Effect of training/competition load and scheduling on sleep characteristics in professional rugby league athletes

Title: Effect of training/competition load and scheduling on sleep characteristics in professional rugby league athletes

Abstract

This study examined the effect of training/competition load, scheduling and associated factors on sleep behaviour in professional rugby league athletes.

Sleep characteristics were assessed in 26 professional rugby league athletesusing wrist-mounted actigraphy and nightly sleep diaries. Sleep actigraphy assessed the time into and out of bed, the duration in bed, sleep duration, efficiency, latency, wake after sleep onset (WASO), number of awakenings and the awakening length. Sleep was measured during three different weeks; i) pre-season low training load (TL) (2356 ± 322 AU), ii) pre-season high TL (3542 ± 445 AU) and iii) in-season match week (1526 ± 409 AU). The influences of internal TL [session rating of perceived exertion (sRPE) load], training schedule, age and training location on sleep behaviour were analysed. Repeated-measures two-way ANOVAs and Effect Size analyses (d) compared sleep variables between training weeks.

Mean weekly sleep duration was significantly lower during high TL week (5 h 53 min ± 14 min/night; p=0.015, d=0.59) compared to the low TL (6 h 25 min ± 8 min/night) or match weeks (6 h 26 min ± 10 min/night; p=0.02, d=2.04). Reduced sleep duration in the high TL week occurred alongside earlier out-of-bed times compared to the low TL (p=0.003, d=1.46) and match weeks (p=0.001, d=5.99). Regardless, the lowest sleep duration was on match night (p=0.0001, d=1.22). Earlier training start times resulted in earlier wake times (p=0.003, d=4.84), shorter in-bed durations (p=0.0001, d=0.62), and shorter sleep durations (p=0.002, d=0.32). Younger athletes slept for longer durations (p=0.029, d=1.70) and perceived their sleep quality to be superior (p=0.006, d=14.94) compared to older athletes.

Sleep attained by rugby league athletes is influenced by training and competition schedules, with early training start times and late-night matches being primary drivers of sleep behaviour. Coaching staff should have awareness surrounding the implications of training and playing schedules on athlete sleeping patterns.

Keywords: training load, sleep disruption, recovery

INTRODUCTION

Sleep is considered essential for health, athletic performance and recovery due to its physiological and psychological restorative effects (32,8). In elite rugby league, it is paramount to balance the physically demanding stress of training and competition with appropriate timing, volume and quality of recovery (1). Sleep is integral to this process and is suggested to be one of the more effective and accessible recovery strategies, particularly during periods of high training loads (TL) (9). Research in athletic populations has shown that training volume (15), training schedules (30) and competition itself (20,28) can reduce an athlete's sleep quantity or quality (32). In turn, disturbances to the duration, quality, or timing of sleep may negatively affect recovery, ensuing preparation and ultimately the stress-recovery balance (8). Thus, the resultant effects of TL and scheduling on sleep characteristics are important to understand in planning for optimal performance outcomes.

Excessive exercise loads may disturb the stress-recovery balance, which could lead to performance decrements and injury (17,8). Reductions in sleep may affect cognitive performance and mood (2), metabolism (35), immune function (35), and power/strength (34), highlighting the importance of sleep for athletic performance (10). Previous studies have reported reduced sleep quantity (37,5) and quality (17,8,11) during periods of high physical load. For example, in swimmers higher training volumes are associated with poorer sleep quality due to a greater number of sleep disruptions (37). In ballet dancers, periods of high physical and mental stress (e.g. long days of training and rehearsal) are associated with significant reductions in sleep duration, sleep efficiency, time in bed, and an increase in wakefulness after sleep onset (5,37). These findings are also evident in other sports, with a reduction in total sleep time and sleep efficiency evident during periods of high TL in cyclists, swimmers and rugby league athletes (20,31,39,18). Research into Australian Rules Football demonstrates reductions in sleep duration when sRPE load increased (27). More specific to rugby league, sleep duration was negatively correlated with an increase in total distance

(38); whilst acceleration load was associated with small increases in sleep duration and efficiency (38). Whilst these relationships showed small associations, contributors to the disturbed sleep might be from exercise-induced muscle damage, increased perceptual fatigue or perceived soreness (26).Although high TL may negatively affect sleep, there is limited information on how variations in TL affects sleep behaviour in team-sport athletes, particularly rugby league athletes.

