CREATION OF A BEHAVIOURAL SLEEP INTERVENTION FOR STUDENT-ATHLETES

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Abstract

Introduction: Sleep is a fundamental behavioural state linked to various aspects of health and wellbeing. However, student-athletes often experience suboptimal sleep health across multiple dimensions. This thesis sought to assess sleep health amongst British student-athletes, identify the upstream influences that underpin suboptimal sleep health, and design and evaluate a behavioural sleep intervention targeted towards British student-athletes.

Methods: Five linked studies were conducted: a scoping review mapping behaviour change techniques in athlete sleep interventions; a cross-sectional survey examining self-reported sleep in British student-athletes; an actigraphy-based assessment of sleep in a team undergoing early morning training; semi-structured interviews exploring the barriers to sleep health; and the development and pilot testing of a behavioural sleep intervention.

Results: The scoping review identified limited use of behaviour change theory in existing interventions, and informed the approach taken to intervention development. The survey revealed suboptimal sleep health across dimensions such as duration and regularity, with frequent morning training predicting poorer sleep outcomes. Actigraphy findings indicated significant irregularity in sleep patterns among student-athletes exposed to early training, with a median Sleep Regularity Index (67.0) lower than previous findings in student and athlete populations. Reflexive thematic analysis of interviews identified key barriers to sleep and were mapped onto the COM-B model to guide intervention development. The resulting pilot intervention, featuring a workshop and personalised feedback incorporating nine behaviour change techniques, did not yield significant improvements in sleep outcomes, affect, or mental wellbeing. A planned adjustment to training schedules—a potentially impactful element—was not implemented due to logistical constraints.

Conclusion: British student-athletes exhibit suboptimal sleep health, with early morning training scheduling as a significant contributing factor. Stakeholders should prioritise addressing training timing to mitigate negative effects on sleep and health. This thesis demonstrates the utility of integrating behaviour change theory into intervention design and provides a framework for developing sleep health interventions in similar populations.

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Publications

The following findings within this thesis have been peer-reviewed and published as journal articles:

1. Wilson, S. M. B., Sparks, K. V., Cline, A., Draper, S. B., Jones, M. I., & Parker, J. K. (2024). Behavioral interventions and behavior change techniques used to improve sleep outcomes in athlete populations: A scoping review. *Behavioral Sleep Medicine*, 31, 1-23. https://doi.org/10.1080/15402002.2024.2374257
2. Wilson, S. M. B., Jones, M. I., Draper, S. B., & Parker, J. K. (2024). Early morning sport scheduling is associated with poorer subjective sleep characteristics in British student-athletes. *Scandinavian Journal of Medicine and Science in Sports*, 34(3):e14598. https://doi.org/10.1111/sms.14598
3. Wilson, S. M. B., Jones, M. I., Draper, S. B., & Parker, J. K. (2025). Irregular sleep/wake patterns in student-athletes exposed to early morning training. *Journal of Sports Sciences*. Advance online publication. https://doi.org/10.1080/02640414.2025.2452726

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1. Wilson, S., Draper S., Jones, M., & Parker, J. (2023). O11 Irregular sleep/wake patterns in student-athletes. *BMJ Open Respiratory Research, 10*(S1), A6-A7. https://doi.org/10.1136/bmjresp-2023-bssconf.11
2. Wilson, S. M. B., Jones, M. I., Draper, S. B., & Parker, J. K. (2023). D2.S1.3(1) The napping behaviours of British student-athletes. *Journal of Sports Sciences, 41*(S1), 16. https://doi.org/10.1080/02640414.2023.2258666
3. Wilson, S., Draper, S., Jones, M., & Parker, J. (2024). P1398 Evaluation of a targeted behavioural sleep intervention for student-athletes. *Journal of Sleep Research, 33*(S1), 594. https://doi.org/10.1111/jsr.14291

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List of abbreviations

APEASE - acceptability, practicability, effectiveness, affordability, side-effects, and equity criteria

ASBQ – Athlete Sleep Behaviour Questionnaire

ASSQ - Athlete Sleep Screening Questionnaire

BCT – Behaviour Change Technique

BCTTv1 - Behaviour Change Technique Taxonomy version 1

BCW – Behaviour Change Wheel

BUCS - British Universities and Colleges Sport

COM-B – ‘capability, opportunity, motivation – behaviour’ model

ESS - Epworth Sleepiness Scale

NCAA - National Collegiate Athletics Association

NREM – non-rapid eye movement

PANAS – Positive and Negative Affect Schedule

PRISMA-ScR - Preferred Reporting Items for Systematic Reviews and Meta-Analysis Extension for Scoping Reviews

PSQI - Pittsburgh Sleep Quality Index

REM – rapid eye movement

rMEQ – Reduced Morningness-Eveningness Questionnaire

RTA – reflexive thematic analysis

SATED - satisfaction, alertness, timing, efficiency, and duration (dimensions of sleep health)

SE – sleep efficiency

SHI – Sleep Hygiene Index

SOL – sleep onset latency

SRI – Sleep Regularity Index

TST – total sleep time

WASO – wake after sleep onset

WEMWBS - Warwick-Edinburgh Mental Well-being Scale

CHAPTER ONE: INTRODUCTION

1.1. Background

Sleep can be conceptualised as a "reversible behavioural state of perceptual disengagement from and unresponsiveness to the environment" and is considered a fundamental state essential for human functioning (Carskadon & Dement, 2005, p. 13). The importance of sleep is underscored by its association with numerous short- and long-term health consequences, including stress, psychosocial functioning, increased morbidity, and mortality (Medic et al., 2017). Despite its critical role in health and wellbeing, many people experience difficulties with sleep. While evidence suggests that overall sleep durations may not have declined in modern society, disrupted and shortened sleep remain prevalent issues, representing an important public health concern (Bin et al., 2012; Youngstedt et al., 2016).

Sleep has gained significant attention in athlete populations due to research highlighting a high prevalence of undesirable sleep characteristics, such as short nocturnal sleep durations (e.g., Lastella et al., 2015) and irregular sleep/wake patterns (e.g., Halson et al., 2022). These findings are attributed to sport-specific upstream influences including training, travel, and competition, in addition to non-sport factors (Walsh et al., 2020). Improved sleep in athletes could offer benefits such as improved muscular recovery, which may improve performance, although evidence supporting this link is inconsistent (Fullagar et al., 2015). Nevertheless, in a sector where marginal gains are highly valued, improving sleep may yield broader benefits for both performance and health. As a result, there is growing interest in sleep interventions for athletes (Bonnar et al., 2018).

Student-athletes, who combine participation in performance sports with higher education (Wylleman et al., 2017), represent a unique sub-population of athletes, with over 33,000 student-athletes registered with British Universities and Colleges Sport (BUCS, 2019). While findings from elite athlete sleep research have been applied to student-athletes, these often overlook the additional sleep-related risk factors related to university study. Indeed, university students are another population characterised by a high prevalence of poor sleep, driven by factors such as exams and financial stress (e.g., Lund et al., 2010). The combined demands of sport and study may interact and exacerbate sleep difficulties, highlighting the need to consider student-athletes as a distinct population in sleep research. Emerging research indicates that student-athletes display undesired sleep characteristics, potentially at a higher prevalence than elite athletes (Kroshus et al., 2019). However, significant gaps remain, particularly in the study of British student-athletes, as most research has focused on international student-athletes such as those competing in the American collegiate system despite potential differences in factors that can influence sleep (e.g., academic structures).

Historically, sleep has been viewed in terms of the presence or absence of sleep disorders. However, recent research has considered 'sleep health', which conceptualises sleep as a continuum comprising multiple dimensions, where all individuals stand to benefit from improvements in one or more dimension (Buysse, 2014; Hale et al., 2020). This approach is particularly suited to student-athlete populations, where poor sleep characteristics are a product of the dual demands of sport and study. Evidence of this is seen in clear improvements in sleep during periods where demands in one or both domains are reduced or removed, such as holidays (e.g., Astridge et al., 2021). While sleep regulation is underpinned by circadian and homeostatic biological processes, sleep is significantly influenced by social-environmental contexts, with individual, social, and societal factors all playing a role (Grandner, 2017). Thus, identifying the factors that influence sleep health in student-athletes, many of which may be modifiable, is crucial to determining the most effective strategies to improve it.

Taking the view that upstream factors influence and act upon sleep health, it is appropriate to approach sleep in student-athletes through a behavioural lens. Behavioural sleep interventions, such as educational resources and workshops, have previously been implemented in this population (Harada et al., 2016; Kaier et al., 2016). However, despite evidence that incorporating behavioural theory into health interventions improves outcomes (Glanz & Bishop, 2010), there has been minimal application of behavioural theory in the design of athlete sleep interventions (Halson, 2019). Frameworks like the Behaviour Change Wheel, which integrate behaviour change principles to create targeted interventions (Michie et al., 2011), have been widely used in other health behaviours such as physical activity but remain underutilised in sleep research.

1.2. Research objectives

The overarching aim of this thesis was to examine sleep in a student-athlete population, addressing gaps in the current literature. This aim is divided into three specific research objectives:

1. To assess sleep health amongst British student-athletes
2. To identify the upstream influences that underpin suboptimal sleep health in British student-athletes
3. To design and evaluate a behavioural sleep intervention targeted towards British student-athletes

These objectives were specified based on contemporary literature discussed in Chapter 2, and each research study is directly linked to one or more of these objectives. A detailed research agenda is provided in Chapter 3.

1.3. Thesis Overview

The thesis comprises eight chapters following this introduction:

- Chapter 2: A narrative review that provides an overview of sleep in humans and examines previous research in student-athlete populations.
- Chapter 3: A research agenda that details the research objectives, and the methodological approach used to address these objectives.
- Chapter 4: A scoping review that assesses existing athlete sleep interventions from a behavioural perspective to inform future intervention development. *
- Chapter 5: A cross-sectional survey that evaluates subjective sleep characteristics within a cohort of British student-athletes. *
- Chapter 6: A longitudinal examination of sleep parameters in a team of student-athletes exposed to early morning training sessions. *
- Chapter 7: Semi-structured interviews exploring perceptions of sleep in student-athletes to identify upstream influences and downstream consequences for sleep health.

- Chapter 8: The development and pilot testing of a behavioural sleep intervention targeted towards student-athletes.
- Chapter 9: A summary and discussion of key findings, limitations, theoretical implications, and practical recommendations arising from this research.

* The research presented in Chapters 4, 5, and 6 has been previously published in peer-reviewed academic journals. These chapters are based on the published works but have been adapted for this thesis, including additional information and removing redundant text where appropriate.

CHAPTER TWO: NARRATIVE REVIEW ON SLEEP HEALTH IN THE STUDENT-ATHLETE

2.1. Rationale

This narrative review provides a background on previous sleep research relevant to this thesis. It will first offer a brief overview of human sleep regulation and introduce the concept of sleep health, which is used throughout the thesis. The review then examines existing sleep research on student-athletes. This expands upon previous reviews by Brauer et al. (2019) and Kroshus et al. (2019), which relied heavily on research with elite athletes due to the limited student-athlete literature available at that time. Although a range of studies have been conducted since 2019, the review will refer to research on elite athletes or university students where it offers important insights not yet examined in student-athletes or enables relevant comparisons. A narrative literature review was conducted for this chapter to provide a comprehensive overview, drawing upon evidence from diverse fields (e.g., sleep science, athlete wellbeing, applied interventions) and employing varied methodologies (e.g., cross-sectional, experimental, and analytical; Grant & Booth, 2009). This approach allows for the identification of literature gaps to inform the research agenda and methodology outlined in Chapter 3, rather than aiming to address a specified objective.

2.2. Overview of sleep in humans

2.2.1. The role of sleep

Sleep is a dynamic process that can be considered a "reversible behavioural state of perceptual disengagement from and unresponsiveness to the environment" (Carskadon & Dement, 2005, p. 13). Sleep is distinguishable from wakefulness by observable and unobservable signs, which may be physiological (e.g., brain activity) or behavioural (e.g., quiescence). The essential role of sleep is most apparent when considering its evolution in some form in all mammals, despite the negative selective pressures associated with a period of reduced consciousness and arousal (Cirelli & Tononi, 2008). There is no consensus on the primary functions of sleep from an evolutionary perspective. Proposed theories include immune functions to recover from disease, reduced caloric expenditure, increased energy metabolism in the brain, a glymphatic function for the removal of waste products, restoration of performance during wake, and neuronal plasticity. However, sleep likely has multiple primordial and other co-evolved functions (see review by Krueger et al., 2016).

Regardless of any evolutionary functions, the importance of sleep is best demonstrated when examining the consequences of insufficient sleep. Sleep disruption has been associated with various short-term (e.g., increased stress) and long-term (e.g., increased prevalence of morbidity) health effects (e.g., Medic et al., 2017). Additionally, experimental sleep restriction (partial sleep loss) and deprivation (total sleep loss) can impair cognitive performance and physiological functioning (Cundrle et al., 2014; Killgore, 2010; Van Dongen & Dinges, 2005).

2.2.2. Sleep structure

Although sleep is often perceived as a single global state, it is a dynamic process comprising distinct phases of brain activity, which can be differentiated through electrophysiological signals using electroencephalograms and other physiological measurements. Using the sleep scoring nomenclature established by the American Academy of Sleep Medicine (Iber et al., 2007), sleep is categorised into two primary states: rapid eye movement (REM) and non-rapid eye movement (NREM).

The lightest stage of NREM sleep is termed N1 and serves as a transitional phase between wakefulness and sleep (Iber et al., 2007). The next stage in depth, termed N2, is characterised by the appearance of brain patterns not observed during wake such as K-complexes and sleep spindles. The deepest NREM stage, termed N3 and often referred to as ‘deep sleep’, can be identified by low-frequency, high-amplitude electroencephalogram waves. In contrast, REM sleep can be considered as distinct from NREM states as it is from wakefulness (Sullivan et al., 2021). The REM sleep stage is named for the characteristic bursts of eye movements, with additional distinguishing features including skeletal muscle atonia and heightened brain activity comparable to wakefulness. The function of each sleep stage in relation to health remains unclear as the neural mechanisms that regulate sleep pose challenges to identifying specific roles for each stage. For instance, while REM sleep is often considered to be the critical stage for memory consolidation, the empirical evidence to support this perception is mixed (Siegel, 2011), and the complexity of sleep makes disentangling specific functions very challenging. Nonetheless, both REM and NREM sleep contribute to a behavioural state that is essential for life and optimal functioning.

In healthy young adults, REM and NREM sleep stages alternate in a cyclical pattern with each NREM-REM cycle lengthening slightly throughout the sleep episode, averaging 90–110 minutes. A typical nocturnal sleep episode for a young adult consists of about 20-25% REM, 10-20% N3, and 45-60% N1/N2. However, sleep stage distribution exhibits significant age-related changes, with notable reductions in N3 and REM as age increases in adults (Ohayon et al., 2004). Additionally, the distribution of sleep stages varies throughout the sleep episode (Figure 2.1). The N3 stage is the dominant NREM sleep stage in earlier cycles due to the influence of the homeostatic sleep system (Riedner et al., 2007). Meanwhile, REM sleep episodes are extended in later sleep cycles, influenced by circadian processes (Sullivan et al., 2021).

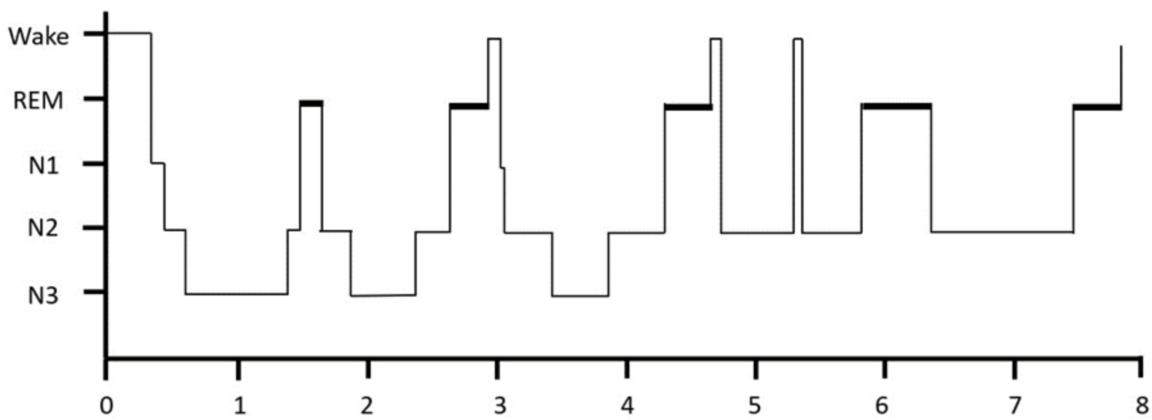

Figure 2.1. Example hypnogram showing the typical progression of sleep stages through the night in a healthy young adult, with increased N3 stage sleep earlier in the sleep episode and increased REM towards the end of the sleep episode.
Adapted from Tubbs, A. S., Dollish, H. K., Fernandez, F., & Grandner, M. A. (2019). The basics of sleep physiology and behaviour. In M. A. Grandner (Ed.), Sleep and health (pp. 3-10). Academic Press. Copyright 2021 by Elsevier. Adapted with permission.

2.2.3. Sleep regulation

A coordinated network of interactions between brain regions including the brainstem, hypothalamus, thalamus and cerebrum, regulate the control of sleep/wake cycles and the transition between sleep/wake states. This is achieved through the release of neuromodulators such as dopamine, histamine, norepinephrine, acetylcholine, serotonin, and orexin which project to various brain regions and have different discharge patterns dependent on sleep/wake state (Tubbs et al., 2019). For example, acetylcholine originating from laterodorsal tegmentum/pedunculopontine tegmentum neuron clusters include two distinct populations: one discharges maximally during wakefulness and REM states, while the other discharges only during wakefulness (Watson et al., 2010). The neurochemical control of sleep is understood to manage the transition between sleep and wakefulness through two mutually inhibitory systems, termed the flip-flop model (Saper et al., 2001).

At a broader level, the two-process model of sleep regulation is a prominent framework for describing the biological control of sleep and how sleep/wake cycles adjust in timing and duration in response to individual needs (Borbély, 1982). The framework posits that sleep regulation has two distinct but intertwined processes: a homeostatic sleep drive (Process S) and a circadian cycle (Process C; Figure 2.2).

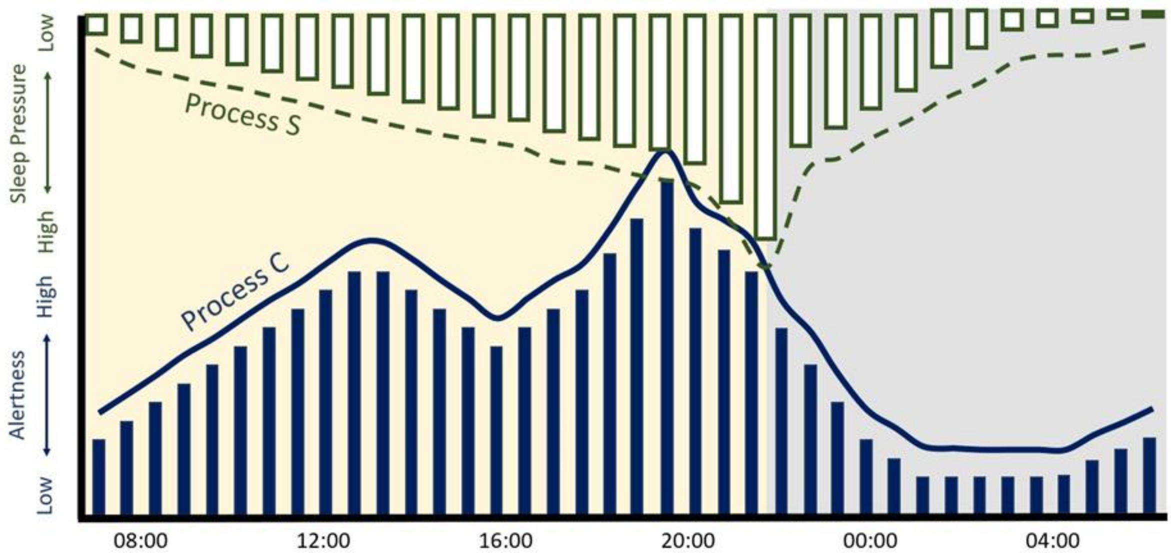

Figure 2.2. Example of the two-process model showing interaction between Process S and C to drive sleep. As homeostatic sleep drive increases and circadian alertness lowers early in the night, a 'sleep gate' opens where the transition from wake to sleep is facilitated. Adapted from Tubbs, A. S., Dollish, H. K., Fernandez, F., & Grandner, M. A. (2019). The basics of sleep physiology and behaviour. In M. A. Grandner (Ed.), Sleep and health (pp. 3-10). Academic Press. Copyright 2021 by Elsevier. Adapted with permission.

Process S reflects the propensity to sleep, accumulating as 'sleep pressure' throughout the day until reaching an upper threshold where a transition from wakefulness to sleep is facilitated, and dissipating at a lower threshold where the opposite transition occurs. However, reaching this upper threshold does not automatically result in a transition to sleep, as the individual may voluntarily remain awake. Alternatively, stimulants such as caffeine can mask sleep pressure by antagonising adenosine binding at A_1 and A_{2A} receptors in the brain (Landolt et al., 2004). Similarly, an insufficient sleep period (e.g., waking early by an alarm) may not dissipate sleep pressure accumulated from the previous day to the lower threshold and impact future sleep/wake regulation (Borbély, 1982).

In addition, Process C represents the circadian cycle, which governs the fluctuation in sleep propensity over a period of approximately 24-hours. The circadian system is regulated by a central biological pacemaker—the suprachiasmatic nucleus in the hypothalamus (Aschoff, 1981). The suprachiasmatic nucleus has an endogenous period of just over 24-hours in most individuals (Czeisler et al., 1999), but is influenced by external environmental cues, known as 'zeitgebers' (*German, translates to 'time givers'),* with light being the most influential zeitgeber (Roenneberg et al., 2007). This entrains the circadian period to a near 24-hour rhythm, generating daily oscillations in physiological parameters such as body temperature and hormone release that impact sleep/wake cycles (Czeisler & Gooley, 2007). With respect to the two-process model, Process C reflects a rhythm of alertness, with alertness reaching a peak in the early evening and a nadir in the early hours before waking. However, the timing of when an individual's clock entrains to the 24-hour light-dark cycle in nature – termed chronotype – can differ substantially. There is a large inter-individual variation in chronotype, in addition to age-dependent changes, with a peak in eveningness (entrainment of the circadian clock to later timing) observed during young adulthood (Roenneberg et al., 2004).

When Process S and C are synchronised, they interact to create a 'sleep gate' that opens during the evening when homeostatic sleep pressure is high, and circadian alertness is decreasing. This alignment promotes a stable and predictable sleep/wake pattern over each 24-hour period. However, as each process is regulated independently, they can become desynchronised (Borbély, 1982).

2.2.4. Sleep health

While the two-process model provides a biological basis to understand sleep/wake timing and duration, it does not account for the external factors that influence sleep practices (Grandner, 2017). The contemporary concept of sleep health offers a more holistic view that considers the various influences that act upon sleep practices (Buysse, 2014). This also aligns with the evolving view of health as a continuum across multiple dimensions (World Health Organization, 2020), marking a move away from the binary view of sleep as healthy or dysfunctional and that can be applied to all individuals. Framing sleep in this way is especially relevant for populations where sleep may not present as a disorder, but where improvements in sleep health could yield benefits for overall health and wellbeing (Hale et al., 2020), such as student-athletes. Sleep health can also be tailored to various populations, accounting for factors like age-related changes in sleep duration (Hirshkowitz et al., 2015).

The concept of sleep health was introduced by Buysse (2014), who described it as a pattern of sleep/wake behaviour adaptable to individual, social, and environmental demands, and that promotes wellbeing. Buysse proposed five primary dimensions of sleep health: satisfaction, alertness, timing, efficiency, and duration, with regularity often included as a sixth dimension due to its emerging importance for health (Sletten et al., 2023). These dimensions are termed ‘Ru-SATED’, and scales developed around these six dimensions have been psychometrically evaluated (Conlon et al., 2024; Ravyts et al., 2021). Table 2.1 provides definitions for each dimension.

Table 2.1. Dimensions of sleep health.

Dimension	**Definition**
Regularity	Similar sleep onset and offset time between days
Satisfaction	Subjective assessment of ‘good’ or ‘poor’ sleep
Alertness	Ability to maintain attentive wakefulness
Timing	Placement of sleep within the 24-hour day
Efficiency	Ability to fall asleep and return to sleep following awakenings
Duration	Total amount of sleep obtained within the 24-hour day

Other approaches to operationalising sleep health have been proposed. For example, the National Sleep Foundation developed a Sleep Health Index, a 12-item survey that, after factor analysis, identified three dimensions: sleep quality, sleep duration, and disordered sleep (Knutson et al., 2017). Additionally, Allen et al. (2020) integrated SATED and the Sleep Health Index to identify four dimensions: sleep quality, sleep adaptability, sleep wellness, and daytime function. Despite differences among these models, they all emphasise the importance of assessing sleep health across dimensions, rather than focusing solely on duration, with evidence linking multiple dimensions of sleep health to health and performance (Czeisler, 2015).

A crucial aspect of sleep health is that it is shaped not only by individual biological processes but also by the broader social-environmental context (Grandner & Fernandez, 2021; Hale et al., 2020). The socioecological model, developed by Bronfenbrenner (1979), explores the complex interactions between social and physical factors influencing individual development across different ecological levels. This model was first applied to sleep health by Grandner et al. (2010), and refined in subsequent publications (Grandner, 2014; 2017; Figure 2.3). At the individual level, sleep health is shaped by fixed characteristics, such as genetics, age, and sex (Ashbrook et al., 2020), as well as modifiable factors, like beliefs and attitudes, which have been linked to sleep quality through their influence on sleep hygiene behaviours (Humphries et al., 2022). Individual-level factors are nested within the social level, where influences such as extended work hours, commutes, and irregular schedules (e.g., shift work) can negatively affect sleep health (Kecklund & Axelsson, 2016; Kim et al., 2019). Both individual and social factors are further embedded within the societal level, encompassing broader influences like globalisation, geography, and modern technology, which are less readily modifiable through intervention (Grandner, 2019). Factors at any of these levels can affect sleep health, which in turn can have extensive downstream health implications (e.g., Medic et al., 2017).

