USO DE CAFEÍNA EN SUPER RUGBY Y RELACIÓN CON EL SUEÑO POST-PARTIDO

Objetivo:

Examinar la relación entre el consumo regular de cafeína en partidos de Super Rugby y el sueño posterior.

Métodos:

Se monitorizó el sueño de 20 jugadores de élite de rugby XV a través de una pulsera 3 días antes, 3 días después y la noche posterior al partido. Los jugadores ingirieron la cafeína como lo hacen habitualmente (por ejemplo: antes y a veces durante el partido) y se tomaron muestras de saliva antes (17:00) y después (21:30) del partido para medir la concentración de cafeína.

Conclusiones:

El consumo de cafeína antes de un partido de Super Rugby aumenta notablemente los niveles de cafeína en saliva después del partido. Esto puede contribuir al retraso observado de 3,5 horas en el inicio del sueño y la reducción de 1,5 horas en el tiempo dormido la noche después del partido. Este estudio resalta la necesidad de un acercamiento estratégico a la utilización de la cafeína en un equipo de Super Rugby considerando el potencial efecto en el sueño post-partido.

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ORIGINAL ARTICLE

Caffeine use in a Super Rugby game and its relationship to post-game sleep

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Abstract
Objective: To examine the relationship between regular game-related caffeine consumption on sleep after an evening Super Rugby game. *Methods:* Twenty elite rugby union players wore a wrist-activity monitor to measure sleep for three days before, three days after and on the night of an evening Super Rugby game (19:00–21:00). Players ingested caffeine as they would normally (i.e. before and sometimes during a game) and saliva samples were collected before (17:00) and after (21:30) the game for caffeine concentration. *Results:* Compared to the nights leading up to the game, on the night of the game, players went to bed 3 h later (23:08 ± 66 min vs 02:11 ± 114 min; $p < .001$) and had 1:30 hh:mm less sleep (5:54 ± 2:59 vs 8:02 ± 1:24 hh:mm; $p < .05$) and four players did not sleep after the game. Post-game caffeine saliva concentrations were greater than pre-game levels in 17 players (Pre-game 0.40 µg/mL vs Post-game 2.77 µg/mL; $p < .001$). The increase in caffeine saliva concentrations was moderately associated with an increase in sleep latency ($p < .05$), a decrease in sleep efficiency ($p < .05$), and a trend for a decrease in sleep duration ($p = .06$) on game night. *Conclusion:* Caffeine consumption before a Super Rugby game markedly increases post-game saliva caffeine levels. This may contribute to the observed 3.5 h delay in time at sleep onset and the 1.5 h reduction in sleep duration on the night of the game. This study highlights the need for a strategic approach to the use of caffeine within a Super Rugby team considering the potential effect on post-game sleep.

Keywords: Competition, team sport, recovery

Highlights
- Caffeine consumption was common in rugby players before a game and resulted in an increase in post-game caffeine saliva levels. This change was related to an increase in sleep latency, decrease in sleep efficiency and tended to be related to a decrease in sleep duration after a Super Rugby game.
- Super Rugby players do not compensate for a reduction in sleep duration on post-game nights, therefore coaches and athletic staff may need to delay training start times to support an increase in sleep duration to support recovery and preparation for subsequent games.
- A caffeine consumption strategy for rugby players based upon pharmacokinetics of caffeine and timing of the game may prove beneficial for performance whilst minimising the subsequent negative effects on sleep latency, efficiency and duration.

Introduction

In the southern hemisphere, the Super Rugby championship is contested across five countries with 18 teams from Australia, South Africa, New Zealand, Japan, and Argentina. A Super Rugby team will

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play 15 games in a season (Home and Away) with games generally played at night, between the hours of 18:00–22:00, at a time of the day when the drive for sleep is increasing (Borbely, 1982). The requirement to compete at this time of day for 80 min in a contact sport that places high demands on players from a strength, aerobic, and anaerobic capacity (Duthie, Pyne, & Hooper, 2003) may negatively affect sleep after games.

Sleep is an important process for recovery in athletes (Fullagar et al., 2014). This is especially true following intense competitive events or training regimes since fatigue, staleness, and soreness is associated with insufficient recovery and contributes to poorer performance in subsequent competitions (Hooper et al., 1995). Unfortunately, in team sports such as soccer, perceived recovery and sleep is often reduced following a night game (Fullagar et al., 2016). Similarly, Sargent and Roach (2016) reported shortened sleep attributable to a delayed sleep onset following an Australian Rules Football (AFL) night game. Such sleep loss leads to decrements in physical (Reilly & Edwards, 2007) and cognitive performance in athletes (Gupta, Morgan, & Gilchrist, 2016).