An important aspect of obtaining sufficient sleep is the time into and out of bed, which determines the actual time available to sleep. These factors are behavioural in nature and often influenced by training and competition schedules in athletes (30,33). At the elite level of rugby league, pre-season training start times are typically earlier to allow for more TL to be completed throughout the day. During the competition phase, reduced load during inseason exists, and athletes are required at training later to allow for an increase in recovery.Consequently, training schedule may affect sleep patterns, and studies in swimmers have shown that the sleep-wake behaviour is directly affected by the time of day required to train (30). Further, sleep disturbances are also reported in elite rugby union (3) and soccer athletes (7) following scheduling of late night competition (8). In a study of 284 elite individual and team sport athletes, 184 self-reported sleep disturbances following a late-night training session or match (14). As sleep has important implications for recovery, and therefore athlete preparation, further understanding of how factors such as TL and/or scheduling can affect sleep behaviour in professional rugby league athletes is needed.

Although previous research has shown training volumes and scheduling can influence sleep in athletic populations (30,5), other contextual factors may also affect sleep behaviour. For example, research in the general population suggests that younger people (20-34 years old) sleep longer than older adults (>35 years old) (12). Changes in sleep location may also affect sleep, with 28% of German athletes reporting sleep disruption in unusual surroundings (4). Given many professional sporting clubs are located in large metropolitan cities, traveling distance/time to training may also impact sleeping behaviours.

Despite the importance of sleep and the aforementioned challenges often faced by elite athletes, little information exists describing how rugby league athletes' sleep behaviour changes with differing physical loads and schedules. Therefore, the primary aim of the present study was to describe sleeping patterns in elite rugby league athletesduring periods of differing physical load. As a secondary aim, this study explored the effect of training schedule, age and location on these sleep patterns.

METHODS

Experimental Approach to the Problem

This descriptive study examined sleep characteristics of professional rugby league athletesduring three different weeks of training; low TL, high TL, and a match week. Data were collected from each athlete from Monday to Thursday throughout the low and high TL weeks, and during the four days leading into the match on match week. Data from the low and high TL weeks were collected during the pre-season period (i.e. no matches during this period), whilst match week was during the early in-season phase (i.e. competition week 14). Training schedules were determined by team coaching and physical performance staff (Table 1). During pre-season (i.e. low and high TL weeks) training start times was scheduled earlier (before 8:00 am) than in-season (after 8:00am) to increase the available training time. Matches were always in the afternoon or evening as scheduled by the respective external football organisations (National Rugby League and New South Wales Rugby League). Within the final cohort, sixteen athletes were involved in an NRL night match, with the remaining ten being involved in a New South Wales Rugby League match, which was performed in the late afternoon. The day after games, all players were required to report to the club at 10:00am to complete 'recovery' activities. Athletes were instructed to maintain usual daily routines behaviours throughout the data collection period, including consumption of nutritional supplements, caffeine and alcohol.

Subjects

Following a full description of procedures and risks, thirty-seven professional rugby league athletes volunteered to take part in the study and provided written informed consent. After the commencement of the study, eleven athletes withdrew from the study, all citing discomfort with wrist-worn accelerometery during sleeping. The final cohort included twenty-six male professional rugby league athletes (age 24.8 ±3.6 y; body mass 97.5 ±7.9 kg; playing experience 68 ± 78 NRL matches) who were part of the same training squad during preseason (n=16 first grade, n=10 second grade) representing one NRL club. Although athletes were not explicitly screened for sleep disorders prior to the commencement of the study, no athletes had reported sleep concerns during club medical examinations or were clinically diagnosed with a sleep disorder. The study was approved by the Australian Catholic University Human Research Ethics Committee (2015-286E).