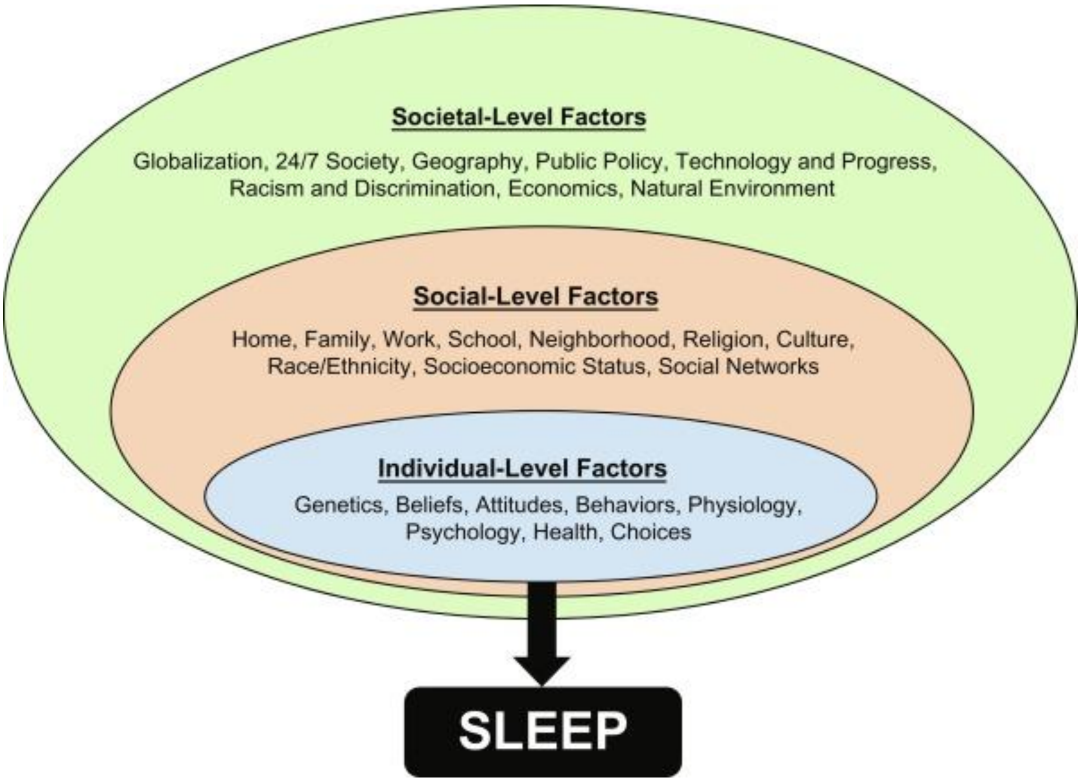

Figure 2.3. Social-ecological model of sleep health.
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2.3. Sleep in the student-athlete

The term 'student-athlete' refers to individuals who are simultaneously engaged in higher education and participate in competitive sports at a high level (Wylleman et al., 2017). Student-athletes represent approximately 1-3% of the total student population in each country, with over 430,000 student-athletes registered by the National Collegiate Athletics Association (NCAA) in the United States (NCAA, 2019b), and over 33,000 registered by British Universities and Colleges Sport (BUCS) in the United Kingdom (BUCS, 2019). The student-athlete sector is also a significant economic enterprise in some countries, with the NCAA generating $1.3 billion in revenue per annum (NCAA, 2023). As discussed above, sleep is a fundamental health behaviour, and all individuals stand to benefit from good sleep health across multiple dimensions (Ramar et al., 2021). Student-athletes stand to benefit from the positive effects of good sleep health in relation to both sport (e.g., physical recovery) and academics (e.g., academic attainment), in addition to more general benefits for cognitive performance, mood, and wellbeing (Brauer et al., 2019; Kroshus et al., 2019).

2.3.1. Historical context

The first study investigating sleep in student-athletes was by Baekeland and Lasky (1966), who used electroencephalography to examine the relationship between exercise and the proportion of delta-wave sleep the following night. However, this population received limited attention until a series of work by Mah and colleagues, who through a series of longitudinal sleep extension studies showed student-athletes typically had poor sleep characteristics at baseline, which significantly improved during the intervention period (Mah, 2008; Mah et al., 2009, 2010, 2011). The Mah research group also conducted one of the earliest cross-sectional studies on subjective sleep outcomes across an entire NCAA athletic programme at Stanford University, revealing a high prevalence of sleep-related difficulties in student-athletes (Mah et al., 2012, 2018). There has been a rapid growth in publications related to sleep in athletes (Lastella et al., 2020), and this trend has been mirrored in student-athletes, with a PubMed search for articles containing "sleep" and synonyms of "student-athlete" in their title or abstract to the end of 2023 yielding over 100 results (Figure 2.4).

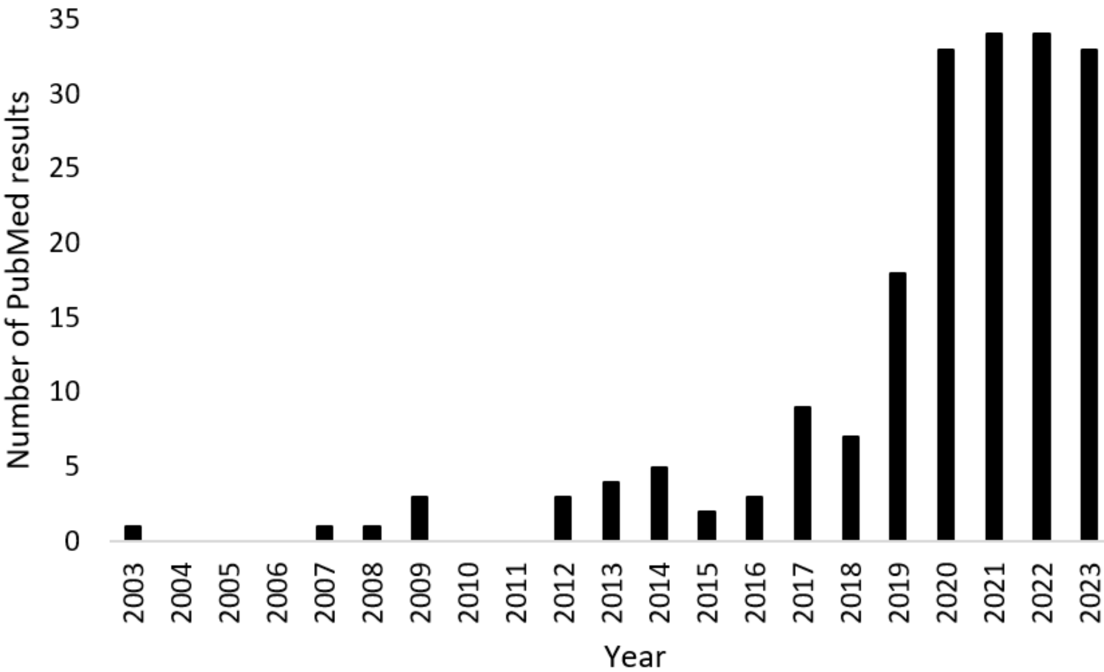

Figure 2.4. PubMed results returned by year for the search term ‘student-athlet*[Title/Abstract] OR student athlet*[Title/Abstract] OR collegiate athlet*[Title/Abstract] OR NCAA[Title/Abstract] OR university athlet*[Title/Abstract]) AND (sleep*[Title/Abstract]’ up to the end of 2023.

2.3.2. Sleep health in student-athletes

The following section presents research on sleep health in student-athletes. These have been organised into subsections using the Ru-SATED dimensions of sleep health proposed by Buysse (2014) to demonstrate the extent of available evidence and general findings for each dimension.

Regularity refers to the maintenance of consistent sleep onset and offset timings. Regularity is an important consideration for sleep as irregular timings between days can lead to circadian misalignment and adversely affect health and performance (Sletten et al., 2023; Windred et al., 2024). Despite this, a systematic review found only 16 studies reporting a measure of regularity in athletes as of early 2022 (Kemp et al., 2023). In student-athletes, a pattern of social jetlag – shifts in sleep timing between workdays and free days (Caliandro et al., 2021) – has been demonstrated between weekdays and weekends, where sleep onset and offset is comparatively delayed on weekends due to the removal of social demands such as training or lectures (Leduc et al., 2020; Mah et al., 2018). However, using social jetlag to assess regularity assumes that student-athletes only work Monday through Friday and are free on weekends. It is likely that most student-athletes will engage in some form of training or competition over the weekend and may not have academic or athletic commitments on all weekdays. Accordingly, there is a need to quantify regularity using alternative metrics. Leduc et al. (2020) demonstrated that student-athletes display had greater intra-individual variability in sleep parameters compared to non-athlete students. However, there has been no consecutive measure of regularity (day-to-day variability) to date.

Satisfaction relates to the subjective perception of sleep. This dimension is possibly best captured through qualitative research, and interviews exploring health in student-athletes would indicate general dissatisfaction and a tendency to neglect sleep to prioritise sport and study (Linnér et al., 2021; Madrigal & Robbins, 2020; Rothschild-Checroune et al., 2012). However, there is a notable lack of qualitative studies where sleep is the primary focus.

The best available proxy for satisfaction comes from screening questionnaires, which have been used to operationalise this dimension previously when evaluating sleep health (Bruno et al., 2024). The Pittsburgh Sleep Quality Index (PSQI) has been the most widely used questionnaire in student-athletes (Buysse et al., 1989), where multiple components are summed to generate a global score identifying 'poor' sleepers (PSQI >5). Multi-sport studies have shown 29-54% of the sampled population to score above this threshold when reported (see Table 2.2), in comparison to the 35% (mean score: 4.1) in a sample of non-clinical young adults (Grandner et al., 2006). Studies on student-athletes using a single sport sample report similar findings (Benjamin et al., 2019; Koikawa et al., 2016; Nishida et al., 2022b; Sheehan et al., 2018). The Athlete Sleep Screening Questionnaire (ASSQ; Samuels et al., 2016), developed as an athlete-specific screening tool, has also been used in recent research. Results indicate that 24–39% of student-athletes exhibit moderate or severe sleep difficulty scores and may require additional support or clinical evaluation (Crutcher et al., 2023; Mountjoy et al., 2023; Rabin et al., 2020; Rebello et al., 2022). Notably, this proportion is higher than typically reported in elite athletes, which only reached 23% during competition periods and lower pre-competition (16%) and post-competition (9%; Biggins et al., 2021).

Table 2.2. Study characteristics and PSQI scoring of multi-sport studies in student-athletes.

Study	Country	N	PSQI Global Score	Poor quality sleepers (PSQI >5)
Carter et al. (2020)	United States	121	5 ± 1	35%
Duffield et al. (2021)	United States	137	6.1 ± 3.5	53%
Hoshino et al. (2022)	Japan	120*	4.5 ± 2.5	29%
Leduc et al. (2020)	United Kingdom	73	6.89 ± 3.03**	65%**
Litwic-Kaminska and Kotysko (2020)	Poland	207	4.40 ± 2.24	-
Mah et al. (2018)	United States	628	5.38 ± 2.45	42%
Monma et al. (2018)	Japan	906	-	47%
Stephenson et al. (2022)	United States	179	5.83 ± 2.80	53%

* Female only
** Value includes student non-athletes, with no significant differences found between student-athletes and student non-athletes

Alertness refers to the ability to maintain attention during wakefulness and has been assessed in student-athletes using the Epworth Sleepiness Scale (ESS; Johns, 1991). Findings indicate that 22-51% of student-athletes score above the threshold (ESS ≥10), indicating excessive daytime sleepiness (Carter et al., 2020; Dobrosielski et al., 2016; Goldman et al., 2024; Koikawa et al., 2016; Mah et al., 2018; Morita & Sasai-Sakuma, 2022), exceeding that typically observed in healthy adults (e.g., Johns, 1991). The large variations in reported daytime sleepiness across studies may reflect differences in questionnaire timing, as perceived alertness is temporally sensitive (Monk et al., 1989). For instance, in the study with the highest prevalence (Mah et al., 2018), questionnaires were administered immediately before or after training when perceived alertness may be heightened.

Timing relates to the placement of sleep within the 24-hour day. The recommendation presented by Buysse (2014) is for a sleep midpoint between 02:00 and 04:00, and cross-sectional studies suggest that average student-athlete sleep midpoints generally fall within this range (e.g., Leduc et al., 2020). However, it is unclear how sleep timing is distributed and the number of student-athletes that have a sleep midpoint outside of this range. Additionally, low sleep regularity likely increases the occurrence of individual nights where the sleep midpoint is substantially earlier or later.

Timing can also be understood through chronotype, which is an individual's preference for sleep timing. Age-related changes in chronotype suggest that student-athlete cohorts, primarily young adults, would include a high proportion of evening-type chronotypes (Roenneberg et al., 2004). This is supported by research showing a slightly higher proportion of evening-type than morning-type chronotypes (Anderson et al., 2018; Crutcher & Moran, 2022; Litwic-Kaminska & Kotysko, 2020; Vitale et al., 2017; Wills et al., 2021). Litwic-Kaminska and Kotysko (2020) found a shift towards morning-types compared to non-athlete peers, although no significant difference was observed by Morita and Sasai-Sakuma (2022).

Efficiency refers to the ability to fall asleep and maintain sleep throughout the sleep episode. This dimension can be assessed using various actigraphy-derived variables, including sleep onset latency (the time between intending to fall asleep and actual sleep initiation), the number of awakenings during sleep, wake after sleep onset (the cumulative duration of awakenings), and sleep efficiency (the proportion of the sleep episode spent asleep). Comparing results across studies is challenging due to differing definitions of variables and the reduced accuracy of actigraphy in detecting wakefulness versus sleep (Miller et al., 2022). However, reported sleep onset latencies of 20-40 minutes (Carter et al., 2020; Litwic-Kaminska & Jankowski, 2022), and sleep efficiencies of 81-92% (Carter et al., 2020; Driller et al., 2017; Fullagar et al., 2019; Sekiguchi et al., 2019), are broadly consistent with findings in elite athletes and suggest potential difficulties with both falling asleep and maintaining sleep compared to other populations (Gupta et al., 2017). Subjective measures report comparable findings with low sleep efficiencies and long sleep onset latencies (e.g., Leduc et al., 2020).

Duration refers to the amount of sleep achieved within a 24-hour period. Wrist-worn accelerometers, using both research-grade and commercial devices (e.g., Fitbit), has been used to estimate sleep duration. These studies generally report average total sleep times of less than seven hours (Carter et al., 2020; Fullagar et al., 2019; Goldman et al., 2024; Litwic-Kaminska & Jankowski, 2022; Sekiguchi et al., 2019; Taber et al., 2021), which falls below recommended durations of seven to nine hours for young adults (Hirshkowitz et al., 2015). In contrast, Driller et al. (2017) observed a higher total sleep time of 7.6 hours per night, though this was still less than non-athlete students in the study (7.9 hours). These findings are supported by self-reported measures, such as the PSQI where around one in three student-athletes report perceived sleep durations under seven hours (e.g., Carter et al., 2020; Mah et al., 2018).

Napping is a sleep behaviour often underreported in student-athlete sleep research, despite cross-sectional studies reporting 68-80% of student-athletes to nap at least once per week (Mah et al., 2018; Rebello et al., 2022; Stephenson et al., 2022). Longer napping episodes appear to be commonplace among student-athletes; for instance, Mah et al. (2018) found that 25% of respondents report a typical nap duration exceeding one hour. Lever et al. (2024) found that napping significantly reduced subsequent nocturnal sleep duration in student-athletes. Therefore, it is important to consider napping behaviour when interpreting nocturnal sleep in student-athletes.

The evidence outlined above would indicate that student-athletes present suboptimal sleep health across multiple dimensions, while some dimensions remain understudied and warrant further investigation. A summary of each Ru-SATED dimension is presented in Table 2.3.

Table 2.3. Summary of evidence for each dimension of sleep health in student-athletes.

Dimension	Current evidence
Regularity	• Social jetlag creating a phase delay in sleep timing at weekends compared to weekdays – unclear whether this accurately reflects workdays and free days. • Emerging evidence of high variability in sleep parameters between days – has not been assessed between consecutive days
Satisfaction	• Low satisfaction using subjective questionnaires (PSQI and ASSQ) • Minimal qualitative research studies to understand perceived satisfaction
Alertness	• Moderate prevalence of excessive daytime sleepiness assessed using ESS questionnaire
Timing	• Average sleep midpoint appears satisfactory - unclear how this varies between days. • Higher proportion of evening-type than morning-type chronotypes due to age-related shift.
Efficiency	• Actigraphy-derived sleep efficiency and sleep onset latency are comparable to elite athletes but may be suboptimal.
Duration	• Shorter self-reported and actigraphy-derived sleep durations than public health recommendations in a high proportion of student-athletes

2.3.3. Upstream influences

When considering sleep health through a socioecological lens, there will be upstream influences at individual, social, and societal levels (Grandner, 2017). The following section presents research relating to the upstream influences acting upon on sleep health among student-athletes. Although six primary influences are discussed for which there is an established evidence base, it is important to note that there are an indeterminate number of factors that could impact sleep health in each individual or population. Additionally, specific risk factors for student-athletes remain underexplored. For instance, 69% of British university students are in part-time employment and report resulting tiredness (National Union of Students, 2023), yet the proportion of student-athletes who are employed is unclear.

Sports training can have a pronounced effect on sleep, particularly in relation to the timing of training sessions. Sleep durations tend to be shorter on nights preceding morning training sessions when compared to nights before evening training sessions or rest days

(Benjamin et al., 2019; Merfeld et al., 2022). The frequency of such sessions may also be important, as a higher frequency of morning sessions (4-7 per week) was associated with poor sleepers assessed using the PSQI, whereas a lower frequency (0-3 per week) and any frequency of evening sessions was not significantly associated (Monma et al., 2018). Similarly, strength and conditioning sessions performed in the afternoon (13:45) were preceded by an increase in self-reported sleep duration of 0.8 hours when compared to the equivalent morning session (07:00) when training intensity and duration were matched (Heishman et al., 2017). While such associations have been observed, it remains unclear whether training timing significantly predicts sleep outcomes when controlling for extraneous variables.

Training load has been identified as a sleep risk factor for athletes due to heightened physiological arousal (Walsh et al., 2020). Assessment of this relationship is complicated in student-athletes due to the concurrent fluctuations in academic demands across the semester. Some studies have indicated that increased training load or changes in the training phase can negatively impact sleep outcomes (Fullagar et al., 2019; Schley et al., 2020), while others report no clear differences (Liao et al., 2022; Sekiguchi et al., 2021; Taber et al., 2021).

Sports competition is an established upstream factor that has an acute impact on sleep in elite athletes (Walsh et al., 2020), there is a notable lack of research on sleep in competition and in the days preceding or following competition in student-athletes. Studies assessing in-season sleep with actigraphy often report average results across the collection period without distinguishing between competition and non-competition nights (e.g., Fullagar et al., 2019). A meta-analysis of studies in elite athletes suggests that while sleep is largely unaffected the night before a competition, it tends to be disrupted the night after (Roberts et al., 2019b). Although a similar effect would be expected in student-athletes, this should not be assumed.

Travel is an established factor that can influence sleep in all individuals. Two travel-related factors that may impact student-athlete sleep are jet lag and travel fatigue. Jet lag occurs with rapid travel across multiple time zones, causing circadian disruption, while travel fatigue is associated with the physical and mental stress resulting from long or frequent travel over extended periods (Janse van Rensburg et al., 2021). Although student-athletes typically face fewer travel demands than those in professional leagues, research on how travel affects their sleep remains limited. Interestingly, a cross-sectional survey by Mah et al. (2018) found that student-athletes reported better sleep during travel compared to on-campus, possibly due to the absence of barriers like noise pollution in student accommodation. Interviews also indicated that student-athletes perceived sport-related travel as negatively impacting their performance, with jet lag and sleep loss identified as contributing factors (Paule-Koba et al., 2024). The impact of travel is likely to be influenced by geographical location: while NCAA conferences may span large distances across multiple time zones, competitions within the UK do not involve such distances or any clock changes.

Academic lessons and their placement in the day can have a similar impact to the timing of sports training, whereby earlier lesson start times reduce nocturnal sleep durations the previous night in university students (Swinnerton et al., 2021; Yeo et al., 2023). However, how this applies to student-athletes remains unclear, as their wake times are often dictated by sport-related demands that are placed before the start of academic classes. Student-athletes face significant time pressures when balancing academic and sporting workloads, with the NCAA reporting a combined workload exceeding 60 hours per week, and many struggling to balance academics with extracurricular activities (NCAA, 2019a). Nonetheless, it has been argued that workload does not necessarily reduce sleep opportunity in student-athlete populations (Meridew et al., 2017).

Sleep outcomes also fluctuate across the academic semester. Bolin (2019) found that sleep duration and variability remained stable early in the semester but worsened progressively as the term advanced. Hamlin et al. (2019) similarly observed a trend toward poorer subjective sleep outcomes as the semester progressed. Additionally, monthly administration of the PSQI revealed the highest prevalence of poor sleep at the end of the academic year in May, with the number of academic assignments each month being the strongest predictor of PSQI score (Astridge et al., 2021). The year of study may also influence sleep, with greater academic stress leading to more sleep difficulties in later years (Rabin et al., 2020).

Sex may influence sleep in student-athletes, although the current evidence reports mixed findings. For instance, perceived sleep assessed using the PSQI in student-athletes are inconclusive (Benjamin et al., 2020; Carter et al., 2020; Duffield et al., 2021; Koikawa et al., 2016). Similarly, mixed findings have been reported for daytime sleepiness (Carter et al., 2020; Koikawa et al., 2016). However, females may experience more sleep-related difficulties than males, as indicated by higher ASSQ sleep difficulty scores (Crutcher et al., 2023; Rabin et al., 2020), and a higher prevalence of travel-related sleep disturbances and daytime dysfunction (Crutcher et al., 2023). Actigraphy-derived sleep parameters typically show fewer sex differences. However, Carter et al. (2020) found that females had higher sleep efficiencies, shorter sleep onset latencies, and less wake after sleep onset compared to males. Moreover, females appeared to more accurately self-assess their total sleep time. Goldman et al. (2024) also reported reduced wake after sleep onset in females, though no significant sex differences were found in other sleep outcomes, including sleep regularity.

Chronotype can also influence sleep, and athletes with an evening-type chronotype may be more vulnerable to sport-related sleep disruptions, as reflected by their inclusion as a risk factor in the Athlete Sleep Screening Questionnaire (Samuels et al., 2016). Evening-type student-athletes are more likely to report poor sleep quality (Litwic-Kaminska & Jankowski, 2022) and greater sleep difficulty (Rabin et al., 2020). In contrast, morning-type soccer players experienced reduced sleep quality after evening training sessions, though neither chronotype group showed differences in sleep outcomes following morning sessions (Vitale et al., 2017). Another important chronotype-related consideration is the time-of-day effect on performance, with swimming performance and effort varying according to circadian phenotype (Anderson et al., 2018).

In addition to gender and chronotype, various upstream influences that are less directly related to sport or education may also affect student-athletes sleep. For example, previous research has explored the relationships between social media use and perceived sleep quality (Watkins et al., 2022), and the impact of adverse childhood experiences on multiple sleep outcomes (Rasmussen et al., 2023). A cluster of studies has also examined changes in student-athlete sleep during the COVID-19 pandemic (Chandler et al., 2021; Melone et al., 2022; Monma et al., 2024; Petrie et al., 2023), though the long-term effects remain unclear. However, there will be many other factors at the individual (e.g., beliefs and attitudes) and social (e.g., family commitments) levels of influence that can impact student-athlete sleep health.

2.3.4. Downstream consequences

Much like the upstream influences discussed above, sleep health viewed from a socioecological perspective has extensive downstream consequences on health and wellbeing, underscoring the fundamental importance of sleep (Grandner, 2017). This section will discuss some of the key consequences for student-athletes relating to sports, academics, and wellbeing. There are likely to be a myriad of consequences beyond these discussed here that are either difficult to disentangle from other health behaviours (e.g., physiological changes) or have yet to be examined in student-athletes (e.g., academic attendance).

Sport performance is often considered an important outcome related to sleep (e.g., Kroshus et al., 2019), although few studies have examined the impact of sleep on performance in student-athletes without experimental manipulation. Carazo-Vargas and Moncada-Jiménez (2020) found that increased sleep efficiency did not enhance general or sport-specific physical performance, while Han et al. (2022) reported that mean sleep duration did not affect tennis performance. However, greater variability in sleep durations was linked to poorer service accuracy. Research on collegiate American football players has shown mixed evidence regarding the impact of self-rated sleep quality on movement parameters such as accelerations during training (Murray et al., 2019; Wellman et al., 2017; Wellman et al., 2019). Meanwhile, Howell et al. (2018) identified differences in tandem gait performance based on self-reported sleep duration, which may have implications for pre-season concussion testing. Notably, there is no research examining changes in cognitive performance, despite evidence that cognitive function is more sensitive to sleep disruption than gross motor performance (Killgore & Weber, 2014).

Academic attainment has been associated with several dimensions of sleep health including regularity, efficiency, and duration, whereby improved sleep health results in improved examination results (Hershner, 2020). Data from the National College Health Assessment suggest that sleep-related factors, such as insufficient sleep and daytime tiredness, correlate with lower academic performance in NCAA student-athletes (Turner et al., 2021). This was particularly true for those who reported having a sleep problem that they perceived to interfere with academic performance, who were 418% more likely to report a D or F grade average compared to an A grade average. However, the reliance on self-reported sleep and academic grades introduces uncertainty over the true impact of sleep on attainment.