When sleep loss occurs after a contact game such as rugby union, it negatively affects reaction time, physical performance, and subjective perceptions of muscle soreness (Skein, Duffield, Minett, Snape, & Murphy, 2013). Sleep loss due to a post-game delay in sleep onset has been reported in several studies of rugby union players (Eagles, McLellan, Hing, Carloss, & Lovell, 2014; Shearer, Jones, Kilduff, & Cook, 2015a), although the specific factors contributing to these sleep-related changes were unclear. It is speculated that these sleep-related changes may include the arousing effects of an evening game, an elevated body temperature (Sargent & Roach, 2016), post-game alcohol consumption (Barnes, 2014; Prentice, Stannard, & Barnes, 2014) and pre-game ingestion of caffeine (Shearer et al., 2015a).

From the standpoint of gaining a competitive edge, athletes often rely on pre-game caffeine ingestion as an ergogenic aid (Del Coso, Portillo, et al., 2013; Del Coso, Ramirez, et al., 2013). Such a strategy appears warranted considering that the consumption of 2–9 mg/kg of caffeine has been shown to increase the sprint speed, power and passing accuracy of rugby players during training (Cook, Beaven, Kilduff, & Drawer, 2012; Stuart, Hopkins, Cook, & Cairns, 2005). Similar doses have been shown to improve reaction time in Taekwondo athletes (Santos et al., 2014).

Unfortunately, while caffeine exerts a number of beneficial effects on waking performance, evening consumption of caffeine can impair subsequent sleep (Drake, Roehrs, Shambroom, & Roth, 2013). Once ingested, caffeine typically reaches peak plasma levels within 60 min and takes about 4–6 h to metabolise half of the initial dose (Burke, 2008). Caffeine consumed shortly before bedtime will decrease sleep duration and sleep efficiency (Drake et al., 2013). The adverse effect of caffeine on sleep duration is primarily due to an increase in the time it takes to fall asleep (sleep latency) which is due to lifestyle factors and/or other demands that are not offset by a delayed wake-up time the next day (Carrier et al., 2009). The adverse effect of caffeine on sleep efficiency is attributable the tendency for caffeine to increase the number of times an individual transiently wakes during the sleep period (McHill, Smith, & Wright, 2014), which also reduces overall sleep duration.

As noted previously, it has been hypothesised that the sleep problems previously reported amongst rugby players may in part be due to the pre-game usage of caffeine as an ergogenic aid. However, to date, no studies have assessed caffeine consumption (self-reported or objectively quantified) and its potential impact on sleep in rugby or other team sport athletes participating in evening or night-time competitions. Anecdotally, elite rugby union players report ingesting caffeine before night games, but objective confirmation of such reports have not been published.

The aim of this study was to; (i) quantify the caffeine concentration levels of professional rugby union players before and after an evening Super Rugby game and (ii) determine any relationships between caffeine concentration levels and post-game sleep. Measures of caffeine concentration were obtained relatively non-obtrusively via saliva assays (which have been shown to reliably reflect blood plasma levels as per Zylber-Katz, Granit, & Levy, 1984), and sleep measures were obtained via wrist actigraphy which has been shown to be closely approximated to sleep assessments made via polysomnography (Dunican, Murray et al., 2017). We hypothesised that an increase in caffeine levels after an evening game would be related to a reduction in the sleep quantity and sleep efficiency of post-game sleep.

Methods

All participants were contracted players from a single professional Super Rugby team based in Perth, Western Australia. The mean age of the players was 26 ± 3 years (range 21–34) with a mean mass of 102 ± 12 kg (range 80–122) (Table I). Ethical approval for the study was obtained from the Human Research Ethics Office of the University of

Table I. Demographic and self-reported caffeine consumption.

	$n = 20$ Mean ± SD
Demographic information	
Age (years)	26 ± 3
Weight (kg)	102 ± 12
Height (cm)	185 ± 7
Body Mass Index (BMI)	30 ± 3
Self-reported caffeine consumption	
Average number of caffeinated drinks consumed per day, per player (count of drinks)	2
Sources of caffeine consumption in the past 7 days (percentage)	
Home brew coffee	13
Cappuccino/Latte/Flat white	31
Tea	28
Energy drinks	3
Cola drinks	25
Time of day when MOST of caffeine is consumed	
06:00–12:00	67%
12:00–18:00	27%
18:00–00:00	6%
Self-reported caffeine use prior to a Super Rugby game	
Number of players who take caffeine prior to a competitive game (count)	9
Time of consumption prior to a competitive game (min)	49 ± 61
Sources of caffeine consumption prior to a Super Rugby game (percentage)	
Home brew coffee	3
Cappuccino/Latte/Flat white	13
Tea	32
Cola drinks	28
No Doze tablets	21
Chocolate	3

Notes: Demographic and descriptive caffeine data as collected from the paper-based survey instrument from $n = 20$ participants. Data are presented as means with standard deviations (SD).