Actigraphy and Sleep Diary

During the three different training weeks, all athletes resided in their own homes, with no out-of-city travel included in the study. Sleep patterns were monitored using actigraphy (ActiGraph wGT3X-BT, Actigraph, FL, USA) worn on the non-dominant wrist (as determined by the player) and continuously recorded accelerations representing body movement (stored in 30 s epochs). Actigraphy data were downloaded via relevant software and sleep information was generated using the manufacturer's algorithms (ActiLife Data Analysis Platform, Actigraph, USA). To make comparisons between all weeks, data was used from day 1 to day 4 (i.e. Monday to Thursday during low and high TL weeks). During match week, the match day was categorised as day 4, as match weeks did not follow a Monday-Friday schedule. The following variables were derived from actigraphy; Time in Bed (hh:mm), Time out of Bed (hh:mm), Duration in Bed (min), Sleep Duration (min), Efficiency [sleep duration/time spent in bed (%)], Latency (min), Wake After Sleep Onset (waso; min), Number of Awakenings, and Awakening Length (min) (10).

Sleep diaries were used in conjunction with actigraphy to establish in- and out-of-bed times (10). Sleep quality score was also rated based on a subjective 0-5 point scale, in 0.5 point increments, with anchors of 1 = insomnia, 2 = restless sleep, 3 = difficulty falling asleep, 4 = good, and 5 = very restful (23). Time in bed information was recorded when athletes got into bed, with time out of bed being recorded upon wakening.

Training Load

Session rating of perceived exertion [sRPE = session duration (min) x rating of perceived exertion] was used to quantify training and match load (6) for all exercise modalities (i.e. match, strength, skills, speed and conditioning) for each week using the CR-10 scale (6). RPE's were collected within 15min following the completion of a training session/match.

Factors affecting sleep behaviour

To further explore factors that may affect sleeping patterns in professional rugby league athletes, participants were classified based on demographic and training characteristics. A median split technique was used for the following descriptive data: Distance from training (< 20 km or > 20 km), Travel time to training (< 30 min or > 30 min), Age (< 24 or > 24 years old), and Training Start Time (before 8:00am or after 8:00 am).

Statistical Analyses

All data are presented as mean ± standard deviation (SD). Sleep data were reported in two ways; 1) collated as within-player weekly means, and 2) daily sleep responses within the respective weeks. A one-way ANOVA was used to assess the difference in sleep variables and TL's between low TL, high TL and match weeks. Further, a one-way ANOVA was used to compare between classification groupings for factors affecting sleeping behaviour. A repeated-measures two-way ANOVA (condition x time) was used to assess day to day variance of all sleep variables within each week. Where significant differences were found, a post hoc analysis was conducted using Tukey and Bonferroni. Significance was set at $p \leq 0.05$. All analyses were conducted using Statistical Package for Social Sciences (SPSS, v17.0, Chicago, IL, USA). Effect sizes (Cohen's d) with 95% confidence intervals were calculated and interpreted as trivial: >0.2, small: 0.2-0.59, moderate: 0.6-1.19, large: 1.2-1.99, and very large: ≥2 (40).

RESULTS

Training and competition load

Higher total weekly TLs were evident during the high TL week when compared to both the low TL (p=0.0001, d=2.64) and match weeks (p=0.0001, d=1.03), likely due to one extra training session being performed. TL during the match week was lowest compared to both high and low weeks (p=0.0001; Table 1).

Weekly sleep responses

All weekly sleep parameters and TL data are presented in Table 2. Athletes had later in-bed times during the match week when compared to both low (p=0.0001, d=0.24) and high TL weeks (, p=0.0001, d=0.05). Similarly, out of bed time was later during the match week compared to the low (p=0.0001, d=6.28) and high TL weeks (, p=0.0001, d=5.99). Athletes spent greater durations in bed during the match week when compared to the high TL week (p=0.013, d=2.10). Additionally, out of bed time was earlier (p=0.003, d=1.46) and sleep time was reduced (p=0.015, d=0.59) during the high TL week compared to low TL week. There were no significant differences (p>0.05) in any of the remaining actigraphy-based (i.e duration, efficiency, latency, WASO, number of awakenings and awakening length) or perceived sleep quality measures between the respective weeks.