Injury is a common product of participation in sport, and some evidence suggests a link between sleep health and injury. Studies have shown that student-athletes with insufficient sleep durations are nearly twice as likely to sustain a concussion (Riegler et al., 2023). Additionally, insomnia symptoms and daytime sleepiness are independently associated with concussion risk (Raikes et al., 2019). Post-concussion, shorter sleep duration may be linked to increased symptom severity and impaired cognitive performance (Blake et al., 2019; Hoffman et al., 2020). Sleep characteristics can also influence baseline concussion assessment scores (Crutcher & Moran, 2022; McAllister-Deitrick et al., 2020; Riegler et al., 2021), underscoring the importance of conducting these assessments when student-athletes have had sufficient sleep.

Research on the relationship between sleep and injury or illness risk in student-athletes is mixed. Some studies suggest that acute sleep characteristics might influence injury risk (Curtis et al., 2021; Haraldsdottir et al., 2021). However, long-term associations between sleep and injury remain inconclusive, with some studies reporting significant correlations (Hamlin et al., 2021; Hamlin et al., 2019; Hayes et al., 2019; Owoeye et al., 2024; Watson et al., 2020), while others found no significant relationships (Burke et al., 2020; Fauntroy et al., 2023). No research has specifically examined sleep's role in injury recovery among student-athletes, though adequate sleep is known to promote muscle regeneration from exercise-induced injuries (Chennaoui et al., 2021).

Wellbeing is an emerging area of interest in student-athletes, as highlighted by the NCAA's recent consensus document on mental health best practices (NCAA Sport Science Institute, 2020), and is related to sleep health. Cross-sectional studies have shown significant associations between various dimensions of sleep health and mental health outcomes such as anxiety and depression (Armstrong & Oomen-Early, 2009; Benjamin et al., 2020; Duffield et al., 2021; Grandner et al., 2021; Monma et al., 2018; Wei & Liu, 2022; Zhou et al., 2022), perceived stress (Grandner et al., 2021; Hwang & Choi, 2016; Litwic-Kaminska & Kotyśko, 2017; Storey et al., 2022), social support (Grandner et al., 2021), psychological distress (Murphy et al., 2022; Wahesh et al., 2023), and suicide ideation (Khader et al., 2020). Additionally, wellbeing-related factors like mindfulness have been shown to improve sleep hygiene (Moreton et al., 2020), while self-compassion is linked to reduced sleep difficulties in student-athletes (Assar et al., 2024). Poor sleep has also been associated with unfavourable changes in mood (Benjamin et al., 2020; Hamlin et al., 2021).

Poor sleep health is also linked to risky health behaviours, especially when combined with alcohol consumption. Studies suggest that poor sleep, mood disturbances, and alcohol use are associated with increased instances of physical altercations and abuse (Charest et al., 2021a). Additionally, sleep difficulties and insufficient sleep are linked to a higher likelihood of driving after drinking alcohol, with student-athletes being more affected than non-athlete students (Bastien et al., 2019). Further data from the NCAA show that 20% of student-athletes experience disrupted sleep after alcohol consumption, and 26% have used marijuana to aid sleep, despite its prohibition by the World Anti-Doping Agency (NCAA Research, 2018).

2.3.5. Previous interventions

To address suboptimal sleep health among student-athletes, various interventions have been developed and implemented. These have adopted diverse approaches with mixed effectiveness and feasibility to implement.

Mah and colleagues conducted a series of sleep extension studies on student-athletes across different sports, including swimming (Mah, 2008), tennis (Mah et al., 2009), American football (Mah et al., 2010), and basketball (Mah et al., 2011). These studies demonstrated that increasing sleep duration can positively impact various aspects of athletic performance. For instance, a nightly increase of 1.8 hours in total sleep time over several weeks led to improvements in shooting accuracy, sprint times, reaction times, reduced daytime sleepiness, and improved mood (Mah et al., 2011). Similarly, a self-reported increase in sleep duration of 1.7 hours per week improved serve accuracy and reduced daytime sleepiness in varsity tennis players (Schwartz & Simon, 2015). Leduc et al. (2022) found that a single night of sleep extension, rather than waking early for an active recovery session, had a positive effect on cognitive function assessed using the Stroop test. However, maintaining extended sleep durations may be unsustainable outside of experimental conditions. Importantly, these studies have not included follow-up periods to assess whether sleep extension interventions lead to lasting changes in sleep behaviours after the intervention ends. It remains possible that the performance improvements experienced by participants could motivate them to adopt longer sleep durations to preserve these benefits.

Conversely, sleep restriction studies have examined how sleep loss impairs performance. Blumert et al. (2007) found that a single night of sleep deprivation did not significantly affect Olympic weightlifting performance, highlighting the relative resilience of physical performance to acute sleep loss (Fullagar et al., 2015). However, they observed substantial negative changes in mood and reduced post-exercise serum cortisol concentrations. Taheri and Arabameri (2012) similarly reported preserved physical performance after sleep deprivation but impaired cognitive performance, particularly in reaction times. Sleep restriction also impaired putting accuracy in collegiate golfers, with morning-type athletes more susceptible to performance declines (Nishida et al., 2022a). While these study designs are valuable for examining the physiological effects of sleep loss, the degree of restriction imposed is unlikely to reflect typical experiences in student-athlete populations. Research investigating more modest reductions in sleep relative to an individual's specific sleep need may offer greater ecological validity. Melatonin supplementation has been suggested as a potential strategy to partially restore performance following sleep restriction or deprivation in student-athletes (Paryab et al., 2021).

Education is often regarded as a cornerstone of health behaviour change. For instance, an educational leaflet designed for Japanese student-athletes improved their perceived sleep quality (Harada et al., 2016). However, sleep education alone may be insufficient to achieve lasting behavioural changes, as while it can increase knowledge, does not always translate into action (Halson, 2019). As a result, education is often combined with other behaviour change techniques. For example, an interactive group workshop improved daytime functioning and reduced daytime sleepiness but paradoxically resulted in poorer perceived sleep hygiene, potentially due to increased awareness of healthy sleep behaviours (Kaier et al., 2016). Similarly, a pilot intervention combining education, sleep tracking, and social support led to improvements in sleep, performance, and health (Alfonso-Miller et al., 2017; Athey et al., 2017; Grandner et al., 2017). In both cases, these studies lack a control group, despite evidence indicating that sleep parameters in student-athletes fluctuate in response to changing demands (e.g., Astridge et al., 2021). As a result, it remains unclear whether any observed changes can be directly attributed to the intervention itself. Interestingly, there appears to be an appetite to receive sleep education to maximise sports performance amongst student-athletes, but only a small proportion report having previously received information on healthy sleep practices (Athey & Grandner, 2017; Ofek et al., 2019).

A few studies have explored the use of mind-body practices to improve sleep and other health outcomes through relaxation and mental awareness. An eight-week mindfulness-based stress reduction program improved both subjective and objective sleep quality in collegiate rowers, along with their physical performance (Jones et al., 2020). Other relaxation techniques, such as autogenic training (Litwic-Kaminska et al., 2022) and progressive muscle relaxation (McCloughan et al., 2016), also led to beneficial changes in sleep outcomes post-intervention. Additionally, alternative approaches such as self-monitoring using mobile phone applications (Jakowski & Stork, 2022) and transcranial direct current stimulation (Charest et al., 2021b) have been investigated, though evidence to support these interventions remains inconclusive.

2.3.6. Differences between student-athletes

While this review has considered student-athletes as a homogenous group that all share the dual roles of performance athlete and university student, they can be further subdivided based on various characteristics that will influence the upstream factors acting upon sleep health. Different sports present different influences related to training schedules, competition structures, and physical workload, all of which can impact sleep health. For instance, athletes in individual sports often demonstrate shorter sleep durations than those in team sports, likely due to earlier training start times (Sargent et al., 2014b). Inter-sport differences in sleep health can be substantial, with Mah et al. (2018) showing sleep satisfaction (PSQI global score) ranging from 3.7 in women's gymnastics to 7.2 in women's lacrosse, and alertness (ESS global score) ranging from 7.8 in men's golf to 12.4 in women's lacrosse at the same university. Performance levels among student-athletes can also vary. In the NCAA, some Division I athletes are approaching elite status compared to lower divisions, reflected in a greater time commitment to sport (NCAA, 2019a; Swann et al., 2015). Meanwhile, a British study included student-athletes competing from international to regional levels (Leduc et al., 2020). Academic demands among student-athletes are less clearly established, though differences in time demands and difficulty are likely to exist both between courses within each university and between institutions. At the individual level, student-athletes may prioritise their future sporting and vocational careers differently, which likely affects how sport-related and academic-related upstream influences impact their sleep health (Cartigny et al., 2021). Additionally, each student-athlete will encounter unique factors influencing sleep health at individual, social, and societal levels separate from their status as student-athletes (Grandner, 2017).

2.4. Summary

This review has provided an overview of human sleep regulation and presented current research on sleep in student-athletes, guided by the concept of sleep health across multiple dimensions (Buysse, 2014) and the social-ecological model of sleep health, to understand upstream influences and downstream consequences (Grandner, 2017). Evidence indicates that student-athletes experience suboptimal sleep health in specific dimensions (e.g., duration). Emerging evidence also suggest challenges in other dimensions (e.g., regularity), although findings remain insufficient to draw firm conclusions. Suboptimal sleep health in this population is influenced by various upstream influences, resulting in undesired consequences in performance, academics, and wellbeing. Improving sleep health through interventions could yield widespread benefits and should therefore be considered a priority for key stakeholders to address. Since the last comprehensive literature reviews (Brauer et al., 2019; Kroshus et al., 2019), substantial research on student-athlete sleep has been conducted. However, this review highlights notable gaps. These will be expanded upon and used to guide the research objectives in Chapter 3.

First, sleep research has predominantly focused on American student-athletes, likely due to the large participation numbers (NCAA, 2019b). As discussed, student-athletes are not a homogenous group, and differences in academic and athletic structures, such as study hours and financial factors, may influence sleep health across national contexts and warrant further investigation (Kerckhoff et al., 2001). This thesis will therefore take a more granular approach by examining sleep health across multiple dimensions in British student-athletes, focusing on underexplored areas such as sleep regularity, which has emerged as a key predictor of physical and mental health (Sletten et al., 2023).

Second, there is a need to identify the primary upstream influences underpinning suboptimal sleep health in British student-athletes. While several factors have been highlighted, the relative impact of each remains unclear. Identifying readily modifiable factors with a significant influence on sleep health could pinpoint appropriate intervention targets. Additionally, the contribution of each upstream influence likely differs in British student-athletes to other nationalities; for example, travel fatigue and jetlag may be less impactful due to geographical factors, whereas other elements, such as drinking culture, could play a more prominent role (Harris et al., 2023).

Finally, there is a scarcity of intervention studies designed to drive sustained improvements in sleep health. The social-ecological model of sleep health supports the use of behavioural theory in intervention design, as upstream influences drive behaviours that, in turn, affect sleep health (Hale et al., 2020). However, current sleep research has been criticised for its limited application of behavioural theory during intervention development compared to other health behaviours (Mead & Irish, 2020). Consequently, it is unclear whether existing interventions effectively target the primary barriers to improved sleep health.

CHAPTER THREE: RESEARCH AGENDA AND METHODOLOGICAL APPROACH

3.1. Rationale

The narrative review presented in Chapter 2 summarised the available research on sleep in student-athletes. Framed using the concept of sleep health (Buysse, 2014) and the social-ecological model of sleep health (Grandner, 2017), the current evidence indicates that student-athletes display suboptimal sleep health across multiple dimensions, driven by a range of upstream influences and resulting in various undesired downstream consequences. These findings align with those observed in both university students (see review by Wang & Biro, 2021) and elite athletes (see review by Walsh et al., 2020). However, the breadth of literature available on student-athletes remains limited compared to these populations (Lastella et al., 2020). Accordingly, there are several lines of enquiry for future research, which this thesis will contribute towards addressing.

The narrative review examined sleep through the concept of sleep health (see Chapter 2), as will be continued throughout the thesis. This approach is particularly well-suited for student-athletes as: (1) there is little evidence or rationale to suggest that student-athletes have a higher incidence of sleep disorders compared to the general population (Emert et al., 2024), and therefore can be considered a non-clinical population; (2) the narrative review in Chapter 2 identified a high prevalence of suboptimal sleep health across multiple dimensions; and (3) when student-athlete demands are reduced or removed, sleep outcomes improve (e.g., Astridge et al., 2021). Accordingly, suboptimal sleep health in student-athletes can be viewed as a health inequity (Hughes et al., 2023), driven by upstream influences related to being a student-athlete, whether through sport, study, or their interaction effects. This aligns with and draws upon the social-ecological model of sleep health (Grandner, 2017), suggesting that understanding which upstream influences drive the behaviours contributing to sleep health can help identify effective intervention targets. The targeting of upstream influences to drive sleep behaviour change has been demonstrated previously; for example, structural adjustments to training or academic schedules have been used to increase sleep durations (Minges & Redeker, 2016; Sargent et al., 2014b), while sleep hygiene interventions have successfully modified sleep-related behaviours at the individual level (Gwyther et al., 2022). Thus, adopting a behavioural approach to sleep health aligns with the social-ecological framework and addresses the criticism of its underutilisation in previous sleep research (Mead & Irish, 2020). A conceptual model illustrating these connections is presented in Figure 3.1. Specific details on the behavioural framework used in this thesis will be discussed in section 3.4.

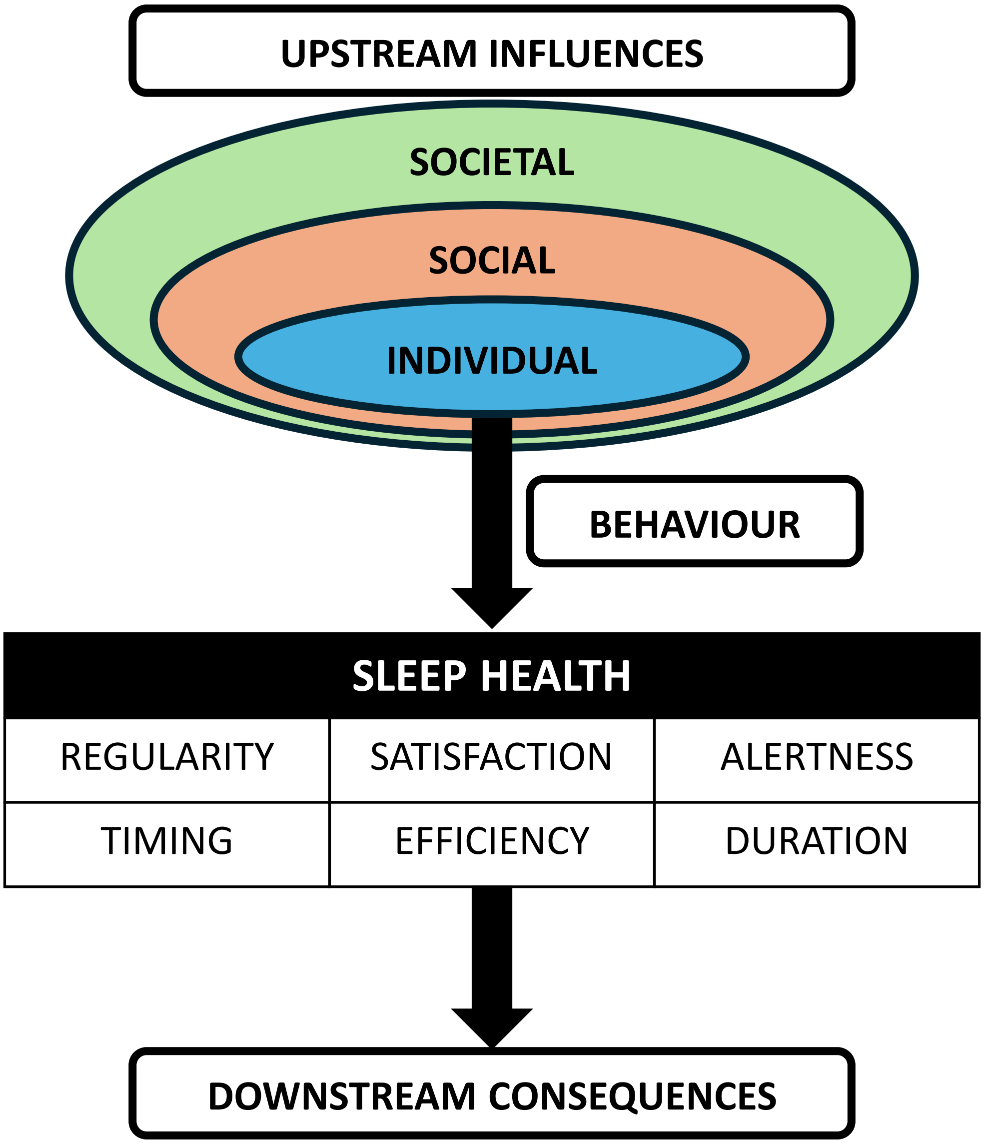

Figure 3.1. Conceptual model of how upstream influences (broader, systemic, and structural factors that shape health) from the social-ecological model drive behaviours that affect sleep health across multiple dimensions, which in turn have downstream consequences (the resulting individual-level outcomes or immediate health effects). Adapted from Grandner (2018).

3.2. Research objectives

Considering the literature gaps identified in the narrative review in Chapter 2, this thesis has three primary research objectives:

1. Assess sleep health amongst British student-athletes (Chapters 5 and 6).

Current evidence indicates a high prevalence of suboptimal sleep health in student-athletes across multiple dimensions (see Chapter 2, section 2.3.2). However, as discussed in the narrative review, treating student-athletes as a homogenous group presents limitations, as the upstream influences impacting sleep health can vary between sub-groups (Chapter 2, section 2.3.6). For instance, comparing British student-athletes to their NCAA counterparts reveals substantial differences in factors such as the level of competition and financial compensation through name, image, and likeness deals (Kunkel et al., 2021; NCAA, 2023), alongside fundamental differences in the educational structure between countries (Kerckhoff et al., 2001). Upstream influences beyond sport and academics, such as cultural norms and practices that impact sleep in university students across nations also contribute to these distinctions (Cheung et al., 2021). Given the limited research on sleep health in British student-athletes (Leduc et al., 2020), further assessment is essential to understand how this compares to other student-athlete cohorts. While it could be argued that sleep health should be evaluated and promoted at an individual level, as each person has unique upstream influences (Fullagar & Bartlett, 2016), assessing sleep health specifically within the context of British student-athletes can be justified. The upstream influences that can be feasibly modified in the student-athlete context —those related to sport or academics—are likely shared among most individuals in this sub-population. Therefore, targeted interventions aimed at these common influences stand to benefit a substantial portion of individuals. This approach allows for tailored strategies that address the unique demands British student-athletes face while recognising that prior research on other student-athlete cohorts may not fully capture the specific sleep health status of this group.

2. Identify the upstream influences that underpin suboptimal sleep health in British student-athletes (Chapters 5, 6, and 7).

There are multiple upstream influences at individual, social, and societal levels that affect sleep health in British student-athletes (Grandner, 2017). While the narrative review identified clusters of upstream factors such as training, travel, competition, and academics (Chapter 2, section 2.3.3), existing studies have typically only correlated these factors with sleep outcomes. Thus, it remains unclear which of these influences are the most significant contributors to sleep health. Additionally, the relative impact of these factors may differ across subgroups of student-athletes. For instance, training timing is likely to be a more significant factor when it overlaps with preferred sleep timing, while travel may be less influential when it is infrequent or limited to shorter distances. Furthermore, findings on these influences have been mixed. For example, the combined time demands of sport and study are often cited as a plausible barrier that reduces sleep opportunity, yet there is limited evidence supporting this claim (Meridew et al., 2017). The lack of qualitative research also leaves a gap in understanding the lived experiences of sleep among student-athletes, and their perceptions of these upstream influences. Such insights could provide valuable context for understanding sleep health and may uncover novel factors that have not been empirically studied previously.

3. Design and evaluate a behavioural sleep intervention targeted towards British student-athletes (Chapters 4, 7, and 8).

The limited use of behaviour change theory in developing sleep health interventions has drawn criticism despite a strong rationale supporting a behavioural approach to sleep health outlined in section 3.1 (Halson, 2019). Although many interventions are likely to incorporate behaviour change components intended to improve sleep health, these components are often not clearly specified, and therefore there is a need for retrospective examination of previous interventions. Such an examination will provide insight into current limitations and help inform a behaviourally informed intervention specifically tailored for British student-athletes. Integrating behaviour change theory into the design and implementation of interventions is expected to drive more effective changes in sleep health behaviours, ensuring that the intervention content is relevant and appropriate for the target population (Mead & Irish, 2020). Furthermore, this is the first known instance of this specific approach being applied to sleep health in a non-clinical population, although it is frequently applied to other health behaviours. As such, this process can assess the applicability of a behaviourally driven approach to sleep health and potentially serve as a roadmap for designing targeted behavioural sleep interventions in sport, education, and beyond.

3.3. Methodological approach

3.3.1. Philosophical position

A pragmatist epistemology was adopted for this research project to address the outlined objectives. Pragmatism, as a philosophical stance, advocates for the use of the most effective philosophical and methodological approaches to address the issue at hand (Giacobbi et al., 2005). This perspective emphasises the practical consequences and real-world implications of research findings, ensuring that the knowledge generated has tangible benefits. Accordingly, a mixed methods approach was employed, combining both qualitative and quantitative methods to provide a comprehensive understanding of the research objectives and their applied impacts. The use of mixed methods also aligns with the concept of sleep health, where different methodologies may be best suited to capture different dimensions (e.g., qualitative methods to understand sleep satisfaction). For instance, Allen et al. (2018) have shown that objective measures of sleep are not always reflective of sleep health status, and therefore a reliance on a single measurement tool may not provide a complete picture of sleep health. Alternative philosophical positions would present limitations for achieving the research objectives set. For example, a positivist approach would struggle to capture the lived experiences of student-athletes, which are crucial for informing intervention design. On the other hand, an interpretivist approach would not adequately address key dimensions of sleep health, such as duration, and would limit the broader practical application of findings.

3.3.2. Instrumental measures

In line with the pragmatist epistemology adopted, different methodologies were employed throughout the thesis. This section elaborates on these methods and justifies their use in each case.

Scoping review

A scoping review is conducted in Chapter 4 to identify previous behavioural interventions in athlete populations, and retrospectively specify the behaviour change techniques employed within these. A scoping review was chosen over a systematic review to explore the types of evidence available, as no previous reviews have focused exclusively on behavioural sleep interventions. Additionally, as the research area is rapidly growing (Lastella et al., 2020), the aim was to examine research methodologies rather than provide evidence for clinical practice (Munn et al., 2018). As it was anticipated that there would be significant heterogeneity between studies with respect to design, the sleep outcomes assessed, and the implementation of behaviour change, it was decided that performing a would not be appropriate.

Given the anticipated lack of literature examining intervention studies in student-athlete populations, the decision was made to extend the review to include all athletes. While this thesis recognises the importance of considering both the sporting and academic aspects of the dual-career paradigm, the rationale for this decision was threefold: (1) The timeframe did not allow for the completion of two separate scoping reviews on student and athlete populations; (2) there are existing reviews in university student populations that align more closely with the objectives of the study than those in athlete populations (e.g., Friedrich & Schlarb, 2018; Lubas & Szklo-Coxe, 2019); and (3) given that the student-athletes participating in studies compete at a relatively high performance level, it was perceived that most would identify more strongly as athletes than as students (Cartigny et al., 2021).

Questionnaires

Sleep questionnaires were the primary assessment tool used in Chapter 5. This offers advantages for population screening on a scale that would be impractical for other methods, such as actigraphy, while also minimising resource and financial burdens. The use of widely recognised questionnaires, such as the Pittsburgh Sleep Quality Index (PSQI), allows for comparisons between populations. The PSQI, for instance, has been used extensively in studies involving student-athletes (see Chapter 2, Table 2.2). However, despite their common use, such questionnaires are not typically validated for athlete populations and should not be relied upon for clinical purposes (Halson et al., 2022a).

More recently, targeted questionnaires like the Athlete Sleep Screening Questionnaire (ASSQ) have been developed (Samuels et al., 2016). While the ASSQ has been validated for athletes (Bender et al., 2018), it was deemed unsuitable for use in Chapter 5 due to its perceived lack of specificity for student-athletes, who face additional upstream influences related to academic demands. Following this study, unpublished research validated the ASSQ for use in student-athletes (Charest, 2022), and it was considered suitable for use in subsequent studies.

In Chapters 6 and 8, questionnaires were used alongside actigraphy as a secondary measure. In Chapter 6, the ASSQ was used as a baseline screening tool to compare the cohort with other athlete populations and for correlational analysis with actigraphy-derived parameters. In Chapter 8, questionnaires were employed pre- and post-intervention to assess changes resulting from the intervention. In addition to the ASSQ, the Athlete Sleep Behaviour Questionnaire (ASBQ) was used to assess changes in sleep hygiene behaviours (Driller et al., 2018). The ASBQ is widely used for this purpose, although recent confirmatory factor analysis has raised concerns about its model fit in student-athletes (Miley et al., 2023). Additional questionnaires used in Chapter 8 to assess secondary health measures are discussed within the chapter.