Western Australia (UWA) (RA/4/1/7235) and written informed consent were obtained from all players before their participation.

Experimental overview

The study was undertaken during the week of a Super Rugby home game in April 2015. This game was selected as no travel occurred for 13 days before the game or for 10 days after the game, thus ensuring that players had access to their usual sleep environment and completed all training within a standard time zone. Wrist-activity monitors were continually worn on each of the three days before (Wednesday, Thursday, and Friday) and after (Sunday, Monday, and Tuesday) a Saturday evening game (19:00–21:00 h). Saliva samples were collected 3 h before the game (16:00–17:00 h) and within 30 min after the game (21:00–21:30 h) to assess caffeine concentration.

Demographic and anthropometric measurements

The team's athletic performance support staff provided measurements of each athlete's height (cm), competition weight (kg), and Body Mass Index (BMI), calculated from weight/height^2 (kg/m^2). Data were collected on each player's regular caffeine consumption in relation to the seven days prior to this Super Rugby game.

Sleep measures-wrist-activity monitor

To obtain measures of sleep in this study, wrist-activity monitors were used as they are ideal to monitor sleep in athletes since they minimally interfere with normal training and sleep opportunities (Leeder, Glaister, Pizzoferro, Dawson, & Pedlar, 2012; Sargent, Lastella, Halson, & Roach, 2016). The wrist-activity monitor used in this study, the Readiband™ (v3, Fatigue Science Inc., Canada), was issued to each player at 17:00 h on the Wednesday before the game and collected at 08:00 h on the Wednesday after the game. The wrist-activity monitors were worn on the non-dominant wrist throughout the 7-day period, including during training sessions.

These devices have been shown to compare favourably both to in-laboratory polysomnography (PSG) and another widely used and validated wrist-activity monitor, the ActiGraph (Dunican,

Murray et al., 2017). In addition, Readiband wrist monitors have been shown to have an epoch-to-epoch sleep/wake scoring accuracy of 82%, sensitivity of 88%, and specificity of 55% in comparison to gold standard in-laboratory PSG (Russell, Arand, Myers, Wubbels, & Downs, 2006). The Readiband has been used in a number of sports-related research studies (Dunican., Martin et al., 2017; Fowler, Duffield, & Vaile, 2014; Fullagar et al., 2015), has undergone an infield validation in AFL (Dennis, Dawson, Heasman, Rogalski, & Robey, 2016) and has been approved by the Federal Drug Administration (Readiband FDA Approval., 2011) for measurement of physical activity and sleep.

Sleep analysis – wrist-activity monitor

A single trained scientist downloaded Readiband™ data and analysed these data using the automated Readiband Sync™ software. Sleep measures included: sleep latency (number of min from time of trying to initiate sleep to time of sleep onset); time at sleep onset (time of the first epoch of sleep between time of trying to initiate sleep and time at wake up); sleep duration (number of min from time of sleep onset to time at wake, minus number of min awake); wake after sleep onset (number of min awake after sleep onset); time at wake (the time of wake from sleep with no further sleep duration); and sleep efficiency (sleep duration divided by time in bed multiplied by 100).

Sleep and training diary

Players were provided with a sleep and training diary, which they carried with them throughout the seven days. The diary contained questions relating to their sleep patterns and training effort and included questions relating to the time players went to bed the previous night and the time they woke up.

Caffeine measures

Saliva samples were collected from each participant under the supervision of the research team twice on the game night. A pre-game sample was collected 3 h before the game (16:00–17:00 h) and a post-game sample was collected within 30 min after the end of the game (21:00–21:30 h). Players were given a pre-labelled blue cap Salivette® (ref. 51.1534.500) with a unique identification code. The Salivette® contained a cotton swab. Players removed the cotton swab, placed it in their mouth and chewed on it for 45 s to stimulate salivation. The cotton swab was then placed back into the Salivette® and sealed with a stopper. When completed, the player handed the Salivette® containing the saliva sample to a member of the research team. Samples were immediately placed in a portable ice container and were placed in a freezer later that night (22:30 h). The following day at 09:00 h, the samples were transported to the UWA laboratory and stored at −20°C.

