measured. There are multiple countermeasures to the effects of jet lag [7], but in this case simply travelling earlier to the competition time zone and extending the 'pre-competition clinic' by one or two days may be a simple solution. In the context of evening games, it may be possible to change the morning routines in order to allow for a later wake up time as this was not altered despite a later bedtime. This scenario may be particularly important in instances where a referee is required to officiate an evening fixture followed by a morning fixture the next day (starting at 11:00). Given that factors relating to arousal were highlighted by referees, some countermeasures to this may focus on sleep education and sleep hygiene to facilitate a more rapid transition to sleep post evening fixtures. Alternatively daytime napping represents an effective method of mitigating the negative impact of lost sleep following evening fixtures [24].

It should be acknowledged that this study is not without limitations. Firstly, the study would have been improved by obtaining measures of general sleep health and 'normal' sleep data and the circadian typology from referees prior to travel to the tournaments in order to establish baseline sleep measurements. Unfortunately, this was not logistically possible as referees are based in 55 different countries across the world and were only provided the necessary equipment once they had attended the 'pre-competition clinic'. Future studies should endeavour to include this information to provide a detailed comparison to their normal sleep pattern. Further limitations are that data were not collected on sleep latency which could have provided more detailed information about any potential sleep disruption. It is also important to note that the device used to measure sleep related behaviours in the current study does provide a slight underestimation of total sleep time (albeit with a greater accuracy than other accelerometery devices used in free living sleep research) [17]. The sleep duration data presented in this study should be considered with this in mind, however, it should not impact the changes in sleep behaviour measured throughout the tournament or when comparing

between different fixtures timings. Future studies should also characterise the chronotype of each individual, in order to assess if there are differing responses in people with a specific circadian typology.

Conclusions

This is the first study to report sleep habits of elite sports officials during international competitions. On average referees slept for 6:23 (h:mm), with 70% sleeping less than the recommended minimum 7 hrs. Sleep was significantly poorer following evening fixtures than after day games or Rest Days. Taken together these findings highlight the poor sleep habits of elite sporting officials during the most important international sporting events. Further to this, referees identified the most common factors leading to poor sleep as 'jet lag' in the first few days of the tournament and refereeing fixtures which took place in the evening. As such, these instances of poorer sleep appear primarily driven by organisational factors, combined with post game arousal.

Practical Applications

Both referees and support staff should be aware of the potential poor sleep habits of referees during international competitions as this could impair their decision making. Key issues appear to be jet lag earlier in the tournament and shorter total sleep duration when officiating evening fixtures. Where possible, support staff should be encouraged to make affordances for these issues by appropriately planning their pre-competition schedules to minimise the impact of jet lag, in this case 2-3 days earlier travel prior to tournament commencement would appear sufficient. During the tournament, daily routines should be adapted to allow referees to sleep longer following evening fixtures or to allow sufficient time to catch up on lost sleep with naps during the day.

Acknowledgements

The authors would like to thank the referees who took part and the support staff from FIBA who approved and facilitated the study. No financial support was provided for the study and there are no conflicts of interest.

References

[1] M. Weston, C. Castagna, F. M. Impellizzeri, M. Bizzini, A. M. Williams, and W. Gregson, “Science and medicine applied to soccer refereeing: An update,” *Sports Medicine*, vol. 42, no. 7. pp. 615–631, 01-Jul-2012.

[2] M. A. Nabli, N. Ben Abdelkrim, M. S. Fessi, M. D. DeLang, W. Moalla, and K. Chamari, “Sport science applied to basketball refereeing: a narrative review,” *Physician and Sportsmedicine*, vol. 47, no. 4. Taylor and Francis Ltd., pp. 365–374, 02-Oct-2019.

[3] H. R. Thornton, J. Miller, L. Taylor, C. Sargent, M. Lastella, and P. M. Fowler, “Impact of short- compared to long-haul international travel on the sleep and wellbeing of national wheelchair basketball athletes,” *J. Sports Sci.*, vol. 36, no. 13, pp. 1476–1484, Jul. 2018.

[4] A. Lee and J. C. Galvez, “Jet Lag in Athletes,” *Sports Health*, vol. 4, no. 3. pp. 211–216, May-2012.

