Abstract

Objective: To describe sleep behaviours of male rugby league athletes and examine the association with self-reported sleep behaviours, attitudes and knowledge. *Methods*: Twenty-two rugby league athletes completed seven consecutive nights of sleep monitoring using wrist-worn actigraphy, with the Sleep Practices and Attitudes Questionnaire (SPAQ) completed at the commencement of the monitoring period. Actigraphy measures included time in-bed(hh:mm), time out-of-bed(hh:mm), duration in bed(min), sleep duration(min), sleep efficiency(%), sleep onset latency(min), wake after sleep onset(min), and number of awakenings. The SPAQ assessed self-reported sleep behaviours, sleep hygiene practices, and sleep knowledge. Linear regressions determined associations between objective sleep measures and subjective self-reported sleep behaviours, sleep knowledge, and sleep attitudes. *Results:* Sleep behaviours showed mean bedtime at 10:25pm±45min and wake time 6:30am±25min, with 484±41min in bed. Sleep efficiency was 73±5%, resulting in a sleep duration of 355±42 min. In contrast, subjective data reported sleep duration as 7.5±1.0h. A small association was observed between lower objective sleep efficiency and longer subjective sleep duration ($p<0.05$, $r^2=0.21$). Earlier bedtimes related to better coping with chronic insomnia ($r^2=0.23$, $p= 0.02$) but showed small associations with greater in-bed activities ($r^2=0.25$, $p<0.05$). Longer time in bed and increased sleep duration had small associations with poorer coping with chronic insomnia strategies ($r^2=0.25$ and$r^2=0.24$, respectively; $p<0.05$). No associations existed between sleep behaviours and sleep knowledge ($p<0.05$). *Conclusions:* Suboptimal sleep duration (<8h) and efficiency (<85%) exist in this cohort of players, despite high sleep knowledge. Therefore, sleep education needs to consider influencing factors on sleep behaviours when designing sleep education programs.

Key Words: Sleep behaviour, Team Sport, Sleep Duration

Introduction

Sleep is widely recognised as an important component of an athlete's preparation and recovery, essential for physiological restoration, cognitive function, and performance outcomes.(Conlan et al., 2022; Lastella et al., 2020b) For rugby league athletes, the frequent exposure to high-intensity training, with high-impact collisions, increases the need for recovery, and accordingly the need for sleep volume and quality.(Fullagar et al., 2015) Current objective sleep data, using wrist worn actigraphy, suggests sub-optimal sleep durations (e.g., 6-7 h per night; (Caia et al., 2018b; Conlan et al., 2022) 1h less than the recommended 8 h per night)(Hirshkowitz et al., 2015) and varying sleep efficiency of 79-89%)(Caia et al., 2017; Conlan et al., 2022; Hirshkowitz et al., 2015). These results mimic findings (TST and SE) in other team sports with similar training and competition schedules.(Lastella et al., 2020b) Despite these findings, subjective data reports rugby league athletes overestimate their sleep duration by approximately 49 ± 42 min per night compared to objective sleep duration.(Caia et al., 2017) Underlying knowledge and attitudes influencing perceived versus actual behaviours may explain these discrepancies.(Ruggiero et al., 2019) For instance, positive attitudes and greater knowledge about consequences are associated with stronger and more consistent engagement in favourable behaviours (e.g., negative expectations (such as impaired cognitive abilities) may lead to reduced alcohol consumption).(Chawla et al., 2007; Ruggiero et al., 2019; Vitale et al., 2023) Therefore, the combination of measuring both objective and subjective sleep outcomes with an understanding of athletes' knowledge and attitudes may enhance the holistic design and effectiveness of future sleep education programs.