Daily sleep responses

Daily sleep parameters for each week are shown in Figures 1 and 2. In-bed time was significantly later during each night of the match week, when compared to the low (d=0.01-0.32) and high TL weeks (p=0.0001, d=0.08-0.43). In addition, match night in-bed time was later compared to other match week nights (d=0.39-0.71). Out of bed time was earlier during the high TL week, when compared to the low TL (p=0.001, d=1.46) and match week (p=0.0001, d=5.99). On all nights, the time spent in bed during the low TL week was longer compared to the high TL week (p=0.015, d=0.28-1.73). Total sleep duration was longer during the low TL week compared to the high TL week (p=0.015, d=0.16-1.54). Duration in bed was longer during the match week when compared to the high TL week (p=0.013, d=1.48-2.29). On night 2, athletes slept for longer durations in a match week when compared to the high TL weeks (p=0.001, d=2.22). In contrast, on night 4 athletes slept less in match week (i.e. match night) when compared to night 4 during the low TL week (p=0.0001, d=1.22).

On match night (i.e. night 4), athletes had lower sleep efficiency compared to night 4 in both the low (p=0.05, d=1.12) and high TL weeks (p=0.002, d=1.18). There were no differences between weeks for latency (p=0.204) or WASO (p=0.088) for days 1-4. On match night (i.e. night 4), the number of awakenings was lower (p=0.022), but these awakenings were longer in duration (p=0.003, d=5.44), compared to night 4 of the high TL week. Perceptual sleep score was reduced on match night (i.e. night 4) when compared to night 4 on a low TL week (p=0.002, d=11.60). No other differences existed between weeks for measures related to sleep quality (i.e. efficiency, latency, WASO, number of awakenings and awakening length) (p>0.05).

Factors affecting sleep behaviour

Sleep parameters for each classification are presented in Table 3. When athletes were required to arrive at training prior to 8:00am, time out-of-bed was earlier than on training days after 8:00am (p=0.0001, d=4.84). On these days (i.e. training starts prior to 8:00am) athletes spent less time in bed (p=0.0001, d=0.62) and slept less (p=0.002, d=0.32). Additionally, awakening lengths were longer when athletes were required to arrive at training prior to 8:00am (p=0.05, d=0.44). Results show that younger athletes spent more time in bed (p=0.006, d=1.73), slept longer (p=0.029, d=1.70) and also reported better sleep quality (p=0.0001, d=14.94) compared with older athletes. Finally, athletes who lived <20 km to the training venue had shorter sleep onset latency (p=0.05, d=4.04), with no significant differences (p>0.05) in any other variable.

DISCUSSION

A key finding of this study was that professional athletes have reduced sleep durations during a high TL week, though this is likely related to the increased number of early morning training start times. The largest disruption to sleep duration was following an evening match, due to a later in-bed time and no change in ensuing wake times. Accordingly, training scheduling (i.e. training start time and training/match finish time) appears to influence sleep behaviour of professional rugby league athletes and should be recognised as a modifiable training variable in recovery and training prescription. Finally, older athletes attained less sleep and perceived their sleep to be worse, which suggests some non-modifable factors (e.g. age) should also be considered in planning individualised preparation strategies.

Professional rugby league athletes (in this particular club) slept for 6-7h/night, which is below recommended values (7 to 9 h/night) (20) for the general population. Reduced sleep durations in athletes appear common, indeed Olympic athletes were reported to attain ≈6 h 55 min of sleep per night (21,22), and ≈6 h 40 min sleep per night has been documented in collegiate basketball athletes during a competitive season. In contrast, some football codes show sleep durations of >8 h per night (28,20), which is likely due to different training and competition schedules (30). Given the current cohort showed low but acceptable sleep efficiency compared to other football codes (28,3,32), collectively, the sleep quantity and quality of this professional team was well below recommended and further highlights concerns about sleep behaviours in professional footballers.