Actigraphy

Actigraphy was the primary measure used in Chapters 6 and 8. Wrist-worn actigraphy monitors are small devices that use a 3-axis accelerometer to assess movement, with algorithms converting raw data into estimates of sleep/wake behaviour (Quante et al., 2015). This method provides an empirically derived measure, reducing recall bias compared to self-reported data, and is widely used in research for longitudinal monitoring in healthy individuals without clinical sleep disorders due to its low participant burden. Actigraphy also offers a practical alternative to polysomnography, with good agreement in athlete populations, while offering advantages in terms of equipment requirements, cost, and expertise (Sargent et al., 2016). However, actigraphy tends to show poorer accuracy in detecting short awakenings during sleep episodes, leading to overestimation of sleep duration and underestimation of sleep onset latency (Ancoli-Israel et al., 2015).

Actigraphy-derived sleep parameters were collected using GENEActiv monitors (Activinsights, Cambridge, United Kingdom), which measure movement via a tri-axial accelerometer (±8 g), as well as light wavelength (400–1100 nm), light intensity (0–3000 lux), and temperature (0–60°C). Participants used a marker button to indicate sleep onset and offset. GENEActiv monitors are widely used in research and provide comparable sleep estimates to other research-grade actigraphs (e.g., Axivity and ActiGraph) when the same analysis methods are employed (Plekhanova et al., 2020). However, their recording of light intensity may be less suitable to assess circadian metrics, and as such were not considered as an outcome measure (Stone et al., 2020). No familiarisation period was included during data collection based on evidence showing no 'first-night' effect in healthy adults (Driller & Dunican, 2021) and to reduce participant burden.

The raw data were processed using the GGIR v3.0 R-package (Migueles et al., 2019). Initial signal processing included automatic calibration using local gravity as a reference, detection of abnormal values, non-wear detection, and the quantification of dynamic wrist acceleration via the Euclidean Norm Minus One metric in 5-second epochs (Van Hees et al., 2013; Van Hees et al., 2015). Sleep periods were determined through a pre-defined analysis pathway that integrated event markers, raw accelerometer and light data, and/or sleep diary entries (Figure 3.2). This process differentiated sustained inactivity bouts classified as sleep from sedentary periods outside the sleep window. Sleep identification utilised the Van Hees et al. (2015) algorithm, which classifies sleep periods when wrist rotation (z-axis) does not change by more than 5° for at least 5 minutes. This algorithm, validated using GENEActiv monitors, achieved an overall accuracy of 83% compared to polysomnography (sensitivity: 91%, specificity: 45%; Van Hees et al., 2015). The same method was applied to detect daytime napping, with sleep period timings informed by sleep diary entries.

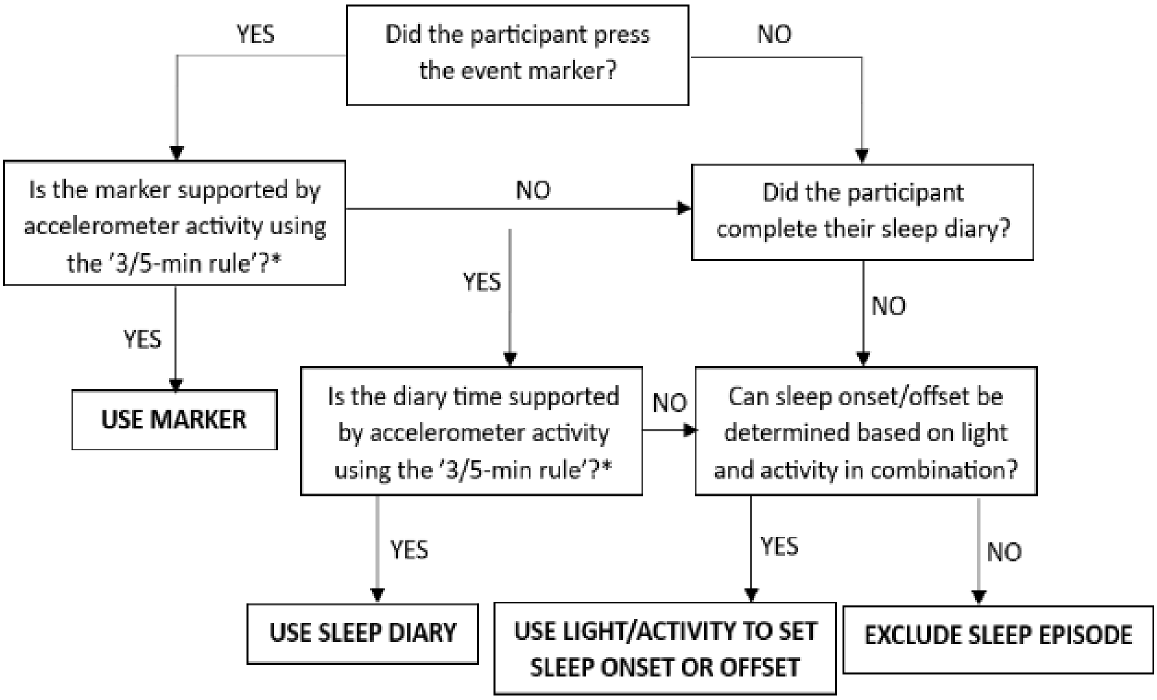

Figure 3.2. Analysis pathway for identification of sleep periods.
*sleep onset = 1st of ≥3 consecutive before minutes of sleep after reported bedtime; offset: last minute of ≥5 consecutive minutes of sleep reported wake time.

Research using actigraphy was supported by sleep diaries to aid in the identification and timing of sleep episodes. The questions were based on the Consensus Sleep Diary, a standardised tool for sleep research (Carney et al., 2012). Following the pilot study in Chapter 6, the diary was simplified to reduce participant burden and improve adherence, reflecting its supporting role to actigraphy. The simplified questions included: "What time did you try to go to sleep?" (Q2), "What time was your final awakening?" (Q6), "How would you rate the quality of your sleep?" (Q9), and "Did you nap yesterday? If so, provide the time and duration of naps" (adapted from Q11a and b). Participants were asked to complete the diary within one hour of waking to increase recall accuracy as recommended by Carney et al. (2012).

A limitation in actigraphy-based sleep research is the inconsistent use of definitions for the same sleep parameters, which are often not clearly specified in publications, complicating comparisons across studies (Fekedulegn et al., 2020). Table 3.1 presents the working definitions of the actigraphy-derived sleep parameters used in this thesis.

Table 3.1. Actigraphy-derived sleep parameters used in analyses.

Sleep parameter	Unit	Description
Sleep period	hr	The amount of time between sleep onset and sleep offset
Total sleep time (TST)	hr	The amount of time spent in sleep between sleep onset and sleep offset
Total sleep time including naps (TST incl. naps)	hr	The cumulative amount of time spent asleep in the 24-hour period between 12:00 and 12:00 the following day
Wake after sleep onset (WASO)	hr	The amount of time spent in wake between sleep onset and sleep offset
Sleep onset latency (SOL)	hr	The amount of time between self-reported bedtime (i.e., derived from sleep diary) and sleep onset
Sleep efficiency (SE)	%	The proportion of the sleep period spent in sleep (i.e., TST/sleep period)
Sleep onset	hh:mm	The time of the first instance of sleep in the nocturnal sleep episode
Sleep offset	hh:mm	The time of the final instance of sleep in the nocturnal sleep episode
Sleep Regularity Index (SRI)	arbitrary units	The probability of being in the same sleep/wake state at any given time point 24-hours apart and averaged across the data collection period. $SRI = -100 + \frac{200}{M(N-1)} \sum_{j=1}^{M} \sum_{i=1}^{N} \delta\left(s_{i.j}, s_{i+1.j}\right)$ *

* M = number of daily epochs; N = number of days; $s_{i.j}$ = 0 for sleep and 1 for wake; and $\delta\left(s_{i.j}, s_{i+1.j}\right)$ = 1 when $s_{i.j} = s_{i+1.j}$ and 0 when $s_{i.j} \neq s_{i+1.j}$.

Interviews

Semi-structured interviews were conducted in Chapter 7 to capture the nuanced, lived experiences of sleep among student-athletes, recognising that the dimensions of sleep health cannot be fully understood through questionnaires and actigraphy alone. Unlike quantitative measures, which may overlook contextual and subjective factors, semi-structured interviews enable in-depth exploration of participants' perceptions and experiences (Braun et al., 2016). These interviews also provided insights into the perceived barriers to sleep health, which were used to inform intervention development. Further information on the approach to interviews and the analysis approach are discussed within Chapter 7.

3.3.3 Methodological considerations

Statistical power: In line with the pragmatic philosophical approach underpinning this thesis, sample sizes were determined primarily based on resource constraints, reflecting the practical limitations associated with participant recruitment in student-athletes (Bretzin et al., 2022; Maguire et al., 2018), equipment availability, and the real-world context in which the studies were conducted. Lakens (2022) highlights that while statistical power is an important consideration, it is not the sole determinant of value, and data collected under resource constraints can still provide valuable information when combined with transparent reporting and a clear discussion of the inferential goals. This approach acknowledges that the practical feasibility of data collection often necessitates balancing statistical power with the broader aim of generating insights that contribute to both theory and practice within applied research settings.

Psychometric properties of measurement tools: The psychometric properties available for most questionnaire-based measures used in this thesis are limited to measures of internal consistency (typically reported as Cronbach's alpha) and test-retest reliability (reported as correlation coefficients, *r*), as more comprehensive psychometric evaluations from validation studies are generally not available. While some of these tools do not consistently demonstrate good or excellent internal consistency or test-retest reliability, they have been selected as pragmatic instruments capable of capturing useful information on sleep health with relatively low participant burden. Alternative approaches, such as using non-validated bespoke Likert scales, would pose greater threats to validity. In addition, none of the selected measures have been specifically validated in student-athlete populations, except for the Athlete Sleep Screening Questionnaire (ASSQ; Charest, 2022). However, this thesis adopts the position that there is no strong theoretical or empirical rationale to expect substantial differences in the validity of these measures in student-athletes compared to the non-clinical populations on which they were originally validated.

3.3.4 Contextual considerations

Institutional: All research was conducted with student-athletes at Hartpury University and College, a unique institution that combines a further education college of approximately 2,000 students (Hartpury College, 2024) with a higher education university of around 2,500 students (HESA, 2024) on the same campus. Sport is a central area of both academic and practical focus at Hartpury, supported by an academy of nearly 1,000 student-athletes with access to elite facilities and coaching. Given the high proportion of student-athletes compared to most British institutions, supporting their health—including sleep—is a key priority, directly impacting a large segment of the student population. The academic and sport academy structures at Hartpury operate under a single umbrella, sharing campus space and resources. This integration offers unique advantages in coordinating sport and study, as both can be managed in relation to one another. From a sleep health perspective, however, this also means that influences affecting one domain are likely to impact the other. Nevertheless, the integrated approach presents a unique opportunity to explore sleep health interventions that may be challenging to implement elsewhere. For example, adjustments to the timing of training sessions or lectures may be more feasible, allowing for practical exploration of interventions within a highly interconnected educational and athletic environment.

The institution is located on a rural site around six miles away from the nearest city (Gloucester). While on-site accommodation is available for some college and first-year university students, other students will be required to commute from surrounding areas each day. Commuting can negatively impact sleep outcomes due to the added time constraints it imposes (Kim et al., 2019), Additionally, limited transport options in this rural setting may further complicate commutes, potentially affecting students' ability to maintain consistent sleep schedules. This geographical context may influence sleep health differently compared to urban-based British institutions with easier access to transportation.

Sport: For the studies presented in Chapters 6-8, male Rugby Union players from the Hartpury sports academy were recruited. This decision was driven by the importance of rugby within the academy, being a key sport with the first team competing in the top national student league and with an aligned semi-professional team in the second tier of

English rugby. Additionally, the rugby coaching staff expressed interest in participating in this research, motivated by observations of sleep difficulties among their players.

The recruitment of rugby student-athletes introduces several considerations for interpreting study results. Previous research has examined sleep health across multiple dimensions in Rugby Union athletes, providing a basis for comparison of findings (e.g., Caia et al., 2018; Dunican et al., 2019; Teece et al., 2024). However, rugby players possess unique physical characteristics, often being taller and heavier than athletes in other sports. These may increase susceptibility to certain sleep disorders, such as obstructive sleep apnea due to factors like increased neck size (Howarth et al., 2022). Although participant exclusion criteria removed any known cases of such disorders, this potential predisposition is important to note. The physical nature of rugby may also impact certain upstream influences affecting sleep health, such as contact-induced pain or discomfort following matches (Walsh et al., 2020), that may disrupt sleep to a greater extent than non-contact athletes.

Temporal: As discussed in section 3.1, student-athlete sleep health is likely to vary based on academic and athletic demands. Monthly assessments over a year have shown that sleep timing tends to be delayed, and sleep duration increases during months with lower academic and training demands (Astridge et al., 2021). Similarly, when assessed by semester, sleep outcomes appear relatively stable early on but tend to decline as academic pressures intensify later in the term (Bolin, 2019; Hamlin et al., 2019). Based on these findings, the decision was made to conduct research during the early weeks in an academic semester, which reflects a period when classes are ongoing but exams and major coursework deadlines have yet to impose additional strain. The very first weeks of the semester were also avoided due to atypical sleep patterns linked to Freshers' Week and initiation activities, during which increased alcohol consumption is common (Harris et al., 2023). This chosen period reflects a time when sleep health is suboptimal and when both academic and athletic influences on sleep are present, making it ideal for identifying modifiable factors that could be addressed in an intervention. This approach aims to inform best practices for key stakeholders by targeting the upstream influences that affect sleep health in a manageable, actionable way. Studies were also scheduled to avoid changes to clock time (e.g., transition to British Summer Time) due to the influence on sleep (Malow, 2022).

3.4. Behavioural framework

In this thesis, human behaviour is defined as "anything a person does in response to internal or external events… that occur in the body and are controlled by the brain," encompassing both overt actions that are directly measurable and covert actions that are indirectly measurable (Davis et al., 2015, p. 327). As discussed in section 3.1, a confluence of biological, psychological, social, and environmental factors can influence sleep health outcomes through behavioural changes (Figure 3.1). Viewing sleep from a behavioural perspective rather than a biological perspective, such as the two-process model, is prudent for this thesis, as behaviours resulting in suboptimal sleep health appear to be underpinned by upstream influences related to being a student-athlete.

Health behaviour change theories are widely used in other health domains, such as physical activity, with a range of social-cognitive, humanistic, and dual-process approaches taken (Rhodes et al., 2019). However, their use in sleep health research has been limited. A review identified only 13 studies using behavioural approaches for sleep interventions, with most relying on the Theory of Planned Behaviour (Mead & Irish, 2020). Despite evidence suggesting that incorporating behavioural frameworks can improve intervention effectiveness, sleep health has often been viewed as primarily biological, with less attention given to social and environmental interactions (Grandner & Fernandez, 2021).

This thesis employs the Behaviour Change Wheel (BCW) as its primary behavioural framework (Michie et al., 2011). The BCW was developed as a practical tool for designing behavioural interventions, following a review of existing frameworks that evaluated their comprehensiveness, coherence, and utility. None of the 19 reviewed frameworks covered all intervention functions and policy categories, prompting the development of the BCW to address this gap.

At the core of the BCW is the COM-B model, which posits that behaviour results from the interaction between three key components: Capability, Opportunity, and Motivation (Figure 3.3). These components feed back into one another and collectively shape behaviour. Capability refers to an individual's psychological and physical capacity to perform a behaviour, including knowledge and skills, and can be divided into physical and psychological capability. Opportunity encompasses external factors that enable or prompt behaviour, including social and physical opportunities. Motivation involves brain processes that energise and direct behaviour, encompassing both automatic (habitual and emotional) and reflective (analytical decision-making) processes (Michie et al., 2011).

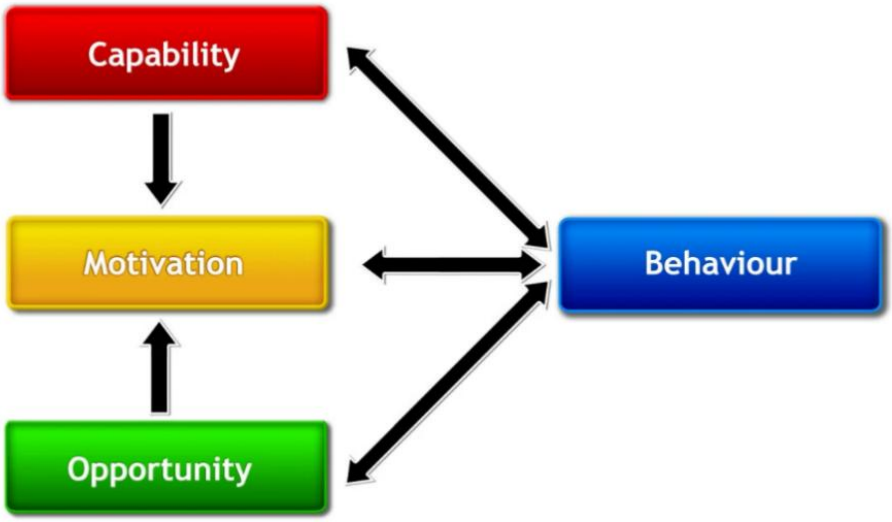

Figure 3.3. The COM-B model and interactions between capability, opportunity, motivation, and behaviour.
Reprinted from Michie, S., Van Stralen, M. M., & West, R. (2011). The behaviour change wheel: A new method for characterising and designing behaviour change interventions. Implementation Science, 6(1), 42. Licensed under CC BY 2.0 (https://creativecommons.org/licenses/by/2.0/).

The COM-B model is useful for identifying barriers to desired behaviours, which can then be targeted through interventions. Once a behavioural diagnosis is made using the COM-B framework, intervention design begins with the BCW by considering intervention functions and policy categories (Figure 3.4). These are mapped onto the COM-B components to ensure that the intervention is both effective and contextually appropriate. For example, an education-based intervention could address psychological capability but may have a limited impact on physical opportunity barriers. The BCW also offers flexibility in delivery formats, ensuring interventions are practical in specific contexts. The application of the COM-B model and BCW in intervention design is discussed further in Chapter 8.

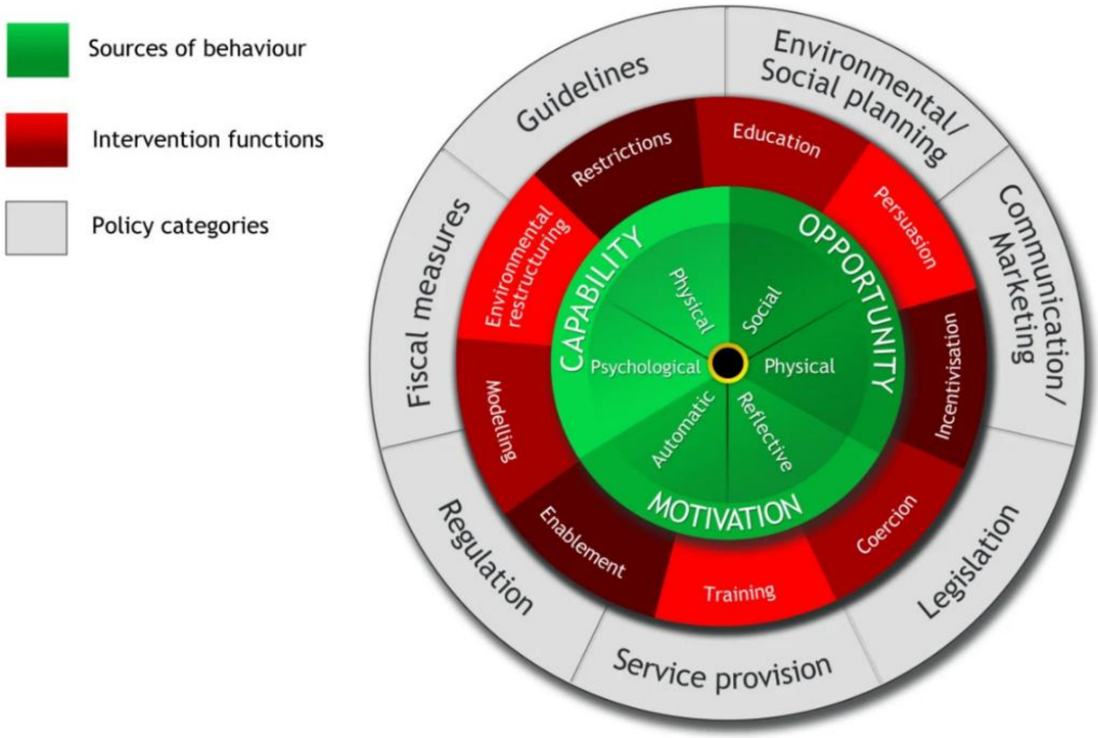

Figure 3.4. The behaviour change wheel (BCW) framework, with the central COM-B model, nine intervention functions, and seven policy categories.
Reprinted from Michie, S., Van Stralen, M. M., & West, R. (2011). The behaviour change wheel: A new method for characterising and designing behaviour change interventions. Implementation Science, 6(1), 42. Licensed under CC BY 2.0 (https://creativecommons.org/licenses/by/2.0/).

A key advantage of the BCW for health intervention design is its integration with the Behaviour Change Technique Taxonomy v1 (BCTTv1; Michie et al., 2013). The BCTTv1 was developed to standardise the terminology used to describe 'active' components of interventions, known as behaviour change techniques (BCTs). This helps to compare intervention content and efficacy across studies, reducing duplication of effort. The BCTTv1 can also be used for retrospective coding of intervention studies that did not originally use the taxonomy, allowing for standardisation across studies. This approach will be employed in the scoping review in Chapter 4. Additionally, the BCTTv1 aids in designing new interventions using the BCW by identifying BCTs that are more likely to elicit behaviour change based on their alignment with COM-B components. This process is further detailed in Chapter 8.

CHAPTER FOUR: BEHAVIOURAL INTERVENTIONS AND BEHAVIOUR CHANGE TECHNIQUES USED TO IMPROVE SLEEP OUTCOMES IN ATHLETE POPULATIONS - A SCOPING REVIEW

Associated publication (see Appendix 1): Wilson, S. M. B., Sparks, K. V., Cline, A., Draper, S. B., Jones, M. I., & Parker, J. K. (2024). Behavioral interventions and behavior change techniques used to improve sleep outcomes in athlete populations: A scoping review. *Behavioral Sleep Medicine,* 31, 1-23. https://doi.org/10.1080/15402002.2024.2374257

Author contribution: S. M. B. Wilson: conceptualisation, data curation, formal analysis, methodology, project administration, resources, writing (original draft preparation), and writing (review and editing) (all lead author); K. V. Sparks: data curation, formal analysis, and writing (review and editing); A. Cline: data curation, formal analysis, and writing (review and editing); S. B. Draper: conceptualisation, methodology, supervision, and writing (review and editing); M. I. Jones: conceptualisation, methodology, supervision, and writing (review and editing); J. K. Parker: conceptualisation, data curation, formal analysis, methodology, supervision, and writing (review and editing)

4.1. Rationale

Substantial evidence suggests that athlete populations display a high prevalence of undesired sleep characteristics (e.g., Lastella et al., 2015; Walsh et al., 2020), despite limited evidence indicating a higher prevalence of clinical sleep disorders (Tuomilehto et al., 2017). Therefore, there is a need to develop targeted interventions for athletes to mitigate potential negative impacts on performance and health. While sleep regulation is primarily governed by biological processes, the interaction with social-environmental factors significantly influences observed sleep practices (Grandner, 2017). Consequently, much research has adopted a behavioural perspective, focusing on interventions aimed at changing sleep practices by addressing upstream influences at the individual (e.g., personal beliefs), social (e.g., the workplace), and societal levels (e.g., public policy), rather than directly manipulating biological regulation through methods like light therapies or pharmacological aids (Grandner, 2017; Halson, 2019).

Behavioural sleep interventions in the general population have employed diverse approaches to improve sleep outcomes, though they have demonstrated mixed effectiveness (Baron et al., 2021). Past systematic reviews of sleep interventions in athletes have included both behavioural and non-behavioural approaches, providing preliminary evidence to support the use of each in improving sports performance, mood, and recovery (Bonnar et al., 2018; Gwyther et al., 2022; Silva et al., 2021). However, the extent of changes in sleep outcomes resulting from behavioural interventions, as well as the specific behavioural components driving these improvements, remain unclear.

The complexity of behavioural interventions and the diverse terminology used to describe intervention content have made it challenging to identify the specific components driving behaviour change. In response, there has been a move toward categorising intervention content into standardised elements termed behaviour change techniques (BCTs; Abraham & Michie, 2008). A BCT is regarded as the active ingredient of an intervention, representing an observable, replicable, and irreducible element aimed at modifying or redirecting the processes governing behaviour (Michie & Johnston, 2013; Michie et al., 2011). Building on prior taxonomies, the Behaviour Change Technique Taxonomy (BCTTv1) was developed through Delphi-type exercises with field experts to create a comprehensive, hierarchically structured classification system (Michie et al., 2013). The BCTTv1 consists of 93 non-overlapping and clearly defined BCTs grouped into 16 clusters.

While the use of the BCTTv1 is becoming more widespread, many studies incorporating behaviour change do not apply the BCTTv1 or other standardised nomenclature when describing their intervention content. However, the BCTTv1 allows for retrospective coding of previously published research, enabling meaningful comparisons between intervention components (Michie et al., 2013). The lack of integrated behaviour change theory in athlete sleep research has been identified as a limitation, with no studies assessing the long-term efficacy of specific BCTs within interventions (Halson, 2019). Therefore, there is a need to systematise previous interventions using a framework like the BCTTv1. This would enable the assessment of specific BCTs and their frequency of use, facilitate comparisons between studies, and help identify the most effective BCTs for improving sleep in athletes, which could be incorporated into future research.

Given the limitations of previous reviews, the objectives of this scoping review were: (1) to identify and map the existing evidence on behavioural sleep interventions and their impact on sleep outcomes in athletes, and (2) to retrospectively classify the BCTs used in these interventions using the BCTTv1. A scoping review was deemed the most appropriate approach for these objectives due to the relative novelty of this research area and the anticipated variations in intervention design. These factors necessitate identifying available evidence types and examining the research methodologies employed (Munn et al., 2018).