Measuring objective sleep behaviours is essential for understanding the recovery process in rugby league and other team sports. Polysomnography (PSG) is considered the gold standard,(Berry et al., 2012) however, the cost and invasiveness limit its feasibility in sport settings.(Jones et al., 2021) Actigraphy, using wrist-worn activity monitors, provides a valid, portable, and non-invasive

alternative(Lastella et al., 2015; Sargent et al., 2016), with reported PSG sensitivity of 80–92% for sleep and specificity of 67–82% for wakefulness, depending on the device model and thresholds used.(Sargent et al., 2016) Research using actigraphy indicates that objective sleep behaviours in rugby league athletes differ from other team sports, with shorter sleep duration, earlier sleep timing, and lower sleep efficiency compared with rugby union, Australian Rules Football, and professional soccer athletes.(Conlan et al., 2022; Lastella et al., 2015; Miller et al., 2017) These differences suggest that rugby league athletes may be particularly vulnerable to inadequate sleep behaviours. Furthermore, during periods of high training load (e.g., pre-season), sleep disturbances have been observed in team sports, with research suggesting that inadequate sleep impairs recovery, increases fatigue, and heightens risk of overreaching.(Fullagar et al., 2015) Collectively, these findings highlight the need for understanding objective sleep behaviours in rugby league athletes to inform and develop effective and tailored sleep strategies.

Evaluating subjective sleep behaviours requires consideration of an athlete's attitude towards their sleep, in terms of quality, quantity, and factors influencing their perceptions that represent key drivers of health behaviours.(Fullagar et al., 2015; Peach & Gaultney, 2017; Ruggiero et al., 2019) Sleep attitudes can be defined by the evaluation of sleep with some degree of favour or disfavour that is formed, informed, and expressed by cognitive, affective, and behavioural processes.(Peach & Gaultney, 2017) Favourable attitudes, of the consequences of a behaviour, are associated with positive engagement in any particular behaviour pattern.(Ruggiero et al., 2019) However, attitudes and perceptions may lead to positive reporting bias, potentially obscuring actual problems with sleep duration or quality.(Carter et al., 2020) To our knowledge no other studies have assessed sleep attitudes specifically in athletic populations. Emerging research in college student populations, an age group similar to that of rugby league, has shown for both objective and subjective measures, positive sleep attitudes but not greater sleep knowledge was directly associated with longer sleep duration, and

indirectly (through sleep hygiene) with better sleep quality (Peach et al., 2018). Understanding how athletes' attitudes on sleep relate to measures such as their duration or efficiency of sleep may help to develop more effective athlete sleep education and long-term behaviour change interventions.

An athlete's knowledge of recommended sleep behaviours is critical for maximising sleep quality and quantity, thereby enhancing recovery and adaptation to training and competition demands.(Conlan et al., 2022) In rugby league, educational interventions have focused on sleep hygiene practices with the expectation of achieving sustained behavioural change.(Caia et al., 2018a) Sleep hygiene practices are sleep behaviours that an athlete carries out to facilitate optimal sleep health.(Caia et al., 2018a) These behaviours include establishing and maintaining regular sleep-wake times, limiting alcohol consumption, establishing regular sleep-wake patterns and establishing sleep environments conducive to sleep.(Hirshkowitz et al., 2015) However, despite increases in sleep hygiene knowledge, there is often a poor translation of knowledge into positive behavioural changes.(Caia et al., 2018a) This disconnect may reflect the influence of habitual behaviours, environmental constraints, and sport-specific demands that limit the translation of sleep knowledge into practice.(Walsh et al., 2021) These results are also observed in other team sports, highlighting the difficulty of converting education into sustained positive behavioural change.(Driller et al., 2019; O'Donnell & Driller, 2017) Collectively, this suggests that improvements in sleep knowledge only may not lead to positive long-term behaviour change; hence, broader influencing factors should be considered when designing and implementing sleep education strategies for rugby league athletes.

Despite the recognized importance of sleep, limited research has examined objective and subjective sleep behaviours concurrently and explored how attitudes and knowledge influence these sleep behaviours in athletes. Addressing this gap may assist practitioners in designing athlete-specific sleep interventions and support strategies that better assist with sleep behaviours. Therefore, the primary aim

of this study is to firstly describe both objective and subjective sleep behaviours of professional rugby league athletes during pre-season training. Additionally, further aims were to examine the relationship between objective and subjective sleep measures, as well as examine the relationship of objective and subjective sleep behaviours with sleep attitudes and knowledge of professional rugby league athletes.