Previous literature suggests that athletes may experience reduced sleep volume and quality when encountering high training demands (30,37). For example, Sargent et al. (30) found that Olympic swimmers had reduced sleep duration during a period of intense training. In the present study, less time was spent in bed during the high TL week, with associated reductions in total sleep time. Whilst high TLs may influence multiple physical/physiological systems that can affect sleep quality (e.g. muscle soreness, central nervous system fatigue), the earlier training start times during high TL week (scheduled to increase available daily training time) and/or the increased frequency of training during the high TL week is likely a major contributing factor in the current study. This is supported by research conducted with a female cohort, where sleep duration was not impacted during three different phases of training (onset of training, heavy training, and pre-competition taper) with a consistent schedule, despite different TL's during each phase (37).

Although this data demonstrates variations in sleep durations between different TL weeks, there were no meaningful differences in sleep quality measures. Supporting the idea that changes in TL do not significantly influence sleep quality, consistent sleep efficiency has been shown in rugby union players over a twelve-night period, including training and two competition matches (3). In contrast, swimmers participating in 14 days of intense training showed a reduction in sleep efficiency, with the subjects taking longer to fall asleep on nights prior to training days, as opposed to recovery days (30). Sleep efficiency in the current study was ~80%, which is lower than the typical sleep efficiency for healthy young adults (90%) (36) and previous reports in team sport athletes (>85%) (20). Match night resulted in even lower efficiency (~73%), combined with longer awakenings and poorer perceived sleep quality. This may be a result of elevated heart rate (2) and increases in metabolic function (35), or through the increase in pain and muscle soreness following exercise-induced muscle damage (26). These findings suggest that during periods of high training or competition load, a reduction in sleep quality may exist. However, this may be more influenced by the scheduling/timing of competition, as opposed to the TL encountered.

The current findings suggest that scheduling of an athlete's training influences their sleep behaviour. Training start times were earlier during the pre-season (i.e. low and high TL weeks) compared with in-season. These earlier start times require athletes to get out of bed earlier, but there was not a sufficient compensatory change to in-bed time behaviour. This led to athletes spending less time in bed, and consequently sleeping for shorter durations during the low and high TL weeks. This is in line with previous research suggesting a reduction in sleep duration is associated with early training start times in athletic populations (13,16,29,30). Similar to the present study, Sargent et al. (30) found that the earlier swimmers were required to train, the less sleep they achieved. Unlike our findings, individual sport athletes have been shown to advance their in bed time in preparation for an early start, though typically not enough to fully compensate for the earlier out-of-bed times, leading to a net sleep loss (20).

Match day demands are multifaceted in rugby league, and the physiological/psychological stressors of competition are not the only factors that may influence an athlete's sleep behaviour. Athletes are also required to engage in a range of post-match duties (e.g. recovery protocols, medical treatment and media commitments) which can regularly span late into the night following evening matches (i.e. the most common match time in the NRL). The disruptive effect of match-day has previously been described in elite rugby league athletes where, following a night match, athletes' bed time was much later (3 hours and 36 minutes later than respective Day 4 data), and therefore total sleep time was reduced (3). In the present study, all matches examined were played in the afternoon or evening, likely contributing to later time in bed times on match day. However, no compensatory change to out of bed time the following day, despite players being required to complete 'recovery' activities at 10:00am.This led to the shortest nightly sleep duration immediately following a match, which further supports the notion that sleep behaviour is dependent on situational and scheduling demands (14,30,28). On match night, athletes in this study had less frequent but longer duration awakenings, with a reduction in efficiency (~73%), suggesting greater overall sleep disruption. It has been suggested that disrupted sleep following a match could be due to a combination of mental arousal (related to the match and post-game commitments), late night scheduling and the physical trauma associated with rugby league (8).