4.2. Methods

This review was conducted in accordance with the JBI methodology for scoping reviews (Peters et al., 2020) and followed the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis Extension for Scoping Reviews (PRISMA-ScR; Tricco et al., 2018). The methodology outlined below was defined *a priori* and registered prospectively as a review protocol on the Open Science Framework on 24 March 2023, and updated on 11 September 2023 (DOI: 10.17605/OSF.IO/BFZWX). The study received institutional ethical approval (ETHICS2022-10), and the associated application and forms are attached as Appendix 2-4.

4.2.1. Inclusion criteria

The review inclusion criteria were defined using the Population, Content, and Context framework (Peters et al., 2020) and are summarised in Table 4.1. A broad definition of sport was applied to encompass all physically demanding activities including non-traditional sports (e.g., mountaineering and dance). Inclusion based on performance level was defined using the framework outlined by McKay et al. (2022), with athletes participating in a sport at Tier 2 (Trained/Developmental) or above, encompassing ∼12%–19% of the global population.

Table 4.1. Study inclusion criteria using the Population, Concept, Context framework.

Study Component	Inclusion	Exclusion
Population	Athletes currently engaged in sport at any level from trained/developmental to world-class (Tier 2-5 of McKay et al. (2022) framework)* Mean age ≥ 18.0 years	Non-athlete population, para-athlete** Participant's inclusion is contingent on diagnosed sleep disorder at baseline
Concept	Prospective sleep intervention with ≥1 behavioural component Report ≥1 sleep outcome pre- and post-intervention, no restriction on type of outcome	Intervention including medication or pharmacological component Intervention including circadian realignment following travel between time zones Outcomes related to, but not directly assessing, sleep (e.g., daytime sleepiness or attention)
Context	No restriction on context or setting	
Types of sources	Experimental and quasi-experimental study designs	Descriptive observational study designs, qualitative studies, and text and opinion papers Systematic reviews, meta-analyses and other review types Any grey literature

* The McKay et al. (2022) framework was specified following the pilot exercise to allow retrospective classification of performance level using standardised definitions.
** The exclusion of studies with para-athletes was specified following the pilot exercise as certain disabilities can impact sleep regulation (Grade et al., 2023).

Due to challenges in accurately classifying performance levels from study manuscripts, studies were categorised into professional, student-athlete, or amateur groups. The exclusion of athletes aged <18 years and para-athletes was imposed due to the impact of age and certain disabilities on sleep regulation (Grade et al., 2023; Hagenauer et al., 2009). A broad definition of behaviour was applied, constituting "anything a person does in response to internal or external events, that may be overt and directly measurable or covert and indirectly measurable, and are physical events that occur in the body and controlled by the brain" (Davis et al., 2015, p. 327). Direct interventions where sleep schedules or targets are specified were included alongside indirect interventions (e.g., education), reflecting the approach used in a previous review by Baron et al. (2021). Studies solely published in

English were included, as the translation from other languages into English could result in the inadvertent exclusion or misinterpretation of BCTs. No restrictions were placed on the publication date of studies to ensure the identification of a wide range of evidence.

4.2.2. Search strategy

A systematic search strategy was employed to identify research articles, conference papers, and abstracts for inclusion. An initial limited search of MEDLINE (PubMed) was undertaken to identify relevant studies on the subject. Article text words and index terms from this preliminary search were used to develop a simple search strategy using Title/Abstract keywords: [(sleep*) AND (athlete* OR sport* OR athletic* OR player) AND (intervention OR hygiene OR education* OR behavior* OR behaviour* OR extension OR counseling OR optimization OR optimization OR workshop)] and restricted to the English language. MEDLINE (PubMed), EMBASE (Ovid), APA PsycInfo, and SCOPUS databases were searched, with the full search term for each database available in Appendix 5. The initial literature search was run on March 21, 2023, and then rerun on September 6, 2023. Additionally, backward citation searching of the included studies was performed to identify any further relevant studies.

4.2.3. Study selection

Following the search, all identified studies were collated and imported to Rayyan online review software (Rayyan Systems Inc, Cambridge, MA, USA; Ouzzani et al., 2016). Duplicate studies were manually removed, and a pilot calibration exercise was performed with a random selection of 25 full-text studies screened by two reviewers in accordance with the JBI pilot framework to increase inter-reviewer consistency (Peters et al., 2020). The level of agreement between reviewers was almost perfect (agreement = 96.0%, Cohen's $\kappa = 0.83$; Landis & Koch, 1977). Adjustments to the inclusion criteria relating to performance level classification and studies including para-athletes were made at this stage (Table 4.1). Both reviewers then independently evaluated the titles, abstracts, and then the full texts of each study. Agreement between reviewers was substantial (agreement = 98.3%, Cohen's κ = 0.61; Landis & Koch, 1977). Disparities or disagreements were resolved through reviewer discussion.

4.2.4. Data extraction

Data from the included studies were extracted by the lead reviewer and verified by a second reviewer. The extracted data encompassed study aims, study format (e.g., journal article or abstract), study design, participant characteristics (country, sport, performance level, sample size, age, and gender), intervention components (e.g., any inclusion criteria, direct or indirect intervention, and any control groups), study duration, sleep outcomes, and key findings, and was documented in a data-charting form based on recommendations from the JBI scoping review methodology (Peters et al., 2020; Appendix 6). Authors of papers were contacted once to request any missing or supplementary data where required.

For the coding of behavioural intervention content, two reviewers who had completed prior online training (www.bct-taxonomy.com) independently performed the coding for the included studies. All 93 BCTs outlined in the BCTTv1 were considered for each study, with both reviewers explaining their rationale for assigning the BCT in each instance. Fourteen discrepancies (i.e., the BCT was only coded by one reviewer) were resolved through discussion; if a consensus could not be reached, the proposed BCT was not included.

4.2.5. Quality appraisal

Quality appraisal was conducted to support the study objective of mapping the available evidence by providing an assessment of the methodological quality and possibility of bias in each study to enable an understanding of the current strengths and limitations in this research area. Quality appraisals were conducted using the nine-question quasi-experimental, and thirteen-question randomised controlled trial JBI critical appraisal checklists corresponding to the study design employed (Tufanaru et al., 2020). No inclusion criteria were applied in relation to quality appraisal scores. Quality appraisal was not performed on conference abstracts. The level of agreement between the two independent reviewers was substantial (agreement = 83.5%, Cohen's κ = 0.64; Landis & Koch, 1977), with discrepancies resolved through discussion. Following the quality appraisal, the overall score for each study was incorporated into data synthesis alongside the data extraction form and coded BCTs.

4.3. Results

The PRISMA flowchart highlighting the study selection process is presented in Figure 4.1. A total of 33 studies were identified and are summarised in Table 4.2.

4.3.1. Study characteristics

The predominant study locations by region were Oceania (*n* = 11), Europe (*n* = 9), and North America (*n* = 9). Professional athletes were used in 17 studies, with 10 using student-athletes and six using amateur athletes (one unknown). Five studies encompassed participants from multiple sports, with rugby union (*n* = 5) and football (*n* = 3) the most prevalent sports in single-sport studies. Amongst the included studies, 19 used all-male participants, with five all-female and eight using mixed-gender samples. The collective participant count across studies was 892, with a median sample size of 21 (IQR: 15), and a median age of 23 (IQR: 4) where reported.

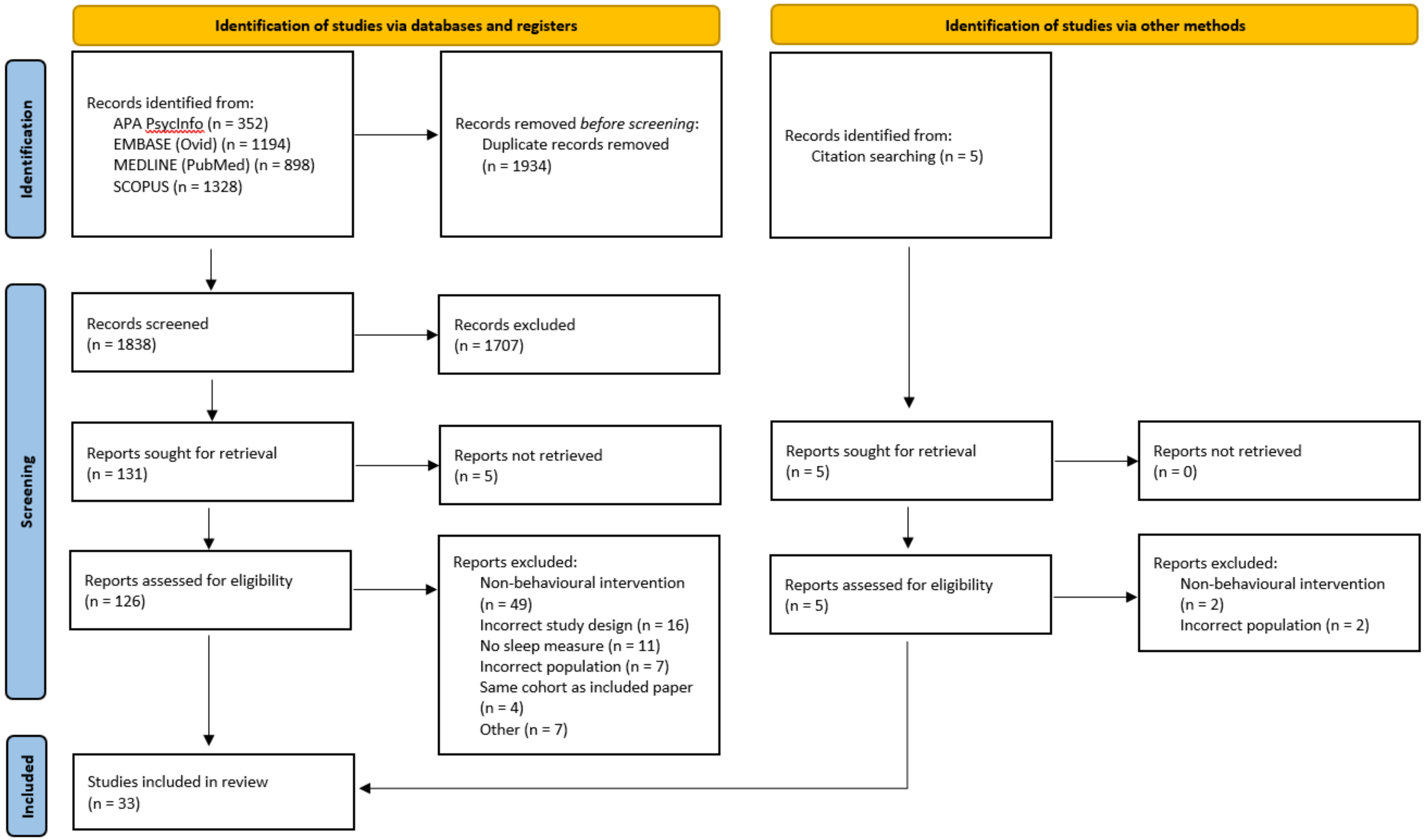

Figure 4.1. Search results and study selection and inclusion process.

Table 4.2. Characteristics of included studies.

Study	Country, Sport, and Level	Intervention Components	Design and duration	Participant Characteristics	Sleep Parameters	Outcomes	QA	BCT Total
Education								
Caia et al. (2018)	Australia, rugby league, professional	Group education sessions (2x30-min) during competitive season. 50% with shortest TST assigned to INT. CON = no education sessions	Non-randomised parallel groups pre-post 14-d BL, 14-d INT, 14-d FU at 1-m post-INT	n: 24 age: 27 ± 4 (INT), 25 ± 3 (CON) gender: all M	Actigraphy: SE, SOL, SOT, TIB, TST, WUT,	↑ TIB (25-min), ↑ TST (20-min), advanced SOT (23-min) post-INT vs BL. ↑ TIB (51-min), delayed WUT (3-min), ↓ SE (4.2%) at FU vs BL.	5/9	3
Driller et al. (2019)	New Zealand, cricket, professional	Group education session (50-min), personalised feedback and recommendations from 1-to-1 consultation (30-min)	Single group pre-post 3-wk BL, 3-wk INT	n: 9 age: 23 ± 4 gender: all M	Actigraphy: SE, SOL, SOT, SOV, TIB, TST, WASO, WE, WED, WUT, WV Questionnaire: PSQI	↑ SE (5%), ↓ SOL (29-min), SOV (28-min), ↓ PSQI global (2-pt)	7/9	4
Dunican et al. (2021)	Australia, basketball, professional	Group education session (2-hr) during competitive season, and personalised feedback and recommendations from 1-to-1 consultation (20-min)	Single group pre-post (Athlete sub-study) 1-m BL, 1-m INT	n: 12 age: 25 ± 2 gender: all F	Actigraphy: SE, SOL, SOT, TIB, TST, WASO, WUT,	No significant findings	7/9	2
Dunican et al. (2023)	Australia, swimming, amateur	Group education session (2.5-hr) with recommendations during training programme	Single group pre-post 7-wk BL, 7-wk INT	n: 24 age: 39 ± 11 gender: 54% F	Actigraphy: FI, SE, SOL, SOT, TIB, TST, WASO, WUT	Delayed SOT and WUT (both 12-min)	7/9	2
Harada et al. (2016)	Japan, football, student-athlete	Educational leaflet with 8 sleep hygiene recommendations	Single group pre-post 1-m INT, FU at 3-m post-INT	n: 84 age: 18-22 gender: all M	Questionnaire: Undefined sleep quality questionnaire	↑ sleep quality at FU vs pre-INT	7/9	1
Jenkins et al. (2021)	UK, rugby union, professional	Group education session (30-min) during competitive season and daily actigraphy feedback	Single group pre-post 3-wk BL, 3-wk INT, 2-wk FU	n: 14 age: 24 ± 4 gender: all M	Actigraphy: SE, sleep quality (1-10 derived from actigraph), SOL, SOT, SOV, TST, TIB, WASO, WE, WED, WUT, WV	No significant findings	7/9	3
Kaier et al. (2016)	USA, multiple, student-athlete	Group workshop: education, simulated sleep deprivation, brainstorming, recommendations	Single group pre-post BL, 1-d INT, FU within 14-d (FU1) and 3-to-4-m (FU2) post-INT	n: 104 age: 19 ± 2 gender: 69% F	Questionnaire: PSQI, SHI	No significant findings	6/9	6

Study	Country, Sport, and Level	Intervention Components	Design and duration	Participant Characteristics	Sleep Parameters	Outcomes	QA	BCT Total
O'Donnell & Driller (2017)	New Zealand, netball, professional	Group sleep hygiene education (50-min) with recommendations and daily reminders	Single group pre-post 1-wk BL, 1-wk INT	n: 26 age: 23 ± 6 gender: all F	Actigraphy: SE, SOL, SOT, SOV, TIB, TST, WE, WED, WUT, WV	↑ TST (22-min), ↓ WED (3-min), ↓ WV (21-min)	8/9	3
Sargent et al. (2021)	Australia, cricket, professional	Group workshop: feedback, education, individual target setting, encouraged to nap CON = no workshop	Randomised control trial 1-wk BL, 1-wk INT	n: 15 age: 22 ± 2 (INT), 26 ± 4 (CON) gender: all M	Actigraphy: SE, SOL, SOT, TIB, TIB (incl. naps), TST, TST (incl. naps), WUT,	↑ TIB (42-min) and ↑ TST (36-min) (both incl. naps) in INT. ↓ TIB (incl. naps; 24-min) in CON	8/13	5
van Ryswyk et al. (2017)	Australia, Australian football, professional	Group education sessions (2 x 1-hr) with written and verbal information. Weekly group feedback and optional individual consultation. Additional individual feedback if <7-hr self-report sleep duration	Single group pre-post 6-wk INT	n: 25 age: 23 ± 2 gender: all M	Actigraphy: TIB, TST (incl. naps), SE, SOL, WASO Sleep diary: SE, TIB, TST (incl. naps) Questionnaire: PSQI	↑ sleep diary TST (incl. naps; 20-min) and sleep diary SE (2%)	4/9	3
Vitale et al. (2019)	Italy, football, amateur	Group education session (45-min) with recommendations following evening training. CON: no session	Randomised control trial 2-d BL, 1-d INT, 1-d FU	n: 29 age: 26 ± 6 (INT), 25 ± 7 (CON) gender: all M	Actigraphy: FI, SE, SOL, SOT, TST, WASO, WUT Questionnaire: sleep quality (0-10 Likert scale)	Group x time interactions: ↓ SOL, ↑ sleep quality	10/13	2
Mind-body practices								
Chen et al. (2018)	Taiwan, baseball, amateur	Mindfulness training protocol (4 x 2.5 to 3-hr sessions) including breathing, yoga, and meditation	Single group pre-post 28-d INT, FU at 28-d post-INT	n: 21 age: 26 ± 3 gender: all M	Questionnaire: PSQI (Chinese version)	↓ PSQI (Chinese version) global (0.9-pt) at FU vs pre-INT	7/9	1
Datta et al. (2022)	India, multiple, unknown	Yoga nidra or progressive muscle relaxation training protocol (3-4 x supervised sessions, daily self-led practice). Individual sleep education session pre-protocol	Randomised control trial 14-d BL, 28-d INT, 14-d FU	n: 45 age: 21 ± 4 gender: all M	Actigraphy + EEG module (n = 20): SE, sleep stages (S1-S3), SOL, TIB, TST, WASO Sleep diary: SE, sleep quality (undefined), SOL, TIB, TST, WASO	Actigraphy: ↓ SOL (26-min) and ↓ TIB (31-min) at FU vs BL Sleep diary: ↑ SE, ↑ TIB, ↓ SOL in yoga nidra vs progressive muscle relaxation at FU vs BL	6/13	5
Jones et al. (2020)	USA, rowing, student-athlete	Mindfulness-based stress reduction protocol (8 x 75-min supervised sessions, self-practice). CON: no protocol	Quasi-randomised control trial 3-to-7-d BL, 56-d INT, 7-d FU at 42-d post-INT	n: 27 age: 18-23 gender: all F	Actigraphy: SE, TST, WASO Questionnaire: PSQI	↑ SE in INT and ↓ SE in CON at FU vs BL, ↓ PSQI global (group x time interaction) at FU vs BL	7/13	3
McCloughlin et al. (2016) [3]	Australia, dance, student-athlete	Daily self-led progressive muscle relaxation (8.5-min audio). Analysis split by SOL and trait anxiety at BL	Single group pre-post 7-d BL, 7-d INT	n: 12 age: 20 ± 1 gender: all F	Actigraphy: SE, SOL, SOT, TIB, TST, WASO, WUT, Questionnaire: sleep quality (1 – 5 Likert scale)	↓ SOL (4-min) in high SOL/high trait social evaluation anxiety group, ↑ sleep quality (0.2 units) in high SOL/high trait social evaluation anxiety group	7/9	4

Study	Country, Sport, and Level	Intervention Components	Design and duration	Participant Characteristics	Sleep Parameters	Outcomes	QA	BCT Total
Rijken et al. (2016)	Netherlands, multiple, professional	Mental coaching protocol (4 x 2.5hr sessions) including stress awareness, breathing techniques, and mindfulness. Additional heart rate variability feedback training using app (INT1) or alpha power feedback using EEG system (INT2)	Non-randomised parallel groups pre-post 35-d INT, FU at 42-d post-INT	n = 21 age: 21-32 (INT1), 16-38 (INT2) gender: all M (INT1), 80% M (INT2)	Questionnaire: PSQI	No significant findings	7/9	1
Direct								
Famodu et al. (2017) [#2]	USA, athletics, student-athlete	Target increase in TIB of 1-hr above individual baseline	Single group pre-post 7-d BL, 7-d INT	n: 21 age: 20 ± 2 gender: all F	Actigraphy: TST	↑ TST (22-min)	-	1
Leduc et al. (2022)	UK, rugby union, student-athlete	Target 10hr TIB after evening training session at the expense of a recovery session the following morning. CON: no sleep extension, attended recovery session	Randomised cross-over 2-d BL, 1-d INT, 2-d FU, 48-hr washout	n: 10 age: 21 ± 1 gender: all M	Actigraphy: FI, SE, SOL, SOT, WUT, TIB, TST, WASO	Delayed WUT (3.5-hr), ↑ TIB (3.3-hr), ↑ TST (2.5hr), ↑ WASO (3-min) in INT vs CON	11/13	2
Mah et al. (2011)	USA, basketball, student-athlete	Target 10hr TIB	Single group pre-post 14-to-28-d BL, 35-to-49-d INT	n: 11 age: 19 ± 1 gender: all M	Actigraphy: TST Sleep diary: napping, TIB, TST, WASO, WUT	Actigraphy: ↑ TST (1.8-hr) Sleep diary: ↑ TST (2.6-hr)	7/9	1
Mah et al. (2017) [#]	USA, baseball, professional	Target 10hr TIB. CON: maintain habitual sleep	Randomised control trial 2-d BL, 5-d INT	n: 17 age: - gender: all M	Actigraphy: TST Sleep diary: TST	Actigraphy: ↑ TST (0.6-hr) Sleep diary: ↑ TST (1.2-hr)	-	1
Roberts et al. (2019a) [4]	Australia, cycling, amateur	Target 30% extension of TIB, with SOT and WUT tailored to chronotype. CON: maintain habitual sleep (additional 30% restriction of TIB condition present but not reported)	Randomised cross-over 3-d INT, >1-wk washout	n: 9 age: 30 ± 6 gender: all M	Actigraphy: SE, TST Questionnaire: sleep quality (1 – 5 Likert scale)	↑ TST on all nights (1.3 – 1.8hr), ↓ SE on night 2 and 3 (3 – 4%) in INT vs CON, ↓ sleep quality on night 3 (0.6-units) in INT vs CON	7/13	1
Schwartz & Simon (2015)	USA, tennis, student-athlete	Target 9hr sleep duration including naps	Single group pre-post 1-wk BL, 1-wk INT	n: 12 age: 18-22 gender: 58% F	Sleep diary: napping, SOT, TST, WUT,	↑ TST (1.7-hr)	6/9	1
Swinbourne et al. (2018)	New Zealand, rugby union, professional	Target 10hr TIB, and sleep education (format and duration unclear)	Single group pre-post 3-wk BL, 3-wk INT	n: 25 age: 25 ± 3 gender: all M	Actigraphy: SE, SOL, TIB, TST, WASO Questionnaire: PSQI	↑ TST (1-hr), ↓ PSQI global (1.9-pt)	6/9	2
Multi-component								
Charest et al. (2017) [#]	Canada, speed skating, professional	Daily napping, increased target TIB, sleep hygiene routine including electronic device removal and blue light glasses	Single group pre-post 2-wk INT	n: 7 age: 24 ± 4 gender: 57% M	Sleep diary: sleep satisfaction, SOL, TST, WE Questionnaire: ASSQ	↑ TST, ↓ SOL, ↑ sleep satisfaction, ↓ ASSQ sleep difficulty score	-	0

Study	Country, Sport, and Level	Intervention Components	Design and duration	Participant Characteristics	Sleep Parameters	Outcomes	QA	BCT Total
de Mello et al. (2020)	Brazil, swimming, professional	Daily light therapy (30-min) and sleep hygiene recommendations during competition period	Single group pre-post 10-d INT	n: 14 age: 27 ± 2 gender: 71% M	Actigraphy: TST, SE, SOL, WE	↑ TST (51-min)	4/9	1
Duffield et al. (2014)	Australia, tennis, professional	Acute cold water immersion, compression garments and sleep hygiene recommendations following high physical loading. CON = 15-min stretching post-session	Randomised cross-over 1-d INT, >1-d washout	n: 8 age: 21 ± 4 gender: all M	Actigraphy: SE, SOL, TIB, TST	No significant findings (Large ES for ↑ TST and ↑ TIB in INT vs CON)	7/13	1
Fullagar et al. (2016)	Germany, football, amateur	Acute environmental changes, electronics curfew, and set time in bedroom/lights out post-match. CON = usual post-match routine, time in bedroom delayed	Randomised cross-over 1-d BL, 1-d INT, 7-d washout	n: 20 age: - gender: all M	Actigraphy: napping, SOL, SOT, TST, WE, WED, WUT	↑ TST (1.7-hr) post-match and ↑ WE (4.6 episodes) in INT vs CON	8/13	1
Grandner et al. (2017) [#1]	USA, Unknown, student-athlete	Initial sleep education session (1.5-hr), sleep/fitness tracking, text reminders, peer and researcher support	Single group pre-post 10-wk INT	n: 35 age: - gender: -	Questionnaire: PSQI (and PSQI-derived SOL, SOT, TST, WUT)	↓ PSQI global (1.3-pt), ↓ SOL (12-min), advanced WUT (32-min)	-	5
Vachon et al. (2022)	France, rugby union, professional (U21)	Sleep education, relaxation strategies, mattress change, foam rolling, and cold water immersion during training taper.	Single group pre-post 3-wk BL, 7-d INT	n: 18 age: 19 ± 1 gender: all M	Questionnaire: PSQI	↓ PSQI global (1.3-pt) with greatest ↓ in participants classified as functional overreaching training status	6/9	4
Vachon et al. (2023)	France, rugby union, professional (U21)	Group education sessions (2 x 1.5-hr) and mind-body practice sessions (3 x 45-to-60-min) including hypnosis, progressive muscle relaxation, and paradoxical interventions	Single group pre-post 4-wk INT, 4-wk BL	n: 11 age: 19 ± 1 gender: all M	Actigraphy: SE, SOL, SOT, TIB, TST, WASO, WE	↓ SOL and ↑ SE at BL vs pre-INT	4/9	5
Other								
Bender et al. (2018)	Canada, multiple, professional	Standardised clinical sleep interview, follow-up interview if classed as moderate/severe sleep difficulty, general recommendations (sleep education sheet) and individualised treatment (e.g., travel/jet-lag management, CBT-Insomnia program, light therapy)	Randomised single-group pre-post (Clinical validation sub-study) 1-d BL, INT duration variable, FU at ~151-d post-INT start	n: 44 age: 24 ± 4 gender: 62% F (age and gender from full study, n = 199)	Questionnaire: ASSQ	↓ ASSQ sleep difficulty score (1.5-pt) at FU vs pre-INT, greatest ↓ in participants with greater sleep difficulty at BL	5/9	2
Jakowski & Stork (2022)	Germany, multiple, student-athlete	Downloaded either Sleep Score (INT1) or Sleep Cycle (INT2) app, used sleep tracking and reports in week 1 then added smart alarm in week 2 alongside sleep diary. CON1: no INT, CON2: sleep diary only.	Randomised control trial 2-wk INT	n: 98 age: 21 ± 2 gender: 62% F	Sleep diary: SE, SOL, SOT, TIB, TST, WE, WED, WUT Questionnaire: PSQI	No significant findings	7/13	1

Study	Country, Sport, and Level	Intervention Components	Design and duration	Participant Characteristics	Sleep Parameters	Outcomes	QA	BCT Total
Tuomilehto et al. (2017)	Finland, ice hockey, professional	Group education session (2-hr). If potential sleep disorder at BL (n = 14), additional polysomnography assessment and individual treatment plan (e.g., typical treatment for clinical insomnia or sleep disordered breathing)	Single group pre-post (sub-study) INT duration variable, FU at 12-m post-INT start	n: 40 age: 17-40 (from main study, n = 109) gender: all M	Questionnaire: sleep quality (1-10 Likert scale)	↑ sleep quality (0.6-units) at FU with greatest ↑ in those with lower BL sleep quality	5/9	2

Presented as an abstract

Additional studies identified presenting the same research: [1] Alfonso-Miller et al. (2017) and Athey et al. (2017); [2] Famodu et al. (2014); [3] McCloughlin et al. (2014); [4] Roberts et al. (2022)

Duration abbreviations: BL: baseline; CON: control; FU: follow-up; INT: Intervention.