Caffeine analysis

Caffeine saliva samples were analysed using an HPLC column (Phenomenex Biphenyl 150 mm × 3 mm, 2.6 μm). Synthetic saliva was from LGC (OraFlx negative-synthetic saliva), LCMS grade water from Thermofisher, LCMS grade methanol from Burdich and Jackson, Formic acid from Merck and pure caffeine and 13C3 caffeine standards from Sigma-Aldrich. Assay samples were defrosted, and 100 μL of saliva was spiked with 50 μL labelled caffeine (5 μg/mL), vortexed briefly then extracted by 1 mL of Ethyl Acetate. This was vortexed for 60 s, then 900 μL was dried down by evaporation. The dried extract was reconstituted in 70 μL of 50:50 Methanol: Water, then 5 μL was injected onto an Agilent 6460 LC-MS/MS. The solvents were A (water +0.1% formic acid), B (Methanol +0.1% formic acid) and the following gradient was applied, 0 min 50% B, 7 min 98% B, 8 min 50% B, 9 min 50% B. The transitions monitored for caffeine and 13C3 caffeine were 195.1 > 137.9 and 197.9 > 139.9 and the retention time was 3.3 min. Assay calibration was achieved by spiking synthetic saliva (LGC) with known amounts of caffeine. A typical calibration curve showed an $R^2 = 0.999$. Assay precision, indicating instrument accuracy, was assessed by running a test sample in triplicate. The coefficient of variation of these measures was 0.7% at 0.152 μg/mL.

Statistical analysis

Linear mixed models were used to compare wrist-activity monitor derived sleep measures over the course of the study. For measures that were taken by both wrist-activity monitor and sleep diary, fixed effects of measurement type (sleep measures taken from the wrist-activity monitor or sleep diary), night (pre-game nights 1, 2, 3, game night, post-game nights 1, 2, 3), along with their interactions were included, in addition to appropriate random effects of the individual. For the measures that were taken by wrist-activity monitor only, fixed effect of night and random individual effects were included. Differences in least squares means were used to assess significant differences and are presented along with 95% confidence intervals for differences. In instances where the model assumptions were violated, a transformation (square root) was performed (Sleep

Latency and WASO). Paired *t*-tests were used to compare pre-game vs post-game caffeine levels, and a series of bivariate correlational analyses were used to examine the association between changes in caffeine against measures of sleep. Unless otherwise specified, all results are presented as mean (lower 95% CI, upper 95% CI) and $p < .05$ was considered as statistically significant for all tests. All analyses were carried out using SAS software (SAS Institute Inc., Cary, NC, USA).

Results

Of the 23 elite rugby union players who were enrolled in the study, 3 were excluded from the final analyses due to their failure to wear the wrist-activity monitor as per instructions. Therefore, data from a total of 20 players were analysed.

Sleep measures – wrist-activity monitor

Time at sleep onset (Figure 1) was different on game night compared to all other nights with a minimum mean earlier time at sleep onset on pre-game 1 by 3:06 hh:mm (2:18, 3:42) and maximum mean earlier time at sleep onset on post-game 1 by 3:30 hh:mm (2:42, 4:06) ($p < .05$ for all). Time at wake was different for all mornings when compared to game night except on the night of pre-game 3 (the morning of the game). The average difference ranged from 0:48 hh:mm (0:12, 1:24) later on pre-game 2 to 2:12 hh:mm (1:36, 2:48) earlier on post-game 2 ($p < .05$ for all). In general, sleep latency was longer on all nights compared to the night of the game with significant differences (transformation square root) occurring on pre-game 1, longer by 3 min (1, 4), longer on pre-game 2 by 2 min (0, 3), and longer on post-game 1 by 2 min (3, 1) ($p < .05$ for all).

Sleep duration was significantly longer on all nights compared to game night with a range of mean differences over the nights from 2:08 hh:mm (1:06, 3:09) to 3:39 hh:mm (2:38, 4:40) ($p < .001$ for all). Wake after sleep onset was only significantly different (transformation square root) on post-game 1 compared to game night greater by 1 min (0, 3) ($p < .001$). Sleep efficiency less on the game night compared to all other nights ($p < .001$) with a range for the differences, greater by 16% (7, 26) on pre-game 2 to greater by 22% on post-game night 3 (12, 32).

Sleep measures – self-reported

Time at sleep onset (Figure 1) was different on game night compared to all nights with a minimum earlier difference of 2:12 hh:mm on pre-game 3 (1:30, 2:48) and maximum difference of 2:48 hh:mm on post-game 3 (2:12, 3:36) ($p < .05$ for all). Sleep duration was recorded as longer on all nights compared to game night with significant differences on pre-game 1 by 1:12 hh:mm (0:10, 2:13), pre-game night 2 by 1:14 hh:mm (0:13, 2:15), and post-game night 2 by 1:13 hh:mm (0:10, 2:14) ($p < .05$ for all). Time at wake was different compared to game night on pre-game night 1 and post-game nights 1–3, with the differences earlier by 0:54 hh:mm on post-game