Subjective data from previous work also demonstrate sleep disturbances following night matches, including problems falling asleep, waking through the night or early morning, unpleasant dreams and/or not feeling refreshed of the morning (14). This is supported in the present study with perceptual sleep scores being poorer following a night match, and remains an area to provide support to athletes. Future educational programs should be considered to assist athletes with sleep strategies.

Appreciating that training/competition load and schedules are not the only factors influencing sleep behaviour, we sought to explore whether other lifestyle factors contribute. One influential factor in our work was athlete age; we found that younger (< 24 y) athletes were sleeping for greater durations than their older (> 24 y) counterparts. Previous research in the general population has reported that younger adults (i.e. 20-34 years old) sleep for longer durations than older adults (i.e. > 35 years old) (12), as older adults are less able to resume sleep after awakening (12). Our research supports the idea of an age effect, although all athletes in this study were < 35 years old, and are therefore not directly comparable to 'older adults' in the aforementioned work. When considering travel time, we hypothesised that those who live closer to the training venue would have greater opportunity to sleep. However, no difference in sleep parameters between those who had greater than or less than 20 km to travel was evident. This null finding may be due to the homogeneity of travel distances and the median-split technique used, or the nature of large metropolitan city travel.

Given that the study was conducted in a field-based setting, there were uncontrollable factors that may have affected participants' sleep (e.g. caffeine and alcohol consumption). Additionally, the amount and quality of sleep obtained by the athletes was assessed using wrist watch actigraphy rather than polysomnography (PSG). PSG is the gold standard measure of sleep, however in a field-based setting such as this, PSG is difficult to use. Despite this limitation, activity monitors are suitable to measure sleeping patterns/timing of sleep (25) and are more reliable than sleep diaries (24). It should be noted that no true baseline data (i.e. non-training phase) were collected, as non-training phases constitute a very small portion of the year (i.e. 4-8 weeks) for professional rugby league athletes. This work also only presents data collected on four nights in each week (i.e. Monday to Thursday during pre-season). More comprehensive data collection may reveal different behaviours on other nights such as weekends.

Conclusion

The present study shows that training and competition schedule impacts on sleep behaviours in professional rugby league athletes. Our data suggest that training start time impacts time in bed and subsequently the total amount of sleep attained by athletes. In part, this occurs as changes in training start time alters required wake time, but athletes do not self-adjust with sufficient compensatory shifts to time in-bed behaviours. Match days negatively influence sleep quality and quantity, which is likely due to a combination of physical/mental stress and late-night competition schedules. Coaches and training staff should therefore consider modifiable factors, such as training start times and session content surrounding competition, with the knowledge that sleep, and therefore recovery and subsequent performance, will likely be affected.

PRACTICAL APPLICATIONS

It is important that coaching and performance staff are aware of the implications that training schedule has on athletes' sleep. Indeed, available sleep time could be considered an indirectly 'modifiable' recovery variable, as training start times appear to have a strong link with time in bed (and subsequently sleep time). Match days have a large negative impact on sleep quality and quantity, and consequently, training schedules and content should be planned with this in mind. It may be argued that training schedules could be adjusted to better align with match times (e.g. evening training times) and therefore produce a more consistent schedule. However, practitioners should also consider cultural aspects specific to their athletic environment. If inconsistent training schedules are unavoidable (e.g. early morning training and late-night competition both required), alternatives to offset reductions in sleep quality/quantity (e.g. availably in schedule for napping) should be encouraged and facilitated/coached.

ACKNOWLEDGEMENTS

No external funding was provided for completion of this research. The authors would like to thank the Wests Tigers Football Club athletes and staff for helping to facilitate this research.