Methods

Participants

After a full description of procedures and risks, 30 professional male rugby league athletes volunteered to take part in the study and provided written informed consent. After the commencement of the study, the final cohort for analysis comprised of 22 athletes (height 186.7 ± 6.0 cm, body mass 102.5 ± 10.9 kg, and age 24.7 ± 3.6 y) who completed all procedures and measures. Eight participants were excluded due to incomplete data sets. Criteria for inclusion involved being over the age of 18 years, currently contracted to a National Rugby League (NRL) club and participating in full team training at the time of data collection. Exclusion criteria involved not being contracted to the club, being under 18 years old and athletes who did not complete all required components of the study. The study was approved by the institutional Ethics Committee (ETH21-6685 & ETH21-6476).

Overview

A week prior to sleep data collection, an initial information session was held to familiarize participants with all measures and data collection processes. Prior to data collection, demographic information, including age (y), body mass (kg) and height (cm) were collated from the club database as part of normal screening procedures within the club. Prior to the sleep assessment, participants were asked to complete the Sleep Practices and Attitudes Questionnaire (SPAQ)(Grandner et al., 2014). Following completion of the SPAQ, objective sleep behaviours were assessed and included time in bed (hh:mm), defined as the time participants went to bed with the intention of sleeping; time out of bed (hh:mm),

defined as the final morning wake time when participants stopped attempting to sleep; duration in bed (min); sleep duration (min); sleep efficiency (sleep duration/time spent in bed x 100 (SE; %)),; sleep onset latency (SOL; min); wake after sleep onset (WASO; min); and number of awakenings. These variables were collected nightly over seven consecutive nights, encompassing five training days and two rest days, to provide an overview of a typical pre-season schedule.

Objective Sleep Behaviours

Sleep patterns were monitored using actigraphy (ActiGraph GT9X Link, ActiGraph LLP, Pensacola, FL, USA) worn on the nondominant wrist (as determined by the player) and continuously recorded accelerations representing body movement (set at 60 Hz and 60-second epochs). The ActiGraph GT9X Link is validated against a previously validated accelerometer, with high sensitivity and specificity with accuracy ranging from 93% (Sadeh's algorithm) to 96% (Cole-Kripke's algorithm).(Lee & Tse, 2019) Actigraph data was analyzed using ActiLife (Florida, USA). The following commonly reported and defined variables were derived, including time in bed (hh:mm), time out of bed (hh:mm), duration in bed (min), sleep duration (min), SE (%), SOL (min), WASO (min) and number of awakenings.(Halson, 2014) Self-reported sleep diaries were used in conjunction with actigraphy to establish time in bed and time out of bed. Data recorded by sleep diaries were used to verify and identify misclassified, sleep/wake states calculated by actigraphy. Participants were provided descriptions for each point on the sleep quality scale to guide their responses. Sleep quality score (AU) was 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.(Conlan et al., 2022)

Subjective Self-Reported Sleep Behaviours, Sleep Knowledge and Sleep Hygiene Practices

The SPAQ questionnaire(Grandner et al., 2014) was used to determine the sleep behaviour, attitudes, and knowledge. The survey consisted of 15 subscales, including (a) knowledge, (b) importance, (c)

impact of sleep on performance, (d) impact of sleep on functioning, (e) self-efficacy, (f) sleep and health. Nine subscales relate to sleep behaviour (g) sleep duration, (h) sleep debt, (i) sleep quality, (j) sleepiness/tiredness, (k) coping with sleepiness, (l) coping with acute insomnia, (m) coping with chronic insomnia, (n) activities in bed, and (p) sleep environment. Subscales (g; sleep duration) were evaluated relative to the previously validated sleep surveys (Pittsburgh Sleep Quality Index (PSQI) and Sleep Hygiene Index).(Grandner et al., 2014) Subscales (d; impact on sleep), (f; sleep and health), and (e; self-efficacy) capture aspects of overall sleep quality and were evaluated relative to their ability to distinguish adequate from inadequate sleepers on the PSQI. The SPAQ has variable validity with a Cronbach's alpha of 0.251–0.864 for the different subscales.(Ali et al., 2020) In our study, the SPAQ was adapted to the specific rugby league demographic to include questions on the effect of sleep on performance, the inclusion of rugby league staff and social media as sleep information sources and adapted to fit in with extra technology (iPad/Phone). Each subscale had its own separate score, thus there is no presence of impact on an overall score from these customized items.(Grandner et al., 2014) All subscales were collated and presented as means and included as predictor variables in the regression analyses. Before commencing the survey, participants were provided with standardised definitions of all relevant sleep terminology (including sleep efficiency, acute and chronic insomnia, and sleep debt) to minimise misinterpretation and improve response consistency. All athletes completed the online survey without assistance using a personal electronic device, with data entered via Research Electronic Data Capture.