Measure abbreviations: ASSQ: Athlete Sleep Screening Questionnaire; FI: fragmentation index; PSQI: Pittsburgh Sleep Quality Index; SE: sleep efficiency; SOL: sleep onset latency; SOT: sleep onset time; SOV: sleep onset variance; TIB: time in bed; TST: total sleep time; WASO: wake after sleep onset; WE: wake episodes; WV: wake variance; WUT: wake up time

4.3.2. Study design

Studies were categorised into five groups for narrative synthesis based on similarities in extracted intervention characteristics before the coding of BCTs: education (*n* = 11), mind-body practices (*n* = 5), direct (*n* = 7), multi-component (*n* = 7), and other (*n* = 3). Pre-post study designs were utilised in 23 studies (single-group: *n* = 21, non-randomised parallel groups: *n* = 2), while ten studies utilised randomised designs (randomised controlled trial: *n* = 5; randomised cross-over, *n* = 4; quasi-randomised trial, *n* = 1). Intervention durations spanned from acute one-day studies to multiple weeks. Assessment of sleep outcomes was typically performed during or immediately post-intervention, with only ten studies conducting a follow-up ≥7-d post-intervention. Sleep outcomes were evaluated using actigraphy (*n* = 21), questionnaires (*n* = 15), and sleep diaries (*n* = 7), with 11 studies utilizing two or more assessment methods.

4.3.3 Behaviour change techniques

Across the 33 studies, a total of 18 distinct BCTs were identified, occurring in 79 separate instances. The most frequently employed BCTs were *"4.1 Instruction on how to perform a behaviour"* (20), *"9.1 Credible source"* (12), and *"1.1 Goal setting (behaviour)"* (9). When categorised into the 16 BCT groupings, 12 groupings were identified in at least one instance (Figure 4.2). Four BCT groupings were not found in any study: *"6. Comparison of behaviour"*, *"14. Scheduled consequences"*, *"15. Self-belief"*, and *"16. Covert learning"*. A comprehensive breakdown of the coded BCTs for each intervention and their definitions can be found in Appendix 7 and 8.

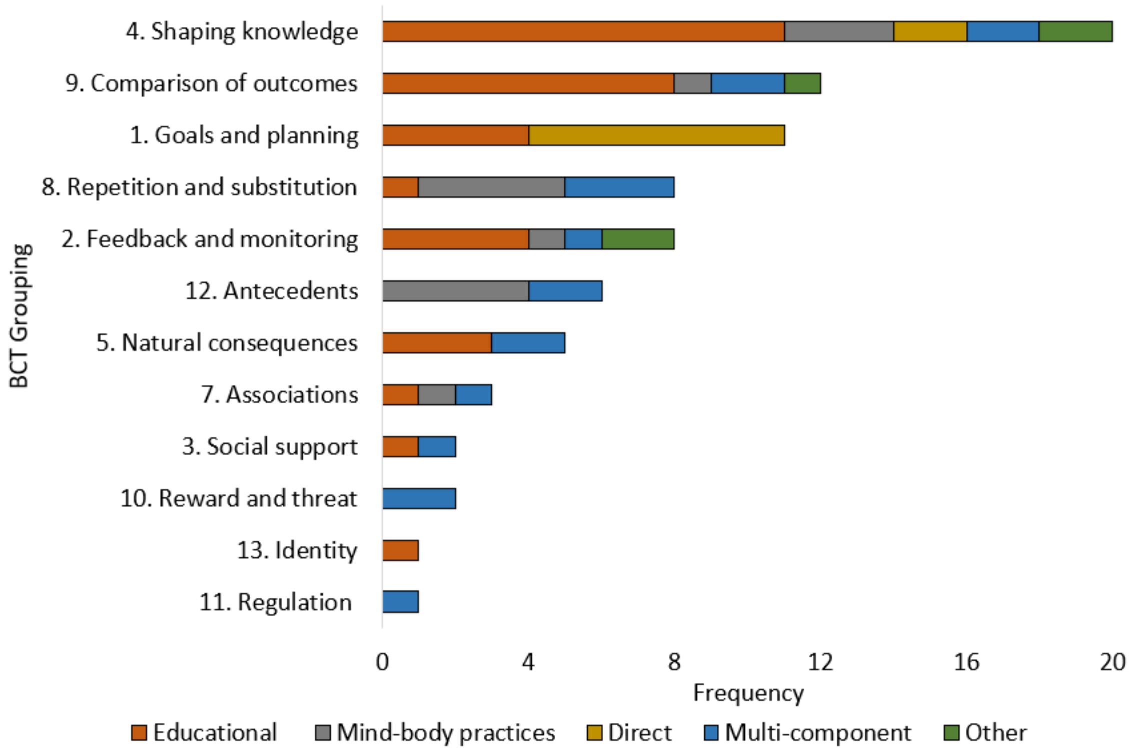

Figure 4.2. Frequency of coded BCTs by BCT grouping and split by intervention category.

4.3.4 Narrative synthesis

Educational: Twelve studies were categorised as educational studies and were primarily focused on the change in sleep behaviours through the dissemination of sleep-related knowledge. Except for Harada et al. (2016), where educational information was conveyed through a text-based information leaflet, all other studies delivered education via one or more group sessions, ranging in duration from 30 to 150 minutes. In four studies, this was complemented by the delivery of an individual session and/or feedback (Driller et al., 2019; Dunican et al., 2021; Jenkins et al., 2021; Van Ryswyk et al., 2017). Eight educational studies demonstrated at least one favourable change in sleep outcomes, while three revealed no significant findings (Dunican et al., 2021; Jenkins et al., 2021; Kaier et al., 2016), and one solely demonstrated a phase delay in sleep timing (Dunican et al., 2023). Notable outcomes included significant improvements in actigraphy-derived total sleep time ranging between 20–36 minutes (Caia et al., 2018; O'Donnell & Driller, 2017; Sargent et al., 2021) and improvements in subjective measures of sleep quality (Driller et al., 2019; Harada et al., 2016; Vitale et al., 2019). The only unfavourable outcome observed was a lower sleep efficiency at the one-month follow-up in the study by Caia et al. (2018).

Educational studies exhibited the highest frequency of BCT usage (mean: 3 ± 1), and also displayed the greatest heterogeneity in content, encompassing nine BCT groupings across the studies. The BCT *"4.1 Instruction on how to perform a behaviour"* was present in all studies due to the nature of education delivery. Additionally, the utilization of sleep experts and healthcare professionals to deliver education sessions resulted in the inclusion of the BCT *"9.1 Credible source"* in eight educational studies.

Mind-body practices: Five studies were categorised as mind-body practices, where a holistic approach was taken to improve health outcomes through relaxation and mental awareness. These interventions encompass practices including yoga, progressive muscle relaxation, mindfulness, and breathing techniques. Amongst the five studies, three incorporated multiple mind-body practices within the delivered intervention, with two of them demonstrating some favourable changes in sleep outcomes (Chen et al., 2018; Jones et al., 2020) and one showing no change (Rijken et al., 2016). While a comparison between different mind-body practices was not feasible, a comparative study suggested that yoga may yield more favourable changes to sleep outcomes than progressive muscle relaxation (Datta et al., 2022).

The mean number of BCTs used in mind-body practice studies was 3 ± 2. The BCTs *"12.6 Body changes"* and "*8.1 Repetition and Substitution"* were each identified in four of the five studies, reflecting the impact of mind-body practices on body awareness and the repeated performance of the practice. Additionally, the BCT *"4.1 Instruction on how to perform a behaviour"* was present in three mind-body practice studies.

Direct: The seven direct studies sought to increase sleep duration above baseline values by establishing a goal to increase sleep by a specific amount or toward a predefined target. This typically occurred as part of an intervention where the change in sleep duration served as an independent variable to assess the effect on a non-sleep dependent variable (e.g., sports performance). In all studies, either actigraphy-derived total sleep time or self-reported sleep duration was increased. However, in each study, the increase fell short of the predetermined goal. An unintended outcome of increased sleep duration can be a corresponding reduction in sleep efficiency, as was observed by Roberts et al. (2019a).

Only one study augmented a direct intervention with a non-direct behavioural intervention component, where the addition of sleep hygiene education demonstrated improvements in self-reported sleep quality and an increase in actigraphy-derived total sleep time (Swinbourne et al., 2018).

Direct studies exhibited the lowest frequency of BCT usage (mean: 1 ± 0). Furthermore, the BCTs used were the most homogenous; *"1.1 Goal setting (behaviour)"* was present in all the direct studies due to the inherent goal-setting aspect, while *"4.1 Instruction on how to perform a behaviour"* was the only other BCT identified, appearing in two instances.

Multi-component: Seven studies integrated two or more distinct types of components within the delivered intervention. In five studies, behavioural components such as education or sleep hygiene strategies were integrated to support the utilization of non-behavioural components including light therapies, cold water immersion, and environmental modifications (Charest et al., 2017; de Mello et al., 2020; Duffield et al., 2014; Fullagar et al., 2016; Vachon et al., 2022). The remaining two studies included the amalgamation of education and mind-body practices (Vachon et al., 2023), and a cluster of behavioural components including education, tracking, and social support (Grandner et al., 2017). All studies exhibited a significant change in one or more assessed sleep outcome apart from Duffield et al. (2014), where large effect sizes were demonstrated within a limited sample size.

The mean number of BCTs utilised per study was 2 ± 2, yet a distinct division was apparent. Three studies featured four or five BCTs present, spanning a diverse range of nine BCT groupings (Grandner et al., 2017; Vachon et al., 2022, 2023). Conversely, the remaining four studies either employed *"8.1 Behavioural practice/substitution"* as the sole BCT, or in the case of Charest et al. (2017), no BCTs were identified.

Other: Three studies did not align with the previously discussed categories. In Bender et al. (2018) and Tuomilehto et al. (2017), the intervention components delivered were contingent on a sleep assessment performed at baseline and thus varied in content and duration between participants. Both studies featured 2 BCTs, though the use of the BCTTv1 framework was limited to the intervention components delivered to all participants. Jakowski and Stork (2022) employed a combination of app feedback and smart alarms using the BCT *"2.2 Feedback on behaviour"*, yet no significant changes in sleep outcomes were observed.

4.3.5. Quality appraisal

Twenty studies underwent appraisal using the nine-item assessment tool for quasi-experimental studies, yielding a mean study score of 6 ± 1. The poorest scored items pertained to the inclusion of a control group (Q4, 1/20 studies) and appropriate statistical analysis (Q9, 8/20 studies). Nine studies were assessed using the 13-item appraisal tool for randomised controlled trials, producing a mean study score of 8 ± 2. The poorest scored items concerned insufficient blinding of participants (Q4) and researchers (Q5) to treatment allocation (both 1/9 studies). A comprehensive breakdown of the quality appraisal scores for each study is presented in Appendix 9 and 10.

4.4. Discussion

The objectives of this scoping review were to identify and map the existing body of evidence on behavioural sleep interventions in athletes, assess their effect on sleep outcomes, and retrospectively code the BCTs employed using the BCTTv1 framework. A total of 33 studies were identified, all published within the last decade, reflecting the growing interest in athlete sleep. The included interventions utilised diverse behavioural strategies, which were grouped into five categories: educational, mind-body practices, direct, multi-component, and other. These categories displayed differences in the specific BCTs employed and their frequency of use. Notably, only 18 of the 93 BCTs outlined in the BCTTv1 were identified across the 33 studies, suggesting that many behavioural strategies remain unexplored in athlete populations. These unexplored BCTs could potentially be effective in promoting favourable changes in sleep outcomes.

The sleep outcomes extracted from the included studies indicate that each category of behavioural intervention can be effective in improving sleep outcomes. This supports the viability of behavioural interventions for enhancing athlete sleep, as highlighted in previous reviews (Bonnar et al., 2018; Gwyther et al., 2022; Silva et al., 2021). However, important considerations beyond changes in sleep outcomes should be noted for each intervention category. Direct interventions demonstrated the most substantial improvements in sleep outcomes, with multiple studies reporting increases in total sleep time exceeding an hour. However, implementing direct interventions outside of controlled settings poses challenges when considering the broader social-environmental context (Grandner, 2017). For instance, sport-related factors may limit opportunities to increase sleep, as seen in Mah et al. (2011), where travel schedules disrupted the ability to maintain a consistent sleep/wake pattern.

Educational interventions were the most used approach. A recent consensus statement recommends regular sleep education as a first-line strategy to improve sleep in athletes, regardless of baseline sleep characteristics (Walsh et al., 2020). However, concerns about the long-term effectiveness of sleep education as a standalone intervention have been raised (Halson, 2019). This was exemplified in Caia et al. (2018), where improvements in sleep outcomes were not sustained post-intervention. This aligns with the COM-B behaviour change model (Michie et al., 2011), which suggests that while education enhances psychological capability, it may not address deficits in opportunity or automatic motivation, both of which are essential for sustained behaviour change. Therefore, integrating education into a multi-component intervention may be more effective.

Mind-body practices and multi-component interventions also showed efficacy in improving sleep outcomes, but quantifying the contribution of behavioural changes in these categories presents challenges. In mind-body practices, behavioural changes are closely intertwined with physical changes, and the primary aim is often to promote holistic health rather than exclusively improving sleep. This is evident in studies where sleep is one of several health outcomes (Chen et al., 2018; Jones et al., 2020; Rijken et al., 2016). Similarly, in multi-component interventions, isolating the effect of each component is difficult without a comparison condition where components are delivered individually. Lastly, studies involving individually tailored interventions are highly relevant for real-world application (Bender et al., 2018; Tuomilehto et al., 2017). However, the limited detail available in journal articles constrains the ability to fully evaluate the behavioural components delivered only to select participants.

While the biological regulation of sleep adds complexity to applying behaviour change theory in sleep health interventions, particularly when compared to more traditional health targets like physical activity, many aspects of sleep remain under behavioural control (Mead & Irish, 2020). This study aligns with previous reviews that view sleep through a behavioural lens and use the BCTTv1 framework to specify the behaviour change techniques (BCTs) employed in sleep interventions across diverse populations. The average number of BCTs used in the studies included in this review (mean: 2.7) is notably higher than a previous review on sleep extension interventions for individuals aged 12 and older (mean: 1.8; Baron et al., 2021) but falls short of the average found in a review focused on interventions for emergent adults aged 18–29 (mean: 4.25; Pegado et al., 2023).

The diversity of BCT groupings identified in this review (12 out of 16) exceeds the eight groupings found by Baron et al. (2021) and the 11 groupings identified by Pegado et al. (2023), although the latter was based on just eight studies. This suggests there is scope for incorporating more BCTs in future behavioural sleep interventions tailored to athletes, with evident gaps in the literature. For instance, group sessions, which were used in all but one educational intervention, could provide an opportunity to integrate multiple BCTs beyond simple education delivery. This potential was demonstrated in two studies that included five and six unique BCTs in a multifaceted workshop format (Kaier et al., 2016; Sargent et al., 2021). The incorporation of multiple BCTs has been shown to increase total sleep times; however, interventions with many curriculum components often resulted in smaller increases in sleep duration compared to those with fewer components (Baron et al., 2021). Therefore, designing workshops to be concise but focused on impactful BCT implementation is critical for enhancing the effectiveness of future interventions. Table 4.3 provides examples of BCTs not identified in any studies within this review, but which could be incorporated into a workshop format to improve outcomes.

Table 4.3. Example BCTs for integration into group sessions.

BCT and grouping	Definition*	Example
Shaping knowledge 4.3 Re-attribution	Elicit perceived causes of behaviour and suggest alternative explanations (e.g. external or internal and stable or unstable)	Ask athletes to reflect on what they believe drives their current sleep behaviours (e.g. lack of time) and offer alternatives to consider and reflect upon (e.g., electronics use before bed)
Natural consequences 5.6 Information about emotional consequences	Provide information (e.g. written, verbal, visual) about emotional consequences of performing the behaviour	During a group session, shift the focus away from sport and highlight the relationships with sleep, mental wellbeing, and mood outcomes
Comparison of behaviour 6.3 Information about others' approval	Provide information about what other people think about the behaviour. The information clarifies whether others will like, approve or disapprove of what the person is doing or will do	Collate information from coaches and sports practitioners on how they value sleep as a recovery modality to share with athletes
Comparison of outcomes 9.2 Pros and cons	Advise the person to identify and compare reasons for wanting (pros) and not wanting to (cons) change the behaviour (includes 'Decisional balance'*)*	Have athletes come up with and discuss the pros and cons of their current sleep practices
Self-belief 15.3 Focus on past success	Advise to think about or list previous successes in performing the behaviour (or parts of it)	Ask athletes to reflect on a time that they engaged with healthy sleep practices, and the downstream effects they experienced when doing so

*BCT definitions from Michie et al. (2013)

While the rationale behind the inclusion of specific behaviour change techniques (BCTs) in studies cannot be fully understood through retrospective coding, the justification for intervention design often lacks clarity and, in some cases, empirical support. The mixed efficacy of sleep health interventions has been partly attributed to the absence of behaviour theory as a foundation for intervention design (Mead & Irish, 2020), and health interventions that embed behaviour change theory into their development tend to yield more consistently positive outcomes (Glanz & Bishop, 2010). As an illustration, the inclusion of the BCT "*4.1 Instruction on how to perform a behaviour*" in an educational sleep intervention would be more effective if supported by evidence that athletes possess insufficient knowledge about sleep behaviours. Various behavioural theories can be applied to sleep health research (Mead & Irish, 2020), but the use of the BCTTv1 taxonomy in conjunction with the COM-B behavioural model could provide a potential pathway to bridge the existing gap between a behavioural diagnosis and intervention development (Michie et al., 2011). The COM-B model helps identify which of the core components—capability, opportunity, and motivation—are driving undesired behaviours, allowing for the mapping of relevant BCTs from the BCTTv1 to create a precisely targeted intervention (Michie et al., 2013). It is plausible that any combination of the COM-B components could underpin both desired and undesired sleep behaviours in athletes, varying based on factors such as age, sex, performance level, and other characteristics. This highlights the importance of specifying the problem in behavioural terms before attempting to address it.

The quality appraisal of the included studies showed generally satisfactory results but highlighted several limitations in the current literature. The inclusion of control conditions in quasi-experimental designs remains a challenge, with methodological constraints such as participant availability and the cost and accessibility of measurement tools. However, given the various sport-related and non-sport-related factors that can act as extraneous variables influencing sleep outcomes (e.g., Astridge et al., 2021), the use of control conditions is crucial, when possible, to ensure that observed changes can be attributed to the intervention, thereby enhancing the robustness of findings. Additionally, the lack of blinding for both participants and researchers was identified as a limitation in randomised controlled trials. While this is a common issue in applied behavioural research, strategies such as the inclusion of an additional unblinded research coordinator can help minimise bias (Friedberg et al., 2010).

One aspect not evaluated by the JBI assessment tools is the pre-registration of studies. None of the included studies referenced pre-registration, and a search of the Open Science Framework and PubPsych repositories identified only a few pre-registered studies from this review (Jakowski & Stork, 2022; Jones et al., 2020; Rijken et al., 2016; Schwartz & Simon, 2015). Furthermore, some studies omitted a priori outcomes and/or definitions of extracted sleep outcomes in their methods sections. Moving forward, behavioural sleep interventions in athletes should pre-register studies in a public repository to improve transparency and increase confidence in the findings (Hardwicke & Wagenmakers, 2023).

4.5. Limitations

A key limitation of this scoping review is that, while BCT coding was facilitated by the BCTTv1, there remains a subjective element influenced by the philosophical standpoint of the coders. In this review, coders adopted a more liberal approach to BCT coding, leading to the identification of slightly more BCTs in several studies compared to a previous review (Baron et al., 2021). This issue is further complicated by the restrictive word counts in most journal articles, which often prevent the inclusion of comprehensive methodological details, creating ambiguity around the application of specific BCTs. Two strategies can be employed in future research to address this limitation: (1) publishing study intervention manuals as appendices or in open repositories, and (2) using standardised terminologies, such as those in the BCTTv1, when describing behavioural components within interventions.

There are also limitations related to the search parameters of this review, particularly concerning age. Although this restriction was applied due to the differences in biological sleep regulation during childhood and adolescence (Hagenauer et al., 2009), recent research has used behavioural sleep interventions in athletes within this age group, incorporating BCTs that may be relevant to adult athletes and warrant further exploration (e.g., Aben et al., 2023; Edinborough et al., 2023; Lever et al., 2021). Finally, there are inherent methodological limitations in the search strategy. These include the exclusion of grey literature and unpublished studies, reliance on only five databases for literature searches, and the inclusion of English-only studies. While these choices were pragmatic, they may have inadvertently excluded relevant studies.

4.6. Conclusion

In summary, this scoping review highlights the wide range of behavioural sleep interventions conducted in athlete populations over the past decade. The identified intervention categories—educational, mind-body practices, direct, multi-component, and other—varied in terms of the prevalence and diversity of BCTs implemented. While each category included studies showing some positive changes in sleep outcomes, no single study type or BCT consistently led to improvements. Moreover, the limited range of BCTs used suggests that alternative behavioural components remain unexplored in athlete populations. The included studies generally lacked sufficient integration of behaviour change theory during intervention development, which may partly explain the mixed effectiveness regarding sleep outcomes. Moving forward, future studies should prioritise conducting a behavioural diagnosis specific to the athlete cohort being targeted before developing interventions. Additionally, behavioural components should be described using standardised terminology, such as the BCTTv1, to facilitate more effective cross-study comparisons. This approach could ultimately support future meta-analyses to identify the most effective BCTs for promoting sleep behaviour change in athlete populations.

4.7. Links to other studies

This scoping review identifies several limitations in the current literature that will inform subsequent research in this thesis. A key finding is the necessity of incorporating behaviour change theory into intervention development. In Chapter 7, perceived barriers to sleep health will be identified using the COM-B model through interviews, and in Chapter 8, a targeted behavioural intervention will be developed based on these insights. The intervention will be specified in terms of BCTs from the BCTTv1 to clarify the mechanisms intended to modify sleep-related behaviours. The review also highlights that most previous interventions primarily focused on sleep duration as the main outcome. However, as discussed in Chapter 2, other dimensions of sleep health could also be impacted by changes in sleep-related behaviours, which will be further explored in Chapters 5 and 6.

In section 4.3.3, the frequency of usage for each BCT grouping was presented, revealing that while some BCT groups are more frequently utilised and easily identifiable during retrospective coding, others appear less often or are entirely absent. This pattern would be expected if certain BCTs consistently improved sleep outcomes. However, the narrative synthesis suggests this is not the case. Additionally, the absence of a clear behavioural diagnosis in these studies raises questions about whether the chosen BCT groups are truly the most appropriate for promoting sleep behaviour change within the target population. Therefore, there is no clear evidence to support a certain type of behavioural intervention at this time, and consequently, in designing the intervention presented in Chapter 8, all BCT groups deemed suitable after conducting a behavioural diagnosis will be considered, with final selections based on their feasibility for implementation. Rather, the main takeaway from this review for the intervention design is the support for a behaviourally informed approach to development and clear specification of how the intervention is designed to drive behaviour change using BCTs.

The scope of the review was expanded to include all adult athlete populations, increasing the number of included studies from ten to 33. This decision was made instead of broadening the scope to all student populations, as existing literature already examines BCT use in sleep interventions for student-athletes as part of a review in young adults (Pegado et al., 2023). Additionally, practical experience working with the target population used in subsequent studies indicate that this cohort tends to prioritise their sporting commitments over academic ones (Cartigny et al., 2021). However, it is essential to consider both aspects of the student-athlete dual career when designing interventions. The use of the Behaviour Change Wheel in Chapter 8 will ensure that the intervention is tailored to student-athletes and considers the influence of sporting and academic upstream influences on sleep.