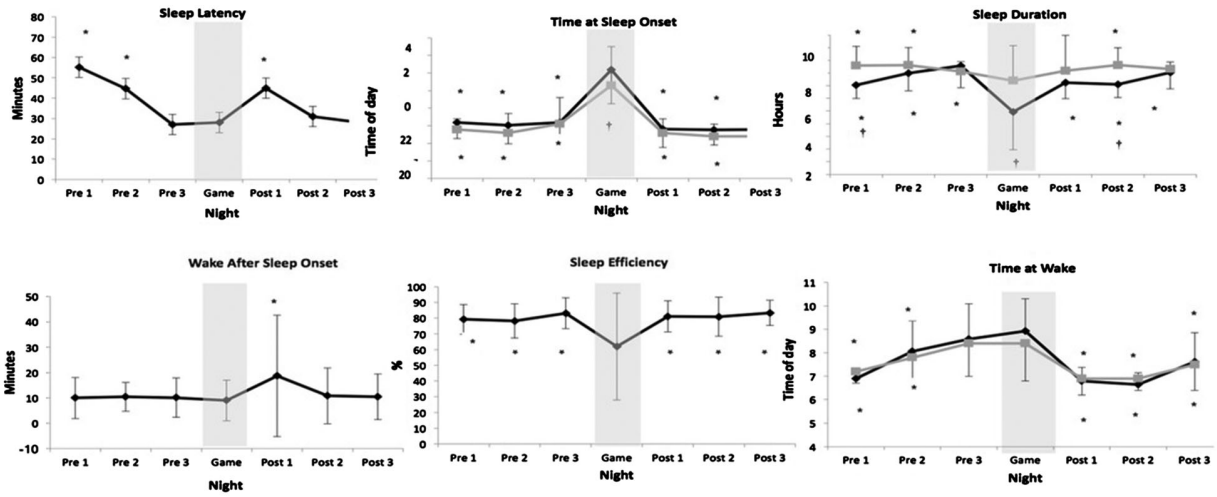

Figure 1. *Wrist-activity measures vs sleep diary measures*: Measures of sleep on pre-game 1 (Pre-1), pre-game 2 (Pre-2) and pre-game3 (Pre-3) day of the game (Game) (transparent box) and post-game 1 (Post-1), post-game 2 (Post-2) and post-game 3 (Post-3). Wrist-Activity Monitor data (solid black line) and the Sleep Diary data (grey line). Data presented as mean ± SD, *Indicates $p < .05$ for within measure comparison v Game Night; †Indicates $p < .05$ for between measures (*Wrist Activity vs Diary data*) within the same night.

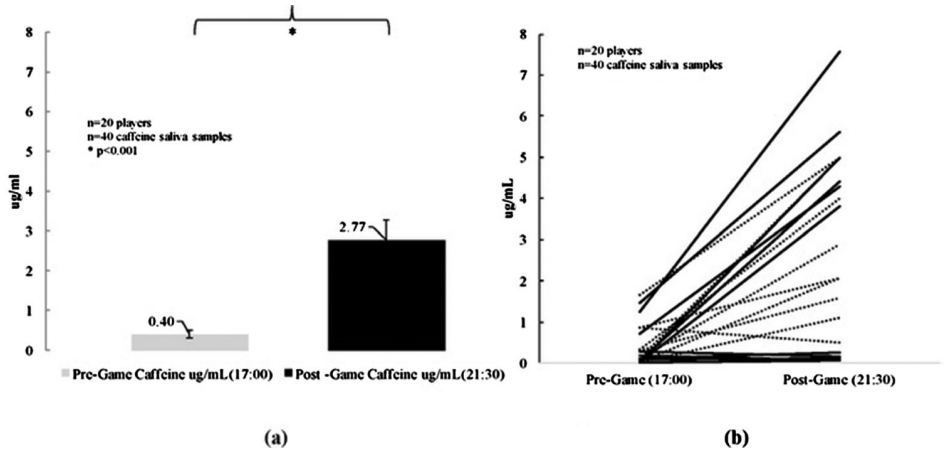

Figure 2. (a) Overall change in caffeine saliva concentrates, (b) Individual changes in caffeine saliva concentrates. (a) Pre-game caffeine vs post came caffeine (ug/mL); $n = 20$ game players, $n = 40$ caffeine saliva samples (pre- and post-game), $^{*}p < .001$ (b) (dashed line) players that self-reported consuming caffeine prior to a game (solid black line) players that self-reported not consuming caffeine prior to a game.

night 3 (0:18, 1:30) ($p < .05$) to 1:33 hh:mm (0:54, 2:06) on post-game night 2 ($p < .001$).