Statistical Analysis

Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS, version 27, Chicago, IL, USA). All data were assessed for normality using the Shapiro–Wilk test. Results are reported as mean ± SD, with statistical significance set at $p < 0.05$. Mean ± SD subscale scores were calculated using a 5-point Likert scale, where 1 = strongly agree and 5 = strongly disagree,

with lower scores indicating greater agreement with the statement. To examine the relationship between objective and subjective sleep measures, linear regression analyses were conducted using objective sleep metrics (time in bed (hh:mm), time out of bed (hh:mm), duration in bed (min), sleep duration (min), efficiency (%), SOL (min), WASO (min) and number of awakenings) as outcome variables and collated sub-scales of subjective self-reported sleep behaviours, sleep knowledge, and sleep attitudes as predictor variables. Secondly, to determine associations between subjective self-reported behaviours and sleep knowledge and attitudes, linear regression analyses were conducted using self-reported behaviours (sleep quality, sleep duration, sleep need, sleep debt, sleep difficulty, and self-efficacy) as outcome variables and collated sub-scales of sleep knowledge and sleep attitudes as predictor variables. Unstandardized regression coefficients (β) and 95% CIs were reported. The strength of these associations was quantified using the coefficient of determination (r^2) and interpreted based on conventional thresholds: small (r^2 = 0.10–0.29), moderate (r^2 = 0.30–0.49), and large (r^2 = 0.50–1.0).(Cohen, 1988)

Results

Objective Sleep Behaviours

An overview of the objective sleep behaviours is provided in Figures 1 and 2. The mean (± SD) bedtime for all athletes was 10:25pm ± 45 min (hh:mm) and wake time 6:30am ± 25 min (hh:mm). Duration in bed was 484.6 ± 41min (8.1 ± 0.7 h), sleep duration was 355.2 ± 42min (5.9 ± 0.7 h), SE was 73 ± 5%, WASO was 121.7 ± 27 min, SOL was 7.8 ± 4 min, and number of awakenings was 31.0 ± 5.9.

195 [Figure 1 Here]

196

197 **Figure 1:** Mean ± SD of (A) Time in Bed (hh:mm) and (B) Time out of bed (hh:mm) of rugby league

198 athletes (n=22) during one week of pre-season.

199

200 [Figure 2 Here]

201

202 **Figure 2:** Mean ± SD of objective sleep variables of rugby league athletes (n=22) during one week of
203 pre-season. (A) Duration in Bed (min). (B) Sleep Duration (min). (C) Sleep Efficiency (%). (D) Wake
204 After Sleep Onset (min). (E) Sleep Onset Latency (min). (F) Number of Awakenings.

205

Associations Between Objective Sleep Measures and Subjective Behaviours

Associations between subjective and objective sleep measures (Table 1) showed there was a small negative, significant association between SE and self-reported sleep duration (r^2=0.21, p=0.03, β=-0.45). WASO showed a small positive, significant association between self-reported sleep duration (r^2=0.24, p =0.02, β=0.47) and sleep need (r^2=0.24, p=0.02, β 0.47). Number of awakenings showed a small positive significant association between self-reported sleep debt and sleep difficulty (r^2=0.26, p=0.01, β=0.51; r^2=0.12, p=0.04, β=0.45) respectively. Number of awakenings showed a moderate, positive significant association between self-reported sleep need (r^2=0.33, p=0.01, β=0.57). No other significant relationship existed between objective sleep behaviours and subjective self-reported sleep behaviours (p > 0.05).