REFERENCES

1. Barnett A. Using recovery modalities between training sessions in elite athletes. *Sports Med* 36: 781-796, 2006.
2. Belenky G, Wesensten NJ, Thorne DR, Thomas ML, Sing HC, Redmond DP, Russo MB, and Balkin TJ. Patterns of performance degradation and restoration during sleep restriction and subsequent recovery: A sleep dose-response study. *J Sleep Res* 12: 1-12, 2003.
3. Eagles A, Mclellan C, Hing W, Carloss N, and Lovell D. Changes in sleep quantity and efficiency in professional rugby union players during home based training and match-play. *J Sports Med Phys Fitness*, 2014.
4. Erlacher D, Ehrlenspiel F, Adegbesan OA, and Galal El-Din H. Sleep habits in German athletes before important competitions or games. *J Sport Sci* 29: 859-866, 2011.
5. Fietze I, Strauch J, Holzhausen M, Glos M, Theobald C, Lehnkering H, and Penzel T. Sleep quality in professional ballet dancers. *Chronobiol Int* 26: 1249-1262, 2009.
6. Foster C, Florhaug JA, Franklin J, Gottschall L, Hrovatin LA, Parker S, Doleshal P, and Dodge C. A new approach to monitoring exercise training. *J Strength Cond Res* 15: 109-115, 2001.
7. Fowler P, Duffield R, and Vaile J. Effects of domestic air travel on technical and tactical performance and recovery in soccer. *Int J Sports Physiol Perform* 9: 378-386, 2014.
8. Fullagar HH, Skorski S, Duffield R, Hammes D, Coutts AJ, and Meyer T. Sleep and athletic performance: the effects of sleep loss on exercise performance, and physiological and cognitive responses to exercise. *Sports Med* 45: 161-186, 2015.
9. Halson SL. Nutrition, sleep and recovery. *Eur J Sport Sci* 8: 119-126, 2008.
10. Halson SL. Sleep in elite athletes and nutritional interventions to enhance sleep. *Sports Med* 44: 13-23, 2014.

11. Hausswirth C, Louis J, Aubry A, Bonnet G, Duffield R, and Le Meur Y. Evidence of disturbed sleep and increased illness in overreached endurance athletes. *Med Sci Sports Exerc*, 2014.

12. Hume K, Van F, and Watson A. A field study of age and gender differences in habitual adult sleep. *J Sleep Res* 7: 85-94, 1998.

13. Ingre M, Kecklund G, Åkerstedt T, Söderström M, and Kecklund L. Sleep length as a function of morning shift-start time in irregular shift schedules for train drivers: Self-rated health and individual differences. *Chronobiol Int* 25: 349-358, 2008.

14. Juliff LE, Halson SL, and Peiffer JJ. Understanding sleep disturbance in athletes prior to important competitions. *J Sci Med Sport* 18: 13-18, 2015.

15. Jürimäe J, Mäestu J, Purge P, and Jürimäe T. Changes in stress and recovery after heavy training in rowers. *J Sci Med Sport* 7: 335-339, 2004.

16. Kecklund G and Åkerstedt T. Effects of timing of shifts on sleepiness and sleep duration. *J Sleep Res*4: 47-50, 1995.

17. Kellmann M. Preventing overtraining in athletes in high-intensity sports and stress/recovery monitoring. *Scand J Med Sci Sports* 20: 95-102, 2010.

18. Knufinke M, Nieuwenhuys A, Geurts SA, Møst EI, Maase K, Moen MH, Coenen AM, and Kompier MA. Train hard, sleep well? Perceived training load, sleep quantity and sleep stage distribution in elite level athletes. *J Sci Med Sport* 21: 427-432, 2018.

19. Krueger JM, Majde JA, and Rector DM. Cytokines in immune function and sleep regulation. *Handbook of clinical neurology* 98: 229-240, 2011.

20. Lastella M, Lovell GP, and Sargent C. Athletes' precompetitive sleep behaviour and its relationship with subsequent precompetitive mood and performance. *Eur J Sport Sci* 14: S123-S130, 2014.