Associations between self-reported and wrist-activity monitor measures of sleep

Sleep diary-based measurements for time at sleep onset were similar to measures derived from the wrist-activity monitor except for the night of the game in which the sleep diary estimates of sleep onset were earlier by 1 h (0:17,1:02), than those obtained via the wrist-activity monitor (Figure 1) ($p < .05$). This resulted in self-reported sleep duration being overestimated by 2:28 hh: min on game night (1:27, 3:29) ($p < .001$). On all other pre- (1–3) and post-game nights (1–3), sleep duration was consistently over-estimated by an average of 1 h per night ($p < .05$). Time at wake was not significantly different between sleep diary and wrist-activity monitor measurements for any of the nights.

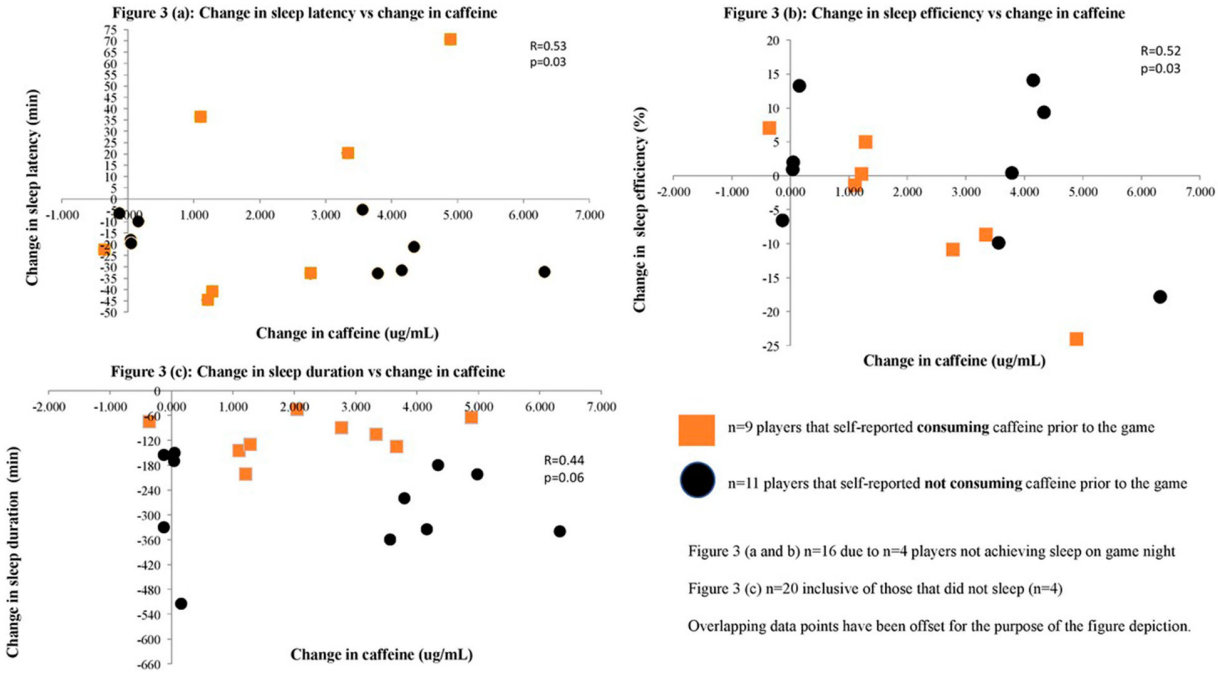

Figure 3. (a) change in sleep latency vs change in caffeine, (b) change in sleep efficiency vs change in caffeine, (c) change in sleep duration vs change in caffeine. (a and b) $n = 16$ due to $n = 4$ players not achieving sleep on game night. (c) $n = 20$ inclusive of those that did not sleep ($n = 4$). Overlapping data points have been offset for the purpose of the figure depiction.

Caffeine saliva concentrations

Post-game caffeine saliva concentrations (Figure 2) increased in 17 of the 20 players and decreased in 3 players. When considered as a group, caffeine saliva concentrations increased by 2.35 ± 2.07 μg/mL, from 0.42 ± 0.52 μg/mL before the game (16:00–17:00) to 2.77 ± 2.27 μg/mL following the game (21:00–21:30) ($p < .001$).

Self-reported caffeine consumption

On average, players reported consuming two caffeinated drinks per day in the seven days prior to the commencement of the study (Table I). Nine of the 20 players reported that when playing a game that they consume caffeine for performance, on average these players consumed caffeine 49 ± 61 min before the commencement of a game.

Associations between sleep and caffeine

On game night, changes in caffeine saliva concentrations from before to after the game were moderately related to an increase in sleep latency ($r = 0.53$, $p = .03$) and a decrease in sleep efficiency ($r = 0.52$, $p = .03$) in post-game sleep (Figure 3). The size of the game-related increase in caffeine tended to be related to a decrease in sleep duration after the game ($r = 0.44$, $p = .06$). Changes in caffeine concentration were not related to any other measure of sleep.