CHAPTER FIVE: ASSESSMENT OF SUBJECTIVE SLEEP CHARACTERISTICS IN HARTPURY STUDENT-ATHLETES

Associated publication (see Appendix 11): Wilson, S. M. B., Jones, M. I., Draper, S. B., & Parker, J. K. (2024). Early morning sport scheduling is associated with poorer subjective sleep characteristics in British student-athletes. *Scandinavian Journal of Medicine and Science in Sports, 34*(3):e14598. https://doi.org/10.1111/sms.14598

Associated conference abstract (see Appendix 12): Wilson, S. M. B., Jones, M. I., Draper, S. B., & Parker, J. K. (2023). D2.S1.3(1) The napping behaviours of British student-athletes. *Journal of Sports Sciences, 41*(S1), 16. https://doi.org/10.1080/02640414.2023.2258666

Author contribution: S. M. B. Wilson: conceptualisation, data curation, formal analysis, investigation, methodology, project administration, resources, writing (original draft preparation), and writing (review and editing) (all lead author); M. I. Jones: conceptualisation, methodology, supervision, and writing (review and editing); S. B. Draper: conceptualisation, methodology, supervision, and writing (review and editing); J. K. Parker: conceptualisation, methodology, supervision, and writing (review and editing).

5.1. Rationale

As highlighted in the narrative review in Chapter 2, previous research on sleep in student-athlete populations has predominantly focused on American cohorts (e.g., Mah et al., 2018). British student-athletes likely share many upstream influences on sleep health with their international counterparts, differences in sport, academics, and culture may contribute to distinct sleep health outcomes. For example, British student-athletes typically follow a Monday-to-Friday training schedule with league competitions on Wednesdays (BUCS, 2024), contrasting with the more varied NCAA schedule. Therefore, it is important to examine sleep characteristics in British student-athletes to determine the similarities and differences to previous research in other countries.

One important but understudied dimension of sleep health in student-athletes is sleep regularity. Previous research has identified a social jetlag effect between weekdays and weekends in student-athletes (Leduc et al., 2020; Mah et al., 2018). Social jetlag refers to the inconsistency in sleep/wake timing between workdays and free days, driven by the misalignment of social and circadian clocks (Wittmann et al., 2006), and is associated with undesired downstream consequences including poorer academic performance in university students (Haraszti et al., 2014), impaired gross skill performance in junior athletes (Ciorciari et al., 2024), and poorer physical and psychological health outcomes across the general population (Beauvalet et al., 2017; Caliandro et al., 2021). In athletes, social jetlag often results from training schedules that conflict with preferred sleep patterns (Sargent et al., 2014b). For example, Sargent et al. (2014a) found that in swimmers, nights preceding early morning training sessions (06:00) saw bedtimes 2.5 hours earlier, wake times 4.0 hours earlier, and sleep duration 2.2 hours shorter compared to nights preceding free days. It remains unclear whether late evening training sessions have a similar disruptive effect, though sleep duration has been shown to shorten after evening competitions (Roberts et al., 2019b). Thus, it is essential to establish whether social jetlag exists among British student-athletes and to explore the impact of training timing on sleep outcomes.

Another perceived sleep risk factor for student-athletes is the challenge of balancing demanding workloads in both sports and university studies (Kroshus et al., 2019). NCAA athletes report a combined sport and academic workload exceeding 60 hours per week, with only 54–66% of Division I athletes feeling they can balance academics with extracurricular activities and keep up with classes during the season (NCAA, 2019a). However, some have contested whether workload is directly responsible for poor sleep in student-athletes (Meridew et al., 2017). It is currently unclear whether British student-athletes face comparable sporting and academic time demands to their NCAA counterparts. Nonetheless, differences in academic structure and sporting culture between countries warrant an investigation into the impact of these demands on sleep in British student-athletes.

This study used questionnaires, as a recommended tool to screen and assess sleep outcomes in athlete populations (Halson, 2019), with the following objectives: (1) assess the sleep outcomes of a cohort of British student-athletes to enable comparisons with other athlete and student-athlete populations; (2) examine differences in sleep outcomes between weekday and weekend nights; and (3) investigate the association between sport scheduling and time demands on sleep, and whether these variables serve as significant predictors of sleep outcomes. It was hypothesised that the sleep outcomes of British student-athletes would align with those observed in student-athletes of other nationalities, that sleep outcomes would significantly differ between weekday and weekend nights, and that both sport scheduling and time demands would emerge as significant predictors of sleep outcomes.

5.2. Methods

5.2.1. Participants

Participants were recruited from Hartpury University and College. Informed consent was obtained from each participant, and study approval was obtained from the Hartpury University Ethics Committee (ETHICS2021-117). Ethics application documents are attached as Appendix 13-16. Participants were excluded if they disclosed any previous or current history of a medically diagnosed sleep-related disorder prior to the study.

All academic and sporting activities, including matches, took place on weekdays. Training and match schedules varied between sports teams. University teams typically had training sessions scheduled around the academic timetable (Weekdays excluding Wednesday, 08:30-20:30). The college academic timetable ran on weekdays from 09:30-15:30, with some student-athletes having sports training integrated into their academic timetable.

5.2.2. Procedure

Participants completed an online survey during Autumn 2022 over a 2-week period. This timeframe was during academic teaching weeks but outside any examination periods, and all sports were in-season. Convenience sampling was used to recruit participants through emails sent directly from the lead researcher to student-athletes on two occasions, and signposting from head sports coaches. The survey was administered through Qualtrics XM online platform (Qualtrics, Provo, UT).

5.2.3. Measures

Participant characteristics were gathered by asking questions related to age, sex, level of study, sport, and residential status. Self-assessed chronotype was captured using the reduced Morningness-Eveningness Questionnaire (rMEQ; Adan & Almirall, 1991). The rMEQ consists of 5 items relating to sleep/wake preferences and alertness to estimate circadian phase, scored from 1-5 (Q1-4) or 0-6 (Q5) with items summed for a global score between 4-26. Higher scores indicate an earlier circadian phase. Cut-off scores were used to categorise evening-type (<12), neither-type (12-17), and morning-type (>17) groups, but were kept as a continuous variable for regression analyses.

The Pittsburgh Sleep Quality Index (PSQI) was used to measure subjective sleep quality (Buysse et al., 1989). The PSQI consists of 19 items relating to habitual sleep over the previous month. These items form seven equally weighted components scored 0-3 and are summed for a global score of 0-21. A threshold score of >5 is used to identify poor quality sleepers (Buysse et al., 1989). A threshold of ≥8 is also reported and has been used to indicate highly disturbed sleep in athletes (Gupta et al., 2017). PSQI questions 1-4 relating to typical bedtime, sleep onset latency (SOL), waketime, and total sleep time (TST) were split into separate questions for weekdays and weekends and used separately for further analyses. For PSQI scoring, a 5:2 ratio of weekday to weekend responses was calculated to reflect the original questions. A systematic review of studies appraising the measurement properties of the PSQI in non-clinical populations indicates generally good internal consistency and moderate structural validity (see Mollayeva et al., 2016). However, caution has been interpreted for use in university students due to overlap with other constructs including depression and stress (Dietch et al., 2016), while it has not been fully validated for use within athlete populations (Halson et al., 2022a). However, the widespread use of the PSQI in student-athletes (Chapter 2) facilitates the aim of enabling comparison of this cohort to previous research.

The Epworth Sleepiness Scale (ESS) was used to measure subjective daytime sleepiness (Johns, 1991). The ESS consists of 8 items regarding sleep propensity in different scenarios. These are scored on a range from 0-3 and summed for a global score between 0-24, with higher scores reflecting higher daytime sleepiness. A threshold score of ≥10 indicates excessive daytime sleepiness (Johns, 1991). The initial validation, performed in a student population by Johns (1992), demonstrated good internal consistency (α = .88) and test-retest reliability (r = .82). No validation studies have been performed in athlete populations.

The Sleep Hygiene Index (SHI) was used to assess the practice of sleep hygiene behaviours (Mastin et al., 2006). The SHI consists of 13 items on the presence of behaviours that can facilitate or hinder sleep. These are scored on a range from 1-5 and summed for a global score between 13-65, with higher scores indicative of poorer sleep hygiene practices. The initial validation by Mastin et al. (2006) demonstrated questionable internal consistency (α = .66) and acceptable test-retest reliability (r = .71). Like the ESS, no validation studies have been performed in athlete populations.

The scheduling of early morning (AM) and late evening (PM) sport was assessed by asking for the typical weekly frequency of training or competition before 9:00 and after 21:00 respectively, to capture training sessions that were placed prior to the academic timetable and may require an earlier awakening than preferred, or were placed close to typical weekday bedtimes and may interrupt sleep onset (Stutz et al., 2019). Sporting and academic time demands were assessed by asking for the typical weekly hours spent on academic-related and sport-related activities.

Napping practices were assessed using a modified version of a 6-item napping questionnaire previously used in University students (Lovato et al., 2014). Participants were asked for their typical weekly napping frequency. Those that reported napping were asked further questions on nap timing and duration, whether naps are initiated spontaneously or are planned, whether naps were ended spontaneously or with an alarm, and the primary reason for napping.

Participants were asked whether they believed balancing sporting, academic, employment, and social activities restricted sleep opportunity below personal preference, and whether they would use extra available time to increase sleep or use it towards other activities. In addition, participants were asked if they had ever received information on the topic of sleep health, and if so, where this was received and in what format. Finally, participants were asked if they would be interested in receiving sleep health information to improve health outcomes, sporting performance, and academic performance.

5.2.4. Statistical Analysis

Raw data from Qualtrics XM was exported to Microsoft Excel (Microsoft, Redmond, WA), and then uploaded to IBM SPSS version 26 (IBM, Chicago, IL) for all statistical analyses. Preliminary data screening was performed using guidelines outlined by Tabachnick & Fidell (2013). Seven participants were removed for reporting a current or previous sleep disorder. Six data points from three cases were considered invalid responses (e.g., out-of-range values) and treated as missing data. As Little's missing completely at random test was non-significant ($\chi 2 = 24.893$, $df = 33$, $p = .844$), data was replaced using multiple imputation so as to not greatly influence the variation in data. Eight data points from five cases were considered univariate outliers assessed using standardised z-scores ($z > 3.29$, $p < .001$). These were manually screened and deemed to be valid responses. To minimise the impact of outliers on correlation and regression analyses, these outliers were assigned to the next most extreme non-outlier score in the distribution. Scores were considered normally distributed through visual inspection of normal Q-Q plots and assessment of skewness and kurtosis (z_{skew} and $z_{kurt} < 3.29$). No multivariate outliers were identified through Mahalanobis distances using a $p < .001$ criterion for Mahalanobis D^2. Reliability analysis was performed on validated questionnaires (PSQI, $\alpha = .62$; SHI, $\alpha = .72$; ESS, $\alpha = .71$; rMEQ, $\alpha = .58$).

Descriptive data are presented as mean ± SD, with bias-corrected and accelerated 95% confidence intervals (10000 bootstrap samples) reported. Differences in sleep outcomes, categorized by participant characteristics, were assessed using independent t-tests (for two factors) or one-way ANOVAs (for three or more factors). Paired t-tests were employed to evaluate differences between self-reported weekday and weekend sleep as derived from the PSQI. Pearson correlations were conducted between sport scheduling and time demand predictor variables, and sleep outcomes. Multiple regression analyses were employed to investigate the predictive ability of sport scheduling and time demands on sleep outcomes while controlling for fixed predictor variables derived from participant characteristics data. Fixed predictors included age, sex, and chronotype as these have been related to dimensions of sleep health (Bjorvatn et al., 2023). Residential status was also included, given the established relationship between commuting and reduced sleep duration (e.g., Basner et al., 2014). Each sleep outcome was assessed in a separate model using the enter method, with fixed predictors entered at step 1, followed by the inclusion of sport scheduling and time demand predictors at step 2.

5.3. Results

5.3.1. Sleep characteristics

A total of 157 participants, with a mean age of 18 ± 2 years (range 16-25), were included in the analyses. Participant characteristics and differences in sleep outcomes based on participant characteristics are summarised in Table 5.1. Additionally, age was significantly associated with PSQI (r = .171, p = .032, 95%CI [.014, .319]), ESS (r = .189, p = .018, 95%CI [.033, .355]), weekday waketime (r = -.428, p = <.001, 95%CI [-.540, -.315]), and weekday TST (r = -.257, p = .001, 95%CI [-.381, -.146]). The proportion of participants reporting poor perceived sleep quality (PSQI >5) was 49.0% (n = 77), while 23.6% (n = 37) had a PSQI score above the higher threshold (PSQI ≥8). Regarding perceived daytime sleepiness, 22.9% exceeded the clinical threshold (ESS ≥10).

When considering the difference between PSQI-derived sleep outcomes on weekdays and weekends, a statistically significant mean difference was observed for all sleep outcomes. On average, participants went to bedtime 38 minutes earlier (t(156) = -8.45, p <.001, d = 0.67 (.50, .85)), a waketime 118 minutes earlier (t(156) = -16.93, p <.001, d = 1.35 (1.13, 1.57)), had a TST 67 minutes shorter (t(156) = -11.59, p <.001, d = 0.93 (.74, 1.11)), and had a SOL 3 minutes longer (t(156) = 3.90, p <.001, d = 0.31 (.15, .47)) on weekdays when compared to weekends. A total of 39 participants (24.8%) reported a weekday TST <7 hours compared to 13 (8.3%) at weekends.

Table 5.1. Sleep parameters split by participant characteristics.

	Variable	PSQI	ESS	SHI	Weekday Bedtime	Weekday SOL	Weekday Waketime	Weekday TST	Weekend Bedtime	Weekend SOL	Weekend Waketime	Weekend TST
	All (n = 157)	5.7 ± 2.6	6.7 ± 3.7	31.9 ± 6.6	23:01 ± 00:56	22 ± 14	07:00 ± 01:04	7.3 ± 1.1	23:39 ± 01:19	19 ± 12	08:58 ± 01:26	8.4 ± 1.3
Sex	Male (n = 80)	5.2 ± 2.5	6.5 ± 3.3	29.9 ± 6.2	22:59 ± 00:57	21 ± 14	06:49 ± 01:03	7.1 ± 1.1	23:36 ± 01:11	17 ± 12	08:29 ± 01:35	8.2 ± 1.3
	Female (n = 77)	6.2 ± 2.7	6.9 ± 4.0	33.9 ± 6.4	23:03 ± 00:52	23 ± 14	07:11 ± 00:56	7. 3 ± 1.1	23:43 ± 01:16	21 ± 13	09:07 ± 01:16	8.5 ± 1.1
	Effect size	***d* = .39 (.07, .70)***	*d* = .10 (-.21, .41)	***d* = .63 (.31, .95)****	*d* = .07 (-.25, .38)	*d* = .14 (-.18, .45)	***d* =.37 (.06, .69)***	*d* = .24 (-.07, .56)	*d* = .10 (-.21, .42)	***d* = .38 (.06, .69)***	*d* = .21 (-.11, .52)	*d* = .24 (-.08, .55)
Level of study	College (n = 89)	5.2 ± 2.6	6.0 ± 3.4	31.6 ± 7.0	23:06 ± 00:51	20 ± 13	07:19 ± 00:56	7.5 ± 1.0	23:45 ± 01:16	18 ± 13	09:01 ± 01:25	8.4 ± 1.2
	University (n = 68)	6.3 ± 2.6	7.6 ± 3.8	32.2 ± 6.1	22:55 ± 00:59	24 ± 14	06:35 ± 00:57	7.0 ± 1.1	23:32 ± 01:08	19 ± 12	08:54 ± 01:29	8.4 ± 1.4
	Effect size	***d* = .40 (.08, .72)****	***d* = .44 (.12, .75)****	*d* = .09 (-.23, .41)	*d* = .21 (-.10, .53)	*d* = .24 (-.08, .56)	***d* = .79 (.46, 1.12)****	***d* = .53 (.20, .85)****	*d* = .18 (-.13, .50)	*d* = .07 (-.24, .39)	*d* = .08 (-.24, .39)	*d* = .03 (-.29, .34)
Sport	Rugby (n = 86)	5.8 ± 2.7	6.5 ± 3.8	31.8 ± 7.2	23:07 ± 00:59	22 ± 14	07:06 ± 00:56	7.3 ± 1.1	23:37 ± 01:12	19 ± 13	09:03 ± 01:17	8.4 ± 1.2
	Football (n = 42)	5.1 ± 2.3	6.6 ± 3.3	30.4 ± 5.7	22:58 ± 00:43	19 ± 13	06:49 ± 00:54	7.3 ± 1.0	23:39 ± 01:11	16 ± 12	08:48 ± 01:40	8.4 ± 1.4
	Netball (n = 13)	6.2 ± 3.2	9.2 ± 4.1	35.0 ± 6.2	22:48 ± 00:35	19 ± 11	07:14 ± 01:17	7.4 ± 1.1	23:42 ± 01:01	21 ± 13	09:29 ± 01:19	8.7 ± 0.8
	Other (n = 16)	6.1 ± 2.0	6.0 ± 3.0	33.4 ± 5.1	22:50 ± 01:11	29 ± 15	06:45 ± 01:18	7.0 ± 1.1	23:53 ± 01:36	23 ± 14	08:31 ± 01:38	7.7 ± 1.5
	Effect size	*η^2 = .02 (.00, .07)*	*η^2 = .04 (.00, .11)*	*η^2 = .04 (.00, .10)*	*η^2 = .02 (.00, .06)*	*η^2 = .05 (.00, .11)*	*η^2 = .03 (.00, .08)*	*η^2 = .01 (.00, .03)*	*η^2 = .00 (.00, .02)*	*η^2 = .02 (.00, .07)*	*η^2 = .03 (.00, .08)*	*η^2 = .04 (.00, .09)*

	Variable	PSQI	ESS	SHI	Weekday Bedtime	Weekday SOL	Weekday Waketime	Weekday TST	Weekend Bedtime	Weekend SOL	Weekend Waketime	Weekend TST
Residential	On-site (n = 48)	5.1 ± 2.3	6.5 ± 3.5	32.6 ± 6.9	23:15 ± 00:54	19 ± 11	07:36 ± 00:50	7.5 ± 0.9	23:46 ± 01:18	17 ± 11	09:10 ± 01:17	8.5 ± 1.1
	Off-site (n = 109)	6.0 ± 2.7	6.8 ± 3.8	31.5 ± 6.5	22:55 ± 00:54	23 ± 15	06:44 ± 00:58	7.2 ± 1.1	23:36 ± 01:11	20 ± 13	08:53 ± 01:30	8.3 ± 1.3
	Effect size	***d = .35 (.01, .69)****	*d = .06 (-.28, .40)*	*d = .16 (-.18, .50)*	***d = .38 (.03, .72)****	***d = .32 (-.03, .65)****	***d = .92 (.56, 1.27)*****	*d = .33 (-.01, .67)*	*d = .13 (-.20, .48)*	*d = .24 (-.10, .58)*	*d = .19 (-.15, .53)*	*d = .10 (-.24, .44)*
Chronotype	Morning-type (n = 28)	5.2 ± 2.1	5.6 ± 3.7	29.9 ± 6.7	22:12 ± 01:01	22 ± 17	06:20 ± 01:04	7.6 ± 0.9	22:51 ± 01:05	20 ± 16	08:08 ± 01:10	8.2 ± 1.1
	Intermediate-type (n = 105)	5.7 ± 2.6	7.2 ± 3.6	32.2 ± 6.1	23:07 ± 00:46	21 ± 12	07:04 ± 00:56	7.2 ± 1.0	23:41 ± 01:07	17 ± 10	09:00 ± 01:21	8.4 ± 1.2
	Evening-type (n = 24)	6.2 ± 3.2	5.6 ± 3.7	32.8 ± 8.3	23:22 ± 00:49	26 ± 16	07:31 ± 00:52	7.1 ± 1.4	00:29 ± 01:14	24 ± 16	09:49 ± 01:38	8.3 ± 1.5
	Effect size	η^2 = .01 (.00, .06)	**η^2 = .04 (.00, .11)***	η^2 = .02 (.00, .07)	**η^2 = .20 (.09, .30)****	η^2 = .02 (.00, .08)	**η^2 = .12 (.04, .22)****	η^2 = .02 (.00, .07)	**η^2 = .15 (.06, .25)****	**η^2 = .04 (.00, .11)***	**η^2 = .12 (.03, .21)****	η^2 = .00 (.00, .03)

Statistical significance: *p < .05; **p < .01. Abbreviations: PSQI, Pittsburgh Sleep Quality Index; ESS, Epworth Sleepiness Scale; SHI, Sleep Hygiene Index; SOL: sleep onset latency. Statistical significance: *p < .05; **p < .01. Abbreviations: SOL: sleep onset latency; TST: total sleep time

5.3.2. Sport scheduling and time demands

The frequency of AM and PM sport sessions were 2.7 ± 2.0 and 0.7 ± 1.1 per week, respectively. 132 participants (84%) participated in at least one AM or PM sport session, with 63 participants (40%) reporting both AM and PM sport sessions. The weekly time spent on academic-related activities was 17.7 ± 8.8 hours, while 13.2 ± 6.5 hours were spent on sport-related activities. A total of 52.2% of participants believed that balancing sport-related and academic-related activities in addition to social and employment activities restricted sleep opportunity below their personal preference. Meanwhile, 47 participants (29.9%) reported that they would use the extra available time to sleep, while 42 (26.8%) reported they would use the time towards other activities, with the remaining 68 (43.3%) unsure.

A correlation matrix showing the relationships between predictor variables and sleep outcomes is presented in Table 5.2. A higher frequency of AM sport sessions was associated with shorter weekday TST (p <.001, 95%CI [-.415, -.167]), earlier weekday waketimes (p <.001, 95%CI [-.474, -.213]), and higher PSQI (p <.001, 95%CI [.169, .436]), ESS (p = .005, 95%CI [.059, .371]), and SHI (p = .023, 95%CI [.000, .320]) global scores. The frequency of PM sport sessions was not associated with any sleep outcome. Increased academic-related time demands were associated with higher weekend TST (p = .025, 95%CI [.048, .308]), while increased sport-related time demands were associated with earlier weekday bedtimes (p = .036, 95%CI [-.314, -.021]) and weekday waketimes (p = .039, 95%CI [-.321, -.005]).

For the linear regression analyses, the fixed predictors entered into the models at Step 1 were age, chronotype (rMEQ global score), residential status and sex. The level of study was omitted due to the high correlation with age (r = .76, p <.001) and the presence of multicollinearity when included in regression models, as assessed by variance inflation factors. The type of sport was excluded based on the absence of significant differences in sleep outcomes observed in earlier ANOVAs.

Table 5.2. Correlation table showing the relationship between predictor variables and sleep parameters.

Sleep parameter	AM sport	PM sport	Academic time	Sport time
PSQI	**.30****	.03	-.05	-.02
ESS	**.23****	.15	.09	.11
SHI	**.18***	.12	.13	.04
Weekday Bedtime	-.12	-.04	-.15	**-.17***
Weekday SOL	.07	-.08	-.09	.02
Weekday Waketime	**-.35****	.00	.07	**-.16***
Weekday TST	**-.29****	-.03	.14	-.02
Weekend Bedtime	-.06	.02	-.11	-.04
Weekend SOL	.08	-.11	-.03	-.04
Weekend Waketime	-.13	-.11	.05	-.01
Weekend TST	-.12	-.03	**.18***	.07

Statistical significance: *$p < .05$; **$p < .01$
Abbreviations: PSQI, Pittsburgh Sleep Quality Index; ESS, Epworth Sleepiness Scale; SHI, Sleep Hygiene Index; SOL: sleep onset latency; TST: total sleep time.

Regression models revealed four sleep outcomes for which the frequency of AM sport sessions was a significant predictor of the model when fixed predictors were included (Table 5.3). Specifically, AM sport frequency significantly predicted PSQI score ($p < .001$) and SHI global scores ($p = .005$), alongside weekday TST ($p = .003$) and weekday waketime ($p = .024$). However, the frequency of PM sport sessions and academic-related and sport-related time demands did not emerge as significant predictors in these models. The regression models for ESS global score, weekday bedtime, weekend bedtime, and weekend waketime were statistically significant (all $p <.05$), but were only predicted by the fixed predictors entered into the models. The models for the remaining sleep outcomes (weekday SOL, weekend SOL, and weekend TST) did not reach statistical significance ($p >.05$). The full regression analyses for these seven outcomes are available in Appendix 17 and 18.

5.3.3. Napping

A total of 100 participants (63.7%) reported napping at least once weekly and were classified as nappers. The mean nap frequency in nappers was 2.5 ± 1.3 times per week, with most nappers napping once (26%) or twice (31%) weekly (three: 24%; four: 14%; five or more times: 5%). A higher napping frequency was associated with higher SHI ($r(98) = .423$, $p < 0.001$) and ESS ($r(98) = .417$, $p < 0.001$) global scores. Mean (±SD) nap onset time was 14:43 ± 02:09. Participants reported naps were more commonly initiated spontaneously (39%) rather than planned (13%), with 48% of responses reporting a mixture of both. Similarly, naps were ended spontaneously (42%) more often than using an alarm. (28%), with 28% reporting a mixture. Only 28% of participants reported short nap durations of less than 30 minutes, whereas longer durations of 30-45 minutes (22%), 45-60 minutes (31%), and exceeding 60 minutes (19%) were more common. The most reported reason for napping was feeling sleepy during the day (58%), followed by the nap refreshing them (26%), having spare time (5%), avoiding feeling sleepy later (5%), with 6% providing other reasons.

Table 5.3. Hierarchical regression models with AM training as a significant predictor of sleep outcome.