21. Leeder JD, Gardner AS, Foley S, van Someren K, and Pedlar CR. The Effect Of Jet Lag On Parameters Of Sleep In Elite Divers Quantified By Actigraphy.: 1573Board# 175 May 27 9: 30 AM-11: 00 AM. *Med Sci Sports Exerc* 41: 57-58, 2009.
22. Mah CD, Mah KE, Kezirian EJ, and Dement WC. The effects of sleep extension on the athletic performance of collegiate basketball players. *Sleep* 34: 943-950, 2011.
23. McLean BD, Coutts AJ, Kelly V, McGuigan MR, and Cormack SJ. Neuromuscular, endocrine, and perceptual fatigue responses during different length between-match microcycles in professional rugby league players. *Int J Sports Physiol Perform* 5: 367-383, 2010.
24. Monk TH, Buysse DJ, and Rose LR. Wrist actigraphic measures of sleep in space. *Sleep* 22: 948-954, 1999.
25. Morgenthaler T, Alessi C, Friedman L, Owens J, Kapur V, Boehlecke B, Brown T, Chesson Jr A, Coleman J, and Lee-Chiong T. Practice parameters for the use of actigraphy in the assessment of sleep and sleep disorders: an update for 2007. *Sleep* 30: 519-529, 2007.
26. Nédélec M, McCall A, Carling C, Legall F, Berthoin S, and Dupont G. Recovery in soccer. *Sports Med* 43: 9-22, 2013.
27. Pitchford NW, Robertson SJ, Sargent C, Cordy J, Bishop DJ, and Bartlett JD. A change in training environment alters sleep quality but not quantity in elite Australian Rules football players. *Int J Sports Physiol Perform* 12: 75-80, 2016.
28. Richmond L, Dawson B, Hillman D, and Eastwood P. The effect of interstate travel on sleep patterns of elite Australian Rules footballers. *J Sci Med Sport* 7: 186-196, 2004.
29. Roach GD, Sargent C, Darwent D, and Dawson D. Duty periods with early start times restrict the amount of sleep obtained by short-haul airline pilots. *Accid Anal Prev* 45: 22-26, 2012.

30. Sargent C, Halson S, and Roach GD. Sleep or swim? Early-morning training severely restricts the amount of sleep obtained by elite swimmers. *Eur J Sport Sci* 14: S310-S315, 2014.

31. Schaal K, Le Meur Y, Louis J, Filliard J-R, Hellard P, Casazza G, and Hausswirth C. Whole-body cryostimulation limits overreaching in elite synchronized swimmers. *Med Sci Sports Exerc* 47: 1416-1425, 2015.

32. Shearer DA, Jones RM, Kilduff LP, and Cook CJ. Effects of competition on the sleep patterns of elite rugby union players. *Eur J Sport Sci* 15: 681-686, 2015.

33. Sinnerton S and Reilly T. Effects of sleep loss and time of day in swimmers. *Biomechanics and medicine in swimming: swimming science VI*: 399-404, 1992.

34. Souissi N, Sesboüé B, Gauthier A, Larue J, and Davenne D. Effects of one night's sleep deprivation on anaerobic performance the following day. *Eur J Appl Physiol* 89: 359-366, 2003.

35. Spiegel K, Leproult R, and Van Cauter E. Impact of sleep debt on metabolic and endocrine function. *The lancet* 354: 1435-1439, 1999.

36. Spriggs W. *Essentials of polysomnography*. Jones & Bartlett Publishers, 2009.

37. Taylor SR, Rogers GG, and Driver HS. Effects of training volume on sleep, psychological, and selected physiological profiles of elite female swimmers. *Med Sci Sports Exerc* 29: 688-693, 1997.

38. Thornton HR, Delaney JA, Duthie GM, and Dascombe BJ. Effects of preseason training on the sleep characteristics of professional rugby league players. *Int J Sports Physiol Perform* 13: 176-182, 2018.

39. Thornton HR, Duthie GM, Pitchford NW, Delaney JA, Benton DT, and Dascombe BJ. Effects of a 2-week high-intensity training camp on sleep activity of professional rugby league athletes. *Int J Sports Physiol Perform* 12: 928-933, 2017.

40. Varley MC, Elias GP, and Aughey RJ. Current match-analysis techniques' underestimation of intense periods of high-velocity running. *Int J Sports Physiol Perform* 7: 183-185, 2012.