Discussion

The aim of this study was to examine the relationships between caffeine consumption and a variety of actigraphy-derived sleep measures collected after an evening Super Rugby game. The main findings were that: (i) "the increase in salivary caffeine concentrations from pre-to post-match suggests that caffeine consumption was common before and/or during the game"; (ii) this resulted in markedly increased post-game saliva caffeine levels in most players; and (iii) the increase in caffeine concentrations was moderately associated with an increase in sleep latency, a decrease in sleep efficiency, and a tendency toward decreased sleep duration.

Sleep

Our results revealed a significant delay in the time of sleep onset and the duration of sleep after the game compared to what was observed each night leading up to the game and each night following the game. These results are similar to those found in other studies of rugby players in Australia and Wales, in which the athletes slept significantly less after a game (Eagles et al., 2014; Shearer, Jones, Kilduff, & Cook, 2015b). One of these studies (conducted in another Super Rugby team based in Australia), reported an average post-game sleep duration of 4 h 45 min and an average sleep onset time of 02:24 h (Eagles et al., 2014), while in our study players achieved an average sleep duration of 4 h 56 min and fell asleep at 02:12 h. A study conducted on the Celtic League in Wales, indicated that players achieved slightly more post-game sleep (i.e. 6 h 2 min), most likely because they fell asleep earlier (at 00:49 h) compared to 02:12 h in our study. This may be due to the fact that the Celtic League games often started one hour earlier (18:30) than this Super Rugby game (19:30). It may also be that Celtic League players did not have the same amount of media and post-game commitments as the players within the Super Rugby competition. In the Celtic League competition players awakened later the next day (at 08:56 h) (Shearer et al., 2015a) compared to an earlier time of wake in our study of 06:50 h the next morning.

It was of interest that in this study 20% of players did not achieve any sleep after the game. Post data-collection discussions with those specific players confirmed the actigraphy-based findings. The main self-reported mechanism responsible for the complete absence of post-game sleep was continued post-game arousal, the stress of having lost that game, and engagement in post-game socialising with team members. It is important to acknowledge these and other factors that can play a role in delayed sleep times in athletes, including the general arousing effects of an evening game, an elevated body temperature (Sargent & Roach, 2016), alcohol consumption (Barnes, 2014; Prentice et al., 2014) and/or the requirement to attend a post-game press conference, post-game recovery sessions and/or post-game medical evaluations. Any or all of these can negatively affect bedtime, sleep duration, and sleep efficiency in athletes (Fullagar et al., 2016). Our current findings within the context of an evening game in combination of those from other assessments of contact sports such as rugby and AFL suggest that greater emphasis should be placed on the importance of post-game recovery sleep for teams preparing for an additional game the following week (one that may require the additional sleep-disrupting complications of interstate or international travel).

It is surprising that players in the present investigation did not compensate for the increase in sleep latency and the delayed time of post-game sleep onset by delaying the wake-up time the next morning since there were no scheduled team events

which would have prohibited this adjustment. It is possible that the players attempted to sleep later the next day but were unable to do so due to an increase in perceived muscle soreness and/or an increase in creatine-kinase levels since both of these have been reported in rugby league players (Skein et al., 2013). It is also possible that players are "programmed" to wake up according to their own circadian rhythm, making it hard to sleep for later given that their habitual time at wake was in general before 08:00 on pre-game and post-game days. In addition, post-game alcohol consumption may have affected the sleep/wake timing (Murphy, Snape, Minett, Skein, & Duffield, 2013). These factors, as well as the potential effects of family commitments, were not evaluated in our investigation, but should be considered in future studies of athlete sleep characteristics.

In general, the measures of self-reported sleep from players agreed with those obtained via the wrist-activity monitors, but the athletes nevertheless tended to overestimate their sleep duration by an average of 1-h. Such a discrepancy is not surprising since it is difficult for humans to be cognisant of overnight awakenings and the cumulative effect of such awakenings on total sleep time. For this reason, actigraphy-based measures tend to be superior to self-ratings (Kölling, Endler, Ferrauti, Meyer, & Kellmann, 2016). Also, actigraphy-based sleep measures are more accurate than those derived from sleep diaries because they are less likely to suffer from participants' failures to complete the reports on a daily basis or to correctly recall sleep times upon next-day reflection (Jungquist, Pender, Klingman, & Mund, 2015). The Readiband wrist-activity monitor used in the present study proved to be popular amongst the players due to its robust, non-intrusive nature and the ability to collect data continuously over the period of the study. The fact that there were differences between the Readiband data and the sleep diary reports in this study suggests that coaches and athletic staff should interpret self-reported sleep with caution.