217 [Table 1 Here]

218 **Table 1:** Sleep Behaviour Associations with Self-Reported Sleep Duration, Need, Difficultly, Self-
219 Efficacy And Debt of Professional Rugby League Athletes (n = 22) During a Typical Pre-Season Week.
220

Associations Between Objective Sleep Measures and Subjective Attitudes

For sleep hygiene practices (Table 2) there was a small positive significant association between objective in bedtime and coping with chronic insomnia (r^2 =0.23, p= 0.02, β=0.48). Objective in bedtime also showed a small negative significant association with activities in bed (r^2=0.25, p =0.02, β= -0.50). Objective duration in bed and sleep duration both showed a small negative significant association with coping with chronic insomnia (r^2=0.25, p =0.02, β= -0.50, r^2=0.24, p =0.02, β= -0.49) respectively. WASO showed a small negative significant association with coping with sleepiness (r^2=0.18, p =0.05, β= -0.43). No other significant relationship existed between objective sleep behaviours and subjective sleep hygiene practices (p > 0.05).

230 [Table 2 Here]

231

232 **Table 2:** Sleep Behaviour Associations with Sleep Practices; Coping with Sleepiness, Acute

233 Insomnia, Chronic Insomnia, Activities in Bed, and the Sleep Environment in Professional Rugby

234 League Athletes (n = 22) During a Typical Pre-Season Week.

Associations Between Objective Sleep Measures and Subjective Sleep Knowledge

For sleep knowledge (Table 3) there were no significant associations ($p > 0.05$, $r^2 = 0.00\text{-}0.19$) between objective sleep behaviours.

240 [Table 3 Here]

241 **Table 3:** Sleep Behaviour Associations with Sleep Knowledge Scores; General, Rugby League
242 Performance, Health, External Factors and Daytime Functioning in Professional Rugby League
243 Athletes (n = 22) During a Typical Pre-Season Week.

244

245

Associations Between Subjective Sleep Behaviours and Subjective Attitudes and Sleep Knowledge

Subjective sleep behaviours (mean ± SD) are shown in Tables 1-3. For associations between self-reported behaviours, there was a small positive association between self-reported sleep duration and self-reported sleep difficulty (r^2=0.19, p=0.04, β=0.44). Self-reported sleep duration also showed a small negative association with coping with sleepiness and coping with acute insomnia (r^2=0.24, p=0.02, β=-0.49, r^2=0.26, p=0.02, β=-0.510) respectively. For self-reported sleep need, there was a moderate positive association between self-reported sleep need and sleep difficulty (r^2=0.32, p=0.01, β=0.57). Self-reported sleep need also showed a small negative association with coping with sleepiness (r^2=0.22, p=0.03, β=-0.47).

Discussion

The primary aim of this study was to describe objective and subjective sleep behaviours of professional rugby league athletes concurrently during pre-season training. A secondary aim was to examine the relationship between objective and subjective sleep behaviours, attitudes and knowledge of professional rugby league athletes. Professional rugby league athletes in this cohort had an in-bedtime of 10:25pm ± 45 min and wake time 6:30am ± 25 min, resulting in an in-bed duration of 484 ± 41min (8.1 ± 0.7 h). However, with SE of 73 ± 5%, actual sleep duration was 355 ± 42 min (5.9 ± 0.7 h), which is below adult sleep recommendations (7–9 h and 79-89% SE).(Caia et al., 2017; Caia et al., 2018a; Caia et al., 2018b; Conlan et al., 2022; Hirshkowitz et al., 2015) In contrast, subjective data reported sleep duration as 7.5 ± 1.0 h and subjective sleep need was 7.8 ± 1.3 h, which both align with adult sleep recommendations.(Hirshkowitz et al., 2015) When examining the relationship between objective and subjective self-reported sleep behaviours, athletes with a lower objective SE reported longer subjective sleep duration. Secondly, earlier bedtimes related to better coping with chronic insomnia but also greater in-bed activities, whereas longer time in bed and increased sleep duration were linked to poorer coping with chronic insomnia strategies. Furthermore, higher awakenings were

associated with greater perceived debt, need, and difficulty, reflecting poorer subjective experiences. Finally, no associations existed between objective measures and sleep knowledge scores. These findings suggest that during a pre-season period, rugby league athletes may obtain insufficient sleep duration, potentially due to insufficient SE and may overestimate their sleep duration. Although these observations are based on a one-week monitoring period, they highlight the importance of considering sleep attitudes and behaviours when designing sleep education in rugby league, regardless of the level of prior sleep knowledge.