[5] M. Lastella, G. D. Roach, G. E. Vincent, A. T. Scanlan, S. L. Halson, and C. Sargent, “The impact of training load on sleep during a 14-day training camp in elite, adolescent, female basketball players,” *Int. J. Sports Physiol. Perform.*, vol. 15, no. 5, pp. 724–730, Feb. 2020.

[6] L. E. Juliff, S. L. Halson, and J. J. Peiffer, “Understanding sleep disturbance in athletes prior to important competitions.,” *J. Sci. Med. Sport*, vol. 18, no. 1, pp. 13–8, Jan. 2015.

[7] T. Reilly, G. Atkinson, and J. Waterhouse, “Travel fatigue and jet-lag,” *Journal of Sports Sciences*, vol. 15, no. 3. pp. 365–369, Jun-1997.

[8] F. M. Clemente *et al.*, “Perceived Training Load, Muscle Soreness, Stress, Fatigue, and Sleep Quality in Professional Basketball: A Full Season Study,” *J. Hum. Kinet.*, vol. 67, no. 1, pp. 199–207, 2019.

[9] A. Montaruli *et al.*, “The circadian typology: the role of physical activity and melatonin,” *Sport Sci. Heal. 2017 133*, vol. 13, no. 3, pp. 469–476, Aug. 2017.

[10] C. Sargent and G. D. Roach, “Sleep duration is reduced in elite athletes following night-time competition,” *Chronobiol. Int.*, vol. 33, no. 6, pp. 667–670, Jul. 2016.

[11] H. H. K. Fullagar, S. Skorski, R. Duffield, R. Julian, J. Bartlett, and T. Meyer, “Impaired sleep and recovery after night matches in elite football players,” *J. Sports Sci.*, vol. 34, no. 14, SI, pp. 1333–1339, 2016.

[12] L. E. Juliff, J. J. Peiffer, and S. L. Halson, “Night games and sleep: Physiological, neuroendocrine, and psychometric mechanisms,” *Int. J. Sports Physiol. Perform.*, vol.

13, no. 7, pp. 867–873, Aug. 2018.
[13] A. Vaquera, J. Mielgo-Ayuso, J. Calleja-González, and A. S. Leicht, “Sex differences in cardiovascular demands of refereeing during international basketball competition.,” *Phys. Sportsmed.*, vol. 44, no. 2, pp. 164–9, Apr. 2016.
[14] T. Cullen, G. Thomas, and A. J. Wadley, “Sleep Deprivation: Cytokine and Neuroendocrine Effects on Perception of Effort,” *Med. Sci. Sports Exerc.*, vol. 52, no. 4, pp. 909–918, Nov. 2020.
[15] T. Cullen, G. Thomas, A. J. Wadley, and T. Myers, “The effects of a single night of complete and partial sleep deprivation on physical and cognitive performance: A Bayesian analysis.,” *J. Sports Sci.*, vol. 37, no. 23, pp. 2726–2734, Dec. 2019.
[16] H. H. K. Fullagar, S. Skorski, R. Duffield, D. Hammes, A. J. Coutts, and T. Meyer, “Sleep and Athletic Performance: The Effects of Sleep Loss on Exercise Performance, and Physiological and Cognitive Responses to Exercise,” *Sport. Med.*, vol. 45, no. 2, pp. 161–186, Feb. 2015.
[17] A.-K. Pesonen and L. Kuula, “The Validity of a New Consumer-Targeted Wrist Device in Sleep Measurement: An Overnight Comparison Against Polysomnography in Children and Adolescents.,” *J. Clin. Sleep Med.*, vol. 14, no. 4, pp. 585–591, 2018.
[18] S. L. Curran, M. A. Andrykowski, and J. L. Studts, “Short Form of the Profile of Mood States (POMS-SF): Psychometric information.,” *Psychol. Assess.*, vol. 7, no. 1, pp. 80–83, 1995.
[19] B. D. McLean, A. J. Coutts, V. Kelly, M. R. McGuigan, and S. J. Cormack, “Neuromuscular, endocrine, and perceptual fatigue responses during different length between-match microcycles in professional rugby league players,” *Int. J. Sports Physiol. Perform.*, vol. 5, no. 3, pp. 367–383, 2010.
[20] N. F. Watson *et al.*, “Joint Consensus Statement of the American Academy of Sleep Medicine and Sleep Research Society,” *Sleep*, vol. 38, no. 8, pp. 1161–1183, 2015.
[21] S. Oda and K. Shirakawa, “Sleep onset is disrupted following pre-sleep exercise that causes large physiological excitement at bedtime,” *Eur. J. Appl. Physiol.*, vol. 114, no. 9, pp. 1789–1799, Sep. 2014.
[22] J. J. Pilcher and A. I. Huffcutt, “Effects of sleep deprivation on performance: a meta-analysis.,” *Sleep*, vol. 19, no. 4, pp. 318–26, May 1996.
[23] Y. Harrison and J. A. Horne, “The impact of sleep deprivation on decision making: A review.,” *J. Exp. Psychol. Appl.*, vol. 6, no. 3, pp. 236–249, 2000.
[24] H. Daaloul, N. Souissi, and D. Davenne, “Effects of Napping on Alertness, Cognitive,