Caffeine concentrations

Our results indicated that saliva caffeine levels increased by 2.37 μg/mL from pre-game to post-game testing. This would equate to a dose of 2.37 mg/kg of BW as the average mass of players was 100 kg, (Clark & Landolt, 2017; McLellan, Caldwell, & Lieberman, 2016). It is difficult to know with our data if this is within normal levels of consumption for rugby players first study to quantify caffeine consumption and the effect on sleep in rugby players.

Caffeine is beneficial for physical performance when taken at doses of 3 mg/kg BW (Lara et al., 2014). In rugby union players, a dose of 3 mg/kg BW has been shown to improve movement patterns during a simulated game (Del Coso, Ramirez, et al., 2013). At a dose of 5 mg/kg BW, caffeine can lead to a faster reaction time in taekwondo athletes (Santos et al., 2014). Thus, it is not surprising the players assessed in our evaluation would ingest caffeine thinking that such a practice would serve an ergogenic function. Unfortunately, they may not have considered the effects of caffeine on subsequent post-game recovery sleep.

Associations between caffeine and sleep

It is well known that caffeine has negative effects on sleep, even with consumption as low as 1 mg/kg BW (Drake et al., 2013). These effects include; increase in sleep latency, increase in arousals and awakenings, decreased sleep duration and a decrease in sleep efficiency (Clark & Landolt, 2017; McLellan et al., 2016). To date, there is no available data or information on the precise effects of caffeine on the recovery sleep of rugby players. Indeed, there are very few studies investigating the effects of caffeine on sleep in athletic populations. It was notable in our study that the changes in caffeine levels were moderately related to an increase in sleep latency, lower sleep efficiency and a trend to decrease sleep duration. These findings suggest that players who ingested more caffeine before the game had worse sleep after the game.

Of the limited data on caffeine and sleep in athletes, caffeine consumption of 3 mg/kg BW in male cyclists in the late afternoon significantly prolongs sleep latency and decreases sleep efficiency (Miller et al., 2014). A similar dose of caffeine, ingested by male and female athletes in the afternoon increases symptoms of insomnia by way of an increase in the number of awakenings, increasing wake after sleep onset which leads to sleep loss overnight in athletes (Salinero et al., 2014).

It is of interest in our study that that time of sleep onset (02:12, hh:mm) does not occur until the half-life of caffeine (4–6 h) has passed, some 5 h after the post-game saliva sampling (Burke, 2008). This is consistent with the existing research; sleep can be negatively affected when caffeine is consumed within 6 h of the proposed time to bed (Pallarés et al., 2013). It is unlikely that caffeine played a role in the early time at wake on the morning following a game (post-game 1), as the estimated plasma caffeine levels at the time of waking would be very low.

Self-reported caffeine consumption in athletes

Self-reported consumption of caffeine on the game night was very different to the measured changes in caffeine from the saliva samples. Specifically, only 9 players reported consuming caffeine for ergogenic benefit, however, 17 players had an increased saliva caffeine concentrations from pre-to post-game. Such a finding highlights the caution that needs to be applied to self-reported measures of caffeine consumption. It is possible that knowledge of caffeine sources is not well understood, even by professional athletes. Consistent with this, several players commented after the study that they were unaware that the supplement commonly referred to as "pre-workout" or the caffeine tablets contained caffeine.

Limitations

There are several potential limitations of this study. Firstly, the study used wrist-activity monitors to measure sleep behaviours over a 7-day period in 20 athletes. The gold-standard measurement of sleep is polysomnography; however, such an approach would not be practical or acceptable to professional sporting teams during the season. Secondly, the focus of this study was one Super Rugby home game and it is unknown how representative the sleep and caffeine data obtained from this game is of other games in a season. We were unable to obtain self-reported information on the source or quantity of caffeine consumed during the game. However, the difference between the pre- and post-game saliva concentrate samples allows an objective calculation of the change in caffeine saliva concentrates. Finally, we were limited to measuring caffeine saliva to only two time-points, pre- and post-game. Additional sampling on the days leading up to a game, and even during a game, would provide a better understanding of within- and between-individual variability in saliva concentrations, however, such measurements would be challenging to obtain in an elite professional sporting team.

Conclusion

Caffeine consumption before and during a Super Rugby game resulted in markedly increased saliva caffeine levels. The magnitude of the increase in caffeine was related to poorer sleep immediately following the game. This study highlights the need for a strategic approach to the use of caffeine within a Super Rugby team. In particular, a player education programme regarding sources of caffeine, timing, and the potential effect on sleep.

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No potential conflict of interest was reported by the authors.

Supplemental data

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