Sleep in athletic populations needs to be of suitable duration and satisfactory quality, as insufficient sleep can decrease physiological restoration, cognitive function, and optimal performance outcomes.(Conlan et al., 2022; Lastella et al., 2020b) This study showed even though professional rugby league athletes did follow recommended behaviours for in-bed times (10:25pm ± 45min) and wake up times (6:30am ± 25min), they did not meet (355 ± 42 min (5.9 ± 0.7 h)) recommended sleep duration guidelines (8h),(Hirshkowitz et al., 2015) primarily due to reduced SE (73± 5%). Previous research has shown similar findings, whereby rugby league athletes spent a similar time in bed when compared to other team sport athletes, but have lower sleep duration due to lower SE.(Lastella et al., 2015) Previous research has highlighted an athlete's sleep is influenced by a combination of sport-specific and non-sport-specific factors, including training and competition demands, travel, environmental conditions, psychosocial stressors, and individual characteristics such as age and body composition (Walsh et al., 2021).For example, previous research in athletes has shown that higher training loads are negatively associated with SE (and this study was conducted during pre-season), whereas earlier bedtimes and less variable sleep onset times positively associated with SE.(Halson et al., 2022; Walsh et al., 2021) Other considerations may include mobile phone use, with research in general populations showing it as a predictor of poorer SE, particularly among young adults, an age group comparable to rugby league populations.(Exelmans & Van den Bulck, 2016; Lastella et al.,

296 2020a) Furthermore, consideration could also be given to sport and non-sport specific factors. (Walsh
297 et al., 2021) Therefore, further research is warranted to identify factors contributing to reduced SE in
298 rugby league populations, with the aim of informing targeted interventions to improve overall sleep
299 duration in rugby league athletes.
300
301 This is the first study that provides novel insights on the relationship between sleep behaviours and
302 attitudes with objective sleep measures in professional rugby league athletes. Subjective data reported
303 perceived sleep duration as 7.5 ± 1.0h and sleep need was 7.8 ± 1.3h, which aligns with adult sleep
304 recommendations.(Hirshkowitz et al., 2015) However, when compared to objective sleep duration
305 (355 ± 42 min (5.9 ± 0.7 h)), athletes systematically overestimated their perceived sleep durations,
306 which aligns with other reports from athletic and general populations.(Caia et al., 2017; Lauderdale
307 et al., 2008) Athletes may perceive they were in bed long enough without recognizing periods of
308 wakefulness. However, our results showed those who experienced more frequent awakenings reported
309 greater perceived sleep debt, higher sleep need, and increased sleep difficulty, indicating a poorer
310 subjective sleep experience. Furthermore, research in male general populations have shown sleep
311 attitudes appear to better predict sleep hygiene behaviours, with positive sleep attitudes (but not greater
312 sleep knowledge) directly associated with longer sleep duration, and indirectly (through sleep hygiene)
313 with better sleep quality. Understanding this relationship is critical for developing targeted athlete sleep
314 education programs that translate attitudes into sustainable behaviour change within rugby league
315 populations.
316
317 Interestingly, no significant associations were observed between sleep knowledge scores and objective
318 and subjective sleep measures. The present study indicated that athletes agreed that general sleep
319 knowledge (2.5 ± 0.4), the influence of rugby league on sleep (1.6 ± 0.7), sleep health (2.4 ± 0.4), the
320 influence of external factors (2.9 ± 0.4), and daytime functioning (2.2 ± 0.7) were associated with sleep