and Physical Outcomes of Karate Athletes," *Med. Sci. Sports Exerc.*, vol. 51, no. 2, pp. 338–345, Feb. 2019.

Tables

Table 1. Mood throughout the tournament. Day -1 corresponds to the pre-tournament clinic, while days 1-9 are from the tournament itself.

	Day of Tournament									
	-1	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Tense	0.5 ± 0.7	0.5 ± 0.8	0.5 ± 0.8	0.3 ± 0:7	0.3 ± 0.5	0.3 ± 0.8	0.3 ± 0.6	0.3 ± 0.8	0.3 ± 0.6	0.3 ± 0.4
Miserable	0.3 ± 0.4	0.1 ± 0.5	0.3 ± 0.7	0.1 ± 0.4	0.2 ± 0.5	0.3 ± 0.7	0.2 ± 0.4	0.2 ± 0.6	0.3 ± 0.7	0.1 ± 0.4
Angry	0.0 ± 0.4	0.1 ± 0.5	0.1 ± 0.4	0.1 ± 0.4	0.1 ± 0.5	0.1 ± 0.3	0.2 ± 0.6	0.2 ± 0.7	0.2 ± 0.7	0.1 ± 0.5
Lively	2.3 ± 1.3	2.2 ± 1.4	2.0 ± 1.3	2.2 ± 1.3	2.1 ± 1.2	2.0 ± 1.3	2.1 ± 1.3	2.0 ± 1.3	2.0 ± 1.3	2.3 ± 1.3
Fatigued	0.8 ± 0.8	0.5 ± 0.7	0.7 ± 1.0	0.5 ± 0.8	0.6 ± 0.9	0.6 ± 0.9	0.4 ± 0.7	0.5 ± 0.8	0.4 ± 0.7	0.4 ± 0.7
Confused	0.3 ± 0.7	0.2 ± 0.5	0.2 ± 0.5	0.2 ± 0.4	0.3 ± 0.7	0.1 ± 0.3	0.2 ± 0.6	0.2 ± 0.6	0.3 ± 0.6	0.1 ± 0.3

Table 2. Sleep parameters when measured the night following not officiating (Rest Day), officiating on a game that took place during the day (11:00-18:00 start time) and when officiating a game that took place in the evening (20:00 start time).

	Rest Day	**Day Game**	**Evening Game**
Sleep Onset (hh:mm)	00:33 ± 1:55	00:42 ± 1:35	01:49 ± 0:45**
Sleep Offset (hh:mm)	07:20 ± 0:55	07:47 ± 1:32	07:52 ± 1:02
Sleep Time (h:mm)	6:45 ± 1:22	06:59 ± 1:16	6:02 ± 0:58**
Actual Sleep Time (h:mm)	6:24 ± 0:58	6:30 ± 1:13	5:42 ± 0:54**
Actual Sleep Percentage	93 ± 7 %	93 ± 8 %	94 ± 3 %
Subjective Sleep Quality (AU)	3.6 ± 0.7	3.8 ± 0.8**	3.4 ± 0.9

*= Significantly different to Day Game (P<0.05)
**= Significantly different to Rest Day & Day Game (P<0.05)

Table 3. Mood the morning after not officiating on the previous day (Rest Day), officiating a game that took place during the day (11:00-18:00 start time) and when officiating a game that took place in the evening (20:00 start time).

	Rest Day	Day Game	Evening Game
Tense	0.4 ± 0.7	0.4 ± 0.7	0.5 ± 0.9
Miserable	0.2 ± 0.5	0.1 ± 0.4	0.2 ± 0.6
Angry	0.1 ± 0.5	0.0 ± 0.2	0.0 ± 0.1
Lively	2.0 ± 1.3	1.6 ± 0.7	2.0 ± 1.3
Fatigued	0.6 ± 0.8	0.4 ± 0.8	0.6 ± 0.8
Confused	0.2 ± 0.6	0.2 ± 0.5	0.1 ± 0.4

Table 4. The frequency of referee's explanations for instances of poor sleep.

	Absolute	%
Environment	5	7.5
Fatigued	3	4.5
Hungry	1	1.5
Illness	3	4.5
Jet Lag	10	14.9
Late Game	10	14.9
Nerves	7	10.4
Other	4	6
Struggled to get to sleep	10	14.9
Thinking about performance	3	4.5
Woke up too early	11	16.4

Figures

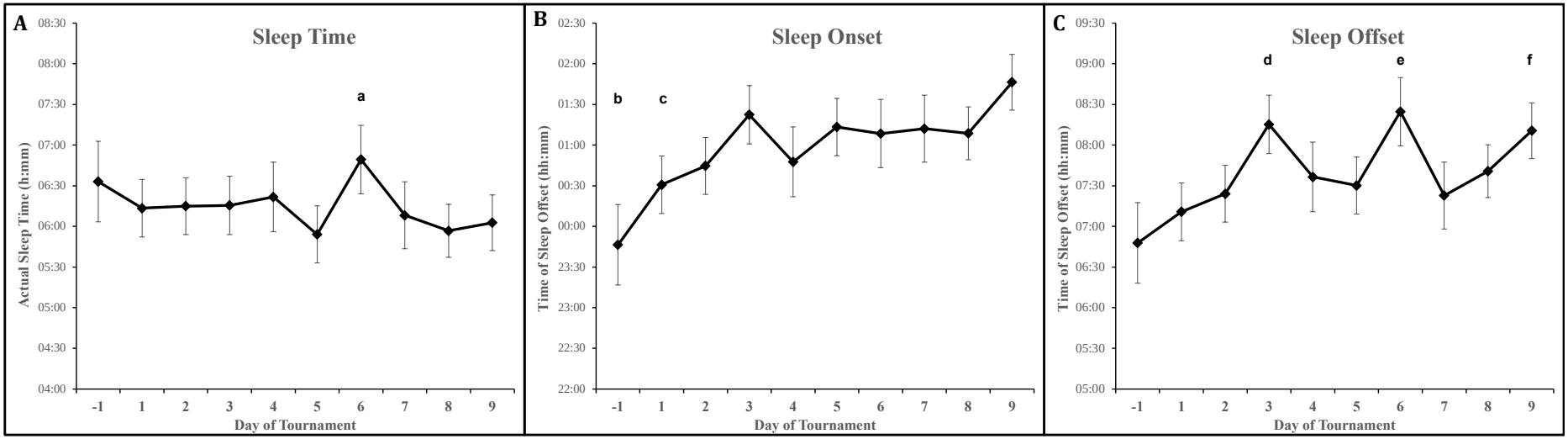

Figure 1. Actual Sleep Time (**A**), Sleep Onset (**B**) and Sleep Offset (**C**) throughout the tournament. Error bars represent 95% confidence intervals.
a= Significantly different to days 5, 8 and 9.
b= Significantly different to days 3, 5, 8 and 9.
c= Significantly different to day 9.
d= Significantly different to days -1, 1 and 2.
e= Significantly different to days -1, 1 and 5.
f= Significantly different to days -1 and 1.