outcomes. These findings suggest that although rugby league athletes possess sound theoretical knowledge about sleep-related factors, this knowledge may not translate into favourable objective and/or subjective sleep behaviours. Previous research in rugby league players has focused on educational interventions aimed at improving sleep hygiene knowledge;(Caia et al., 2018a; Driller et al., 2019; O'Donnell & Driller, 2017) however, despite increases in knowledge, these improvements have not consistently led to long-term behavioural change or better sleep quality.(Caia et al., 2018a) This disconnect between knowledge and behaviour has also been reported in other team sports, suggesting that knowledge alone may be insufficient to modify ingrained sleep behaviours.(Driller et al., 2019; O'Donnell & Driller, 2017) An implication of these results may be the need to move beyond reliance on educational strategies alone. Such findings suggest that while athletes may have knowledge of sleep hygiene strategies, behavioural practices don't align with these sleep hygiene strategies (e.g., screen use in bed). Therefore, sleep interventions (and future research) should extend beyond improving knowledge and target behavioural factors (environmental conditions, psychosocial stressors, and individual characteristics such as age and body composition)(Walsh et al., 2021) that may influence athletes' sleep behaviour.

Given the nature of the present study and the difficulties of conducting research on professional athletes, we acknowledge several limitations. Firstly, rugby league athletes were examined from one club, which could lead to a sample bias. Due to the applied nature of this study and constraints associated with recruitment within an elite sporting organisation, a sample size calculation was not feasible. Furthermore, only the SPAQ was used as the validated survey; as the SPAQ provided a comprehensive assessment of sleep by capturing sleep behaviours alongside attitudes, beliefs, and perceived importance of sleep, allowing identification of behavioural and attitudinal factors that may contribute to suboptimal sleep behaviours. However further research using this tool is needed in athletic populations. As sleep behaviours were not collection prior to the pre-season period, the results

may only reflect pre-season sleep during this seven-day period training, rather than habitual or routine sleep patterns. Additionally, participants were not screened for sleep disorders or medication use, which may partly explain low sleep efficiency despite longer time in bed. Also, as this study was conducted in a field-based setting, there were uncontrollable factors that may have affected subjects' sleep (e.g., caffeine and alcohol consumption). In addition, the amount and quality of sleep obtained by the athletes was assessed using wristwatch actigraphy rather than PSG. Finally, there is a possibility of overestimation issues (e.g. subjective sleep duration) with athlete reporting as noted in previous research.(Caia et al., 2018b) Ideally, future research would use characteristics found in this study and trial these in an intervention conducted over a larger rugby league-wide sample, to determine potential improvements in both objective and subjective sleep outcomes.

Practical Applications

- Consistent monitoring of both subjective and objective sleep outcomes should be implemented as they provide complementary information on sleep behaviours. .
- Sleep education strategies should incorporate sleep attitudes and behavioural practices (e.g., in-bed activities), as sleep knowledge alone was not associated with improved objective or subjective sleep outcomes.
- Practitioners working with rugby league athletes could look at prioritising strategies that improve SE**,** rather than increasing time in bed, to increase total sleep duration.

Conclusions

The current investigation shows that athletes spent over eight hours in bed, with low SE (73.2 ± 5.3%) and reduced actual sleep 5.9 ± 0.7h. In contrast, self-reported duration (7.5 ± 1.0h) and perceived need (7.8 ± 1.3h) were within recommendations, highlighting the tendency to overestimate sleep. Earlier bedtimes related to better coping with chronic insomnia but also greater in-bed activities, whereas

longer time in bed and increased duration were linked to poorer coping, suggesting extending time in bed is insufficient without addressing underlying behaviours. Greater number of awakenings were associated with greater perceived debt, need, and difficulty, reflecting poorer subjective experiences. Athletes demonstrated strong knowledge of sleep, yet this did not consistently translate into improved behaviours, indicating education alone may not be effective. Future strategies should combine education with behaviour focused interventions to promote sustained improvements in objective sleep among rugby league athletes.

Author Contribution

All authors contributed to the study design. AS and BH were responsible for the data collection. AS was involved with analyzing the data as well as drafting the manuscript. RD and HF were responsible for critically reviewing the manuscript. All authors approved the final version of the paper.

Data Availability

Due to the participant's being professional sportsman in the public domain, supporting data is not available for this research.

Institutional Review Board Statement

This study was conducted in accordance with the Declaration of Helsinki and was approved by an Institutional Review Board/Ethics committee (ETH21-6685 & ETH21-6476). See details under Methods.

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