		PSQI				SHI				Weekday Waketime				Weekday TST			
		B	B_{SE}	β	*t*	B	B_{SE}	β	*t*	B	B_{SE}	β	*t*	B	B_{SE}	β	*t*
Step 1: Fixed predictors	(Intercept)	3.68	2.11		1.74	21.83	5.47		**3.99****	648.02	43.02		**15.06****	548.18	53.78		**10.19****
	Age	.34	.12	.24	**2.88****	.29	.30	.08	.94	-8.25	2.40	-.25	**-3.44****	-10.15	3.00	-.28	**-3.38****
	Chronotype	-.20	.06	-.25	**-3.22****	-.41	.16	-.20	**-2.49***	-5.84	1.28	-.31	**-4.56****	4.60	1.60	.23	**2.87****
	Residential Status	-.94	.45	-.17	**-2.11***	.21	1.16	.01	.18	34.37	9.11	.26	**3.77****	10.36	11.39	.07	.91
	Sex	-1.49	.40	-.29	**-3.72****	-4.33	1.04	-.33	**-4.17****	-12.09	8.16	-.10	-1.48	-4.76	10.20	-.04	-.47
	Model fit	*F(4,152) = 7.304, R^2 = .161***				*F(4,152) = 5.617, R^2 = .129***				*F(4,152) = 20.388, R^2 = .349***				*F(4,152) = 5.315, R^2 = .123***			
Step 2: Added scheduling and time demand predictors	(Intercept)	6.49	2.21		**2.94****	25.67	5.79		**4.43****	616.88	46.52		**13.26****	491.39	57.27		**8.58****
	Age	.16	.13	.11	1.27	-.06	.33	-.02	-.17	-5.77	2.64	-.17	**-2.18***	-6.29	3.25	-.18	-1.93
	Chronotype	-.22	.06	-.27	**-3.55****	-.50	.16	-.24	**-3.08****	-5.37	1.32	-.28	**-4.08****	5.16	1.62	.25	**3.18****
	Residential Status	-.93	.44	-.17	**-2.15***	.04	1.14	.00	.03	35.09	9.18	.27	**3.82****	10.51	11.30	.07	.93
	Sex	-1.54	.42	-.30	**-3.69****	-4.03	1.10	-.31	**-3.68****	-14.27	8.81	-.12	-1.62	-4.54	10.84	-.04	-.42
	AM sport	.40	.11	.30	**3.64****	.81	.29	.24	**2.84****	-5.22	2.29	-.17	**-2.28***	-8.45	2.82	-.25	**-2.99****
	PM sport	.12	.18	.05	.65	.61	.48	.10	1.28	1.00	3.84	.02	.26	-2.40	4.72	-.04	-.51
	Academic time	-.02	.02	-.06	-.74	.03	.06	.05	.52	-.20	.52	-.03	-.38	.24	.64	.03	.37
	Sport time	-.01	.03	-.03	-.32	.03	.08	.03	.35	-.17	.66	-.02	-.25	.01	.82	.00	.01
	Model fit	*F(8,148) = 5.402, R^2 = .241***				*F(8,148) = 4.457, R^2 = .194***				*F(8,148) = 10.982, R^2 = .372***				*F(8,148) = 4.044, R^2 = .179***			

Statistical significance: *p < .05; **p < .01. Abbreviations: PSQI, Pittsburgh Sleep Quality Index; SHI, Sleep Hygiene Index; TST, total sleep time; B, unstandardised coefficient; B_{SE}, standard error of unstandardised coefficient; β, standardised coefficient.

5.4. Discussion

This study sought to present the sleep characteristics of British student-athletes, explore differences in sleep between weekdays and weekends, and examine the association and predictive value of sport scheduling and time demands on sleep outcomes. The primary findings are: (1) British student-athletes exhibited a high prevalence of poor sleep characteristics, aligning with previous research in other student-athlete cohorts; (2) significant differences in sleep were observed between weekday and weekend nights; and (3) early morning training frequency emerged as the sole significant predictor of multiple sleep outcomes when controlling for participant characteristics.

The poor sleep characteristics identified through questionnaires in this study are consistent with previous research findings, as discussed in Chapter 2. For instance, 49% of participants reported poor sleep quality (PSQI >5), comparable to mixed-sport, mixed-gender samples of American student-athletes during the competitive season (see Chapter 2, Table 2.2), and exceeding typical scores in other non-clinical populations (Grandner et al., 2006). The prevalence of excessive daytime sleepiness (ESS ≥10, 23%) differs from the 51% observed by Mah et al. (2018), despite comparable PSQI scores, likely due to differences in questionnaire timing, though the lower score in this study aligns with other student-athlete research (e.g., Goldman et al., 2024). These findings indicate suboptimal sleep health across multiple dimensions, including satisfaction, alertness, and duration. Similarly, the SHI global score reflects previous research indicating poor sleep hygiene practices in student-athletes (Wahesh et al., 2023), contributing to sleep health.

The discrepancy in bedtimes and wake times between weekdays and weekends indicates social jetlag in this population (Wittmann et al., 2006). This phenomenon, commonly observed in educational settings where early morning lessons enforce earlier wake times (Urner et al., 2009), has been demonstrated in student-athletes as well (Mah et al., 2018). Social jetlag is associated with impaired cognitive performance and metabolic disruption (Caliandro et al., 2021), underscoring the importance of minimising fluctuations in sleep timing. While this study highlights differences between weekday and weekend sleep, the variation in training schedules throughout the week suggests that sleep outcomes may also vary between weekdays. Previous research has indicated greater variability in sleep/wake timing in student-athletes compared to other populations (Leduc et al., 2020), a factor potentially detrimental to health outcomes and deserving further exploration.

Regression analyses revealed that a higher frequency of morning (AM) sport was predictive of elevated PSQI and SHI global scores, earlier wake times, and shorter sleep durations on weekdays. This finding aligns with research indicating that early morning training negatively impacts sleep outcomes by reducing total sleep time the preceding night (Sargent et al., 2014b). The organisational structure of British institutions often requires training to be scheduled around academic commitments. While delaying the start of training or better integrating academic and sports schedules presents logistical challenges, doing so could significantly improve sleep outcomes. For instance, shifting training from 06:30 to 09:30 improved sleep duration by 46 minutes in judo athletes (Dunican et al., 2017). This finding is notable as earlier start times appear to be more prevalent among NCAA athletes, where, despite embargoes implemented in several conferences, sport-related activities can commence as early as 06:00 (NCAA, 2017). Consequently, the detrimental impact on sleep health in other student-athlete populations may be even greater than that observed in this study.

In contrast, the frequency of evening (PM) sport was not predictive of any sleep outcome, consistent with evidence suggesting that evening exercise does not impair sleep unless performed within an hour of bedtime (Stutz et al., 2019). However, sleep disruption following evening competition is common, likely due to increased arousal (Roberts et al., 2019b). A study by Brand et al. (2014) showed that an increase in evening exercise intensity resulted in increased sleep efficiency, reduced wake after sleep onset, and shorter sleep onset latency, but alongside a shorter time in bed. Therefore, evening exercise may elicit different effects on each dimension of sleep health.

This study found that neither academic-related nor sport-related time demands predicted any sleep outcome. This aligns with a previously published abstract indicating that academic and sporting commitments were not associated with sleep duration in American student-athletes (Meridew et al., 2017). However, this is in contrast with the common perception that balancing academic and sports demands restricts sleep opportunities in student-athletes. Although over half of the participants reported that the demands of being a student-athlete limited their sleep, the combined academic and sporting workload reported in this study (30.9 hours per week) is significantly lower than the 68 hours per week reported by NCAA athletes (NCAA, 2019a). While sport-related time demands did not predict sleep outcomes, the physiological arousal from high training loads remains a sport-specific sleep risk factor in performance athletes (Walsh et al., 2020). Thus, the timing of these commitments, rather than the total hours, appears to be a greater determinant of sleep outcomes in student-athletes.

Lastly, 63.7% of participants reported napping at least once a week, slightly lower than previously reported in American student-athletes (Mah et al., 2018; Rebello et al., 2022; Stephenson et al., 2022). A high prevalence of naps exceeding one hour was also observed, with daytime sleepiness being the primary reason, reflecting the high ESS scores. This suggests that some student-athletes struggle to achieve sufficient nocturnal sleep. This contrasts with research on elite athletes, where napping is often unrelated to sleep pressure but rather reflects an increased ability to nap (Gupta et al., 2021). Future sleep research in student-athletes should capture napping behaviour to provide a comprehensive understanding of sleep patterns across the 24-hour day in this population.

5.5. Limitations

The cross-sectional design of this study limits its findings to the specific time of data collection. Sleep characteristics are temporally sensitive and can fluctuate in response to various factors; for example, higher PSQI scores have been observed in student-athletes during periods of increased academic and sporting stress (Astridge et al., 2021), while the prevalence of PSQI scores >5 was higher pre-exam than post-exam or during the semester in students (Ahrberg et al., 2012). While the sleep questionnaires used in this study are widely applied and generic in nature, they have yet to be validated specifically in student-athlete populations. Athlete-specific sleep questionnaires, such as the Athlete Sleep Screening Questionnaire (Samuels et al., 2016), do exist but may not fully capture the academic-specific risk factors contributing to poor sleep in student-athletes. Additionally, this study grouped all weekdays together for self-reported sleep timing and duration. Although all academic and sporting activities took place on weekdays in this sample, the timing of these activities likely fluctuates throughout the week, potentially leading to variations in sleep patterns across different weeknights. Thus, there is a need for longitudinal study designs in future research to better capture social jetlag and day-to-day variations in sleep/wake timing.

5.6. Conclusion

In summary, British student-athletes exhibit a high prevalence of poor sleep characteristics across multiple dimensions of sleep health, as assessed through self-reported measures. These findings align with previous research on student-athletes from various nationalities. The sports and academic schedules on weekdays contributed to a pattern of social jetlag, with a phase advance in sleep timing and reduced sleep duration on weekdays compared to weekends. Regression analyses showed that the frequency of early morning training sessions (before 09:00) significantly predicted several sleep outcomes, even when controlling for participant characteristics. However, the frequency of late evening training sessions (after 21:00), along with academic- and sport-related time demands, did not emerge as significant predictors of sleep outcomes.

5.7. Links to other studies

Self-reported measures indicate that this student-athlete population exhibits suboptimal sleep characteristics, consistent with previous research on student-athletes. However, to provide a more comprehensive understanding of sleep in this population, alternative measurement tools are needed to capture different dimensions of sleep health. For example, while the questionnaires used in this study identified clear differences in sleep timing between weekdays and weekends, they lack the precision to detect day-to-day variations or assess sleep regularity. Additionally, sleep episodes are not isolated events, and their timing and duration influence both homeostatic and circadian regulation of future sleep episodes. Wrist-worn actigraphy provides a practical method to capture sleep/wake behaviour in real-world conditions, reducing recall bias and offering suitable sensitivity and specificity compared to polysomnography (Plekhanova et al., 2020). Actigraphy also captures sleep/wake behaviour over the 24-hour day, providing a more nuanced view of napping behaviours, expanding on the self-reported findings in this study. For these reasons, actigraphy will be used as the primary sleep measure in Chapters 6 and 8.

One key sleep-related risk factor identified in this research is early morning sport scheduling, which was predictive of various self-reported sleep outcomes in this student-athlete population. Previous research on performance athletes has shown that earlier training start times lead to reduced total sleep time the night before (Sargent et al., 2014b).

Therefore, Chapter 6 will examine sleep outcomes in a student-athlete team exposed to early morning training. Moreover, it is important to explore how morning training impacts other aspects of sleep health. This will be addressed in Chapter 6, while the theme of training schedules will also be discussed as a sleep health risk factor in interviews in Chapter 7 and considered as modifiable intervention targets in Chapter 8.

An emerging dimension of sleep health that is highly important to health and wellbeing is sleep regularity (Sletten et al., 2023). The varying academic and sports schedules throughout the week in student-athletes likely result in significant fluctuations in sleep timing, beyond the social jetlag observed between weekdays and weekends, potentially disrupting circadian regulation. Novel methods using actigraphy-derived sleep parameters can quantify the consistency of sleep timing (Fischer et al., 2021) and have been applied to assess sleep regularity in athlete populations (Halson et al., 2022b). Accordingly, sleep regularity will be evaluated in the studies conducted in Chapters 6 and 8 and explored further in interviews with participants in Chapter 7.

CHAPTER SIX: EXPLORATION OF SLEEP PATTERNS IN STUDENT-ATHLETES EXPOSED TO EARLY MORNING TRAINING SESSIONS

Associated publication (see Appendix 19): Wilson, S. M. B., Jones, M. I., Draper, S. B., & Parker, J. K. (2025). Irregular sleep/wake patterns in student-athletes exposed to early morning training. *Journal of Sports Sciences*. Advance online publication. https://doi.org/10.1080/02640414.2025.2452726

Associated conference abstract (see Appendix 20): Wilson, S., Draper, S., Jones, M., & Parker, J. (2023). O11 Irregular sleep/wake patterns in student-athletes. *BMJ Open Respiratory Research, 10*(S1), A6-A7. https://doi.org/10.1136/bmjresp-2023-bssconf.11

Author contribution: S. M. B. Wilson: conceptualisation, data curation, formal analysis, investigation, methodology, project administration, resources, software, writing (original draft preparation), and writing (review and editing) (all lead author); M. I. Jones: conceptualisation, methodology, supervision, and writing (review and editing); S. B. Draper: conceptualisation, methodology, supervision, and writing (review and editing); J. K. Parker: conceptualisation, methodology, supervision, and writing (review and editing).

6.1. Rationale

The study presented in Chapter 5 highlighted the predictive role of the frequency of early morning training sessions on various self-reported sleep outcomes, which was not observed for evening training frequency or time demands. This emphasises the role of morning training as a key upstream influence acting upon sleep health for student-athletes, for whom the issue is potentially greater than in adult athletes due to the changes in chronotype that occur during young adulthood, marked by a peak phase delay at this age (Roenneberg et al., 2004). The PSQI identified a pattern of social jetlag between weekdays and weekends, although it is unclear whether differences in sleep outcomes are present between days in response to the changeable sporting schedule. Previous research on student-athletes has shown that days with morning training sessions reduce sleep duration the prior night, in contrast to non-training days (Benjamin et al., 2019; Merfeld et al., 2022). Therefore, there is a need for longitudinal research to examine whether there are between-day differences present within student-athletes who are exposed to early morning training.

Maintaining a consistent sleep/wake pattern is an important component of healthy sleep to support the circadian process of sleep regulation and is associated with various health and performance outcomes (Sletten et al., 2023). Additionally, irregular sleep/wake patterns have been associated with poorer academic attainment (Phillips et al., 2017). Previous sleep research in athletes has often presented sleep parameters as an average value over the monitoring period without reporting any measure of within-person variability between days (Halson et al., 2022b). A recent systematic review identified only 16 studies reporting within-person variability in sleep for athletes (Kemp et al., 2023). The most common metric used in these studies is intra-individual variability, where sleep parameters on each night are compared to an individual's average sleep pattern (Fischer et al., 2021) and it is evident that athletes exhibit high intra-individual variability in sleep parameters (Kemp et al., 2023; Nedelec et al., 2018). A study on British student-athletes revealed greater intra-individual variability in sleep parameters compared to non-athlete students (Leduc et al., 2020), while elite junior athletes exhibited greater intra-individual variability in time in bed and sleep duration measures compared to elite and sub-elite senior athletes (Caia et al., 2017). Therefore, student-athletes may be more susceptible to greater sleep variability than other athlete groups.

One potential limitation in applying intra-individual variability as a measure of sleep regularity to student-athlete groups is that it functions as an 'overall' metric, establishing variability in comparison to an individual mean across a monitoring period. To gauge day-to-day variability, a 'consecutive' measure is required (Fischer et al., 2021). This is especially pertinent for a student-athlete population, where significant variations in daily schedules (e.g., training timings) may influence sleep parameters between consecutive days. The Sleep Regularity Index (SRI) is a novel consecutive metric that calculates the probability of an individual being in the same sleep/wake state at time points 24-hours apart (Phillips et al., 2017). Another advantage of assessing sleep across a 24-hour window is the ability to capture daytime napping, which is a common practice amongst student-athletes (Mah et al., 2018; Stephenson et al., 2022) and also observed within Chapter 5. The SRI has previously been used to evaluate sleep regularity in University students (Phillips et al., 2017; Windred et al., 2021b) and elite athletes (Alves Facundo et al., 2022; Halson et al., 2022b; Teece et al., 2024), and therefore the calculation of SRI can enable comparisons against these populations.

Understanding the sleep/wake patterns of student-athletes has important implications for sports stakeholders and can help make informed decisions on the timing of training sessions to facilitate healthy sleep practices, including sleep regularity. However, despite a rationale to anticipate irregular sleep/wake patterns in student-athletes, it has not been examined using a consecutive measure of sleep regularity in empirical research. Therefore, this study aimed to; (1) present the sleep parameters and SRI of a cohort of student-athletes that train in the early morning, (2) examine differences in sleep parameters when categorised by day of the week and the presence or absence of morning training, and (3) examine the relationship between SRI and sleep parameters.

6.2. Pilot study

This study expanded upon a pilot study between 06 March, 2023, and 20 March, 2023, that are not included in the primary study dataset and with separate ethical approval from the Hartpury University Ethics Committee (ETHICS2022-102). The purpose of this pilot was to test the GENEActiv monitors that had not been previously used for research purposes and test the feasibility of the proposed study. A particular concern was participant adherence to wearing the monitor, particularly due to the requirement to remove the monitor during training sessions, and the completion of sleep diaries. Previous sleep research in collegiate athletes has highlighted poor adherence as an important consideration (Bretzin et al., 2022; Maguire et al., 2018). Only ten of the 21 participants completed the pilot study. A conference proceeding summarising results from the pilot study has been previously published (Appendix 20). To improve adherence for the main trial, the following changes were made: (a) the sleep diary, which had used the Consensus Sleep Diary (Carney et al., 2012), was shortened to encourage completion (see Chapter 3 for further detail); (b) coaching staff were asked to encourage continued adherence during training sessions; and (c) incentives were offered in the form of a prize draw.

In addition to the sleep diary, participants in the pilot study were asked to report the timing of their academic lessons to better understand the required start times on weekdays without training sessions. However, this approach was deemed unfeasible during the main trial due to challenges with diary adherence discussed above and the inability to cross-reference lecture attendance with academic records due to data protection constraints.

6.3. Methods

6.3.1. Participants

Twenty-eight male student-athletes were recruited from a single Rugby Union team competing in the BUCS Super Rugby league, the highest level of university competition in the United Kingdom and gave informed consent to participate in the study. Student-athletes were excluded from participation if they had any previous history of a sleep-related disorder, a current medication that may interfere with sleep, or any concussion in the prior month. These were self-reported and checked against medical records kept by team staff. Participants were required to provide valid actigraphy data for ≥5 days of overlapping epochs of actigraphy to enable an accurate assessment of sleep regularity for inclusion (Fischer et al., 2021). Six participants were excluded for insufficient valid actigraphy data, one of which was related to a device fault. One further participant was excluded for a suspected irregular sleep/wake rhythm disorder (SRI = 3.9 with multiple sleep bouts and fragmented nocturnal sleep), with the participant signposted towards their General Practitioner.

Twenty-one participants were included in statistical analyses with a mean (±SD) age of 21 ± 2 years, a height of 1.80 ± 0.17m, and a mass of 97.9 ± 24.5kg. The majority of the sample identified as White (n = 18), while 3 participants identified as Black, Black British, Caribbean, or African. The level of study varied across undergraduate 1st year (n = 7), 2nd year (n = 6), 3rd year (n = 5) and postgraduate (n = 3), with all participants residing off-campus. The sample included both forwards (n = 11) and backs (n = 10) playing positions.

The study received approval from the Hartpury University Ethics Committee (ETHICS2023-01), and the associated application and forms are attached as Appendix 21-24. Participants were offered individual feedback and entered into a prize draw for three £25 gift vouchers upon study completion.

6.3.2. Procedure

Data collection was conducted between October 9, 2023, and October 23, 2023, during the competitive sporting season and academic teaching weeks (semester one, teaching weeks three and four). The training and match schedule during the data collection period is detailed in Table 6.1. Recovery sessions on Thursday were optional, and Saturday conditioning sessions were completed at a self-selected time with an approximate duration of 1.5 hours. All other sessions were mandatory. The academic timetable commenced no earlier than 09:30 for all participants with no lessons scheduled on the Wednesday before matches.

Table 6.1. Training and match schedule of participants split by day.

Day of week	Session type	Timing
Monday	Field and gym training	Week 1 and Week 2: 06:30 – 10:30 and 12:00 – 12:30
Tuesday	Field training	Week 1: 06:45 – 08:30 Week 2: 06:30 – 08:30
Wednesday	Match (including preparation and travel)	Week 1: 14:00 – 22:00 (away, kick-off 18:00) Week 2: 17:15 – 21:00 (home, kick-off 18:30)
Thursday	Recovery – Medical and Yoga	Self-scheduled
Friday	Field and gym training	Week 1: 06:30 – 10:30 Week 2: 07:00 – 10:30
Saturday	Conditioning	Self-scheduled
Sunday	Rest day	-

Participants were instructed to maintain their usual sleep habits throughout the study. On each morning, participants completed a short questionnaire including a shortened version of the core Consensus Sleep Diary (Carney et al., 2012), and self-reported training attendance and daytime napping. This was administered in both paper and online formats based on participant preference.

6.3.3. Measures

Before data collection, participants completed the Athlete Sleep Screening Questionnaire (ASSQ; Samuels et al., 2016). The ASSQ has been validated for use with elite athletes demonstrating acceptable internal consistency ($\alpha = .74$) and good test-retest reliability ($r = .86$), alongside a high level of inter-rater reliability with a sleep medicine physician (Cohen's weighted $\kappa = .84$; Bender et al., 2018). Furthermore, there has also been unpublished research to indicate that the ASSQ is suitable for use in student-athletes without modification (Charest, 2022). Six Likert scale questions are summed to provide a sleep difficulty score (ASSQ-SDS) and can be used to categorise athletes into none (0-4), mild (5-7), moderate (8-10) and severe (11-17) sleep problem groups. Chronotype is estimated through four Likert scale questions that are summed (ASSQ-Chronotype) and range from 0 (greatest eveningness) to 14 (greatest morningness). ASSQ-Chronotype does not cluster participants into chronotype groups but can be used to identify extreme evening-types (ASSQ-Chronotype ≤4). The ASSQ includes additional modifier questions related to sleep-disordered breathing, travel-related disturbance, napping, caffeine consumption and electronics use which were not used for analyses.

Actigraphy-derived sleep parameters were collected using GENEActiv monitors (Activinsights, Cambridge, United Kingdom). Monitors sampled at 40Hz to allow sufficient capacity over the data collection period. Participants were asked to wear monitors on the non-dominant wrist at all times except for contact training and to use the event marker button to denote sleep onset and offset. Data was extracted and saved in raw format files (.bin) using GENEActiv PC software v3.3 and processed using the GGIR v3.0 R-package in RStudio v2022.12.0.353 (Migueles et al., 2019; Posit Team, 2022). The actigraphy-derived sleep parameters examined for each sleep episode (including naps) were *sleep onset*, *sleep offset*, and *total sleep time* (TST). In addition, the following parameters were extracted for nocturnal sleep episodes: *sleep period*, *wake after sleep onset* (WASO), *sleep efficiency* (SE), and *sleep onset latency* (SOL). The *cumulative sleep duration* across each 24-hour from 12:00 to 12:00 was also calculated. SRI across the study duration was calculated using the sleepreg R-package using a binary sleep/wake format was used, with diurnal shifts in the sleep/wake cycle assessed using the actigraphy-derived sleep onset and offset times

(Windred et al., 2021a). Further details on the actigraphy analysis approach and definitions for sleep parameters are presented in Chapter 3.

6.3.4. Statistical Analysis

The distribution of sleep onset, sleep offset, WASO, SE and SOL were considered non-normal (Shapiro-Wilk, p <.05). SRI scores were also treated as non-normal due to negative skew, confirmed through visual inspection of Q-Q plots and in alignment with previous research (Windred et al., 2021a). Descriptive analyses of sleep parameters are presented as median (IQR). Differences between nights preceding morning training and free mornings were assessed using Wilcoxon signed-rank tests. Differences in sleep parameters across days of the week were evaluated with Friedman tests, and significant results underwent post-hoc analysis using Wilcoxon signed-rank tests for each day-pair, with Bonferroni correction applied for multiple tests to determine p-value significance. A Mann-Whitney U test was performed to compare SRI between napper and non-napper groups. Pearson bivariate correlations assessed the relationship between SRI and other sleep parameters, with bias-corrected and accelerated 95% confidence intervals (1000 samples) reported. Data analysis was performed using R (v4.1.3) and SPSS (v29.0.0) statistical software.

6.4. Results

6.4.1. Athlete Sleep Screening Questionnaire

The mean ASSQ-SDS was 6 ± 2, with players categorised into none (n = 5), mild (n = 13) and moderate (n = 3) sleep problem groups. No participants presented with severe sleep problems. The mean ASSQ-Chronotype score was 7 ± 2, with one student-athlete classed as having an extreme evening chronotype (ASSQ-Chronotype ≤ 4).

6.4.2. Sleep parameters

Table 6.2 presents actigraphy-derived nocturnal sleep parameters across all nights. At the person-level, 14/21 (66.7%) displayed a mean TST of <7 hours per night. A total of 12/21

(57.1%) participants napped at least once across the study duration. The median nap TST was 1.91hr (1.28hr) with a nap onset of 13:28 (02:33) and a nap offset of 15:11 (03:30). The median cumulative sleep duration was 6.90hr (2.44hr), with 9/21 (42.9%) participants displaying a mean cumulative sleep duration of <7 hours across the study.

Table 6.2. Nocturnal sleep parameters for all nights split by nights preceding morning training and preceding free mornings.

Variable	All nights	Nights preceding morning training	Nights preceding free mornings	Morning training vs. free mornings effect size *(r)*
Sleep period (hr)	**7.48** (2.59)	**6.73** (1.37)	**8.86** (2.06)	**.69** (large)*
TST (hr)	**6.67** (2.19)	**5.86** (1.32)	**7.66** (1.85)	**.67** (large)*
WASO (hr)	**0.85** (0.65)	**0.72** (0.42)	**0.98** (0.72)	**.49** (medium)*
SE (%)	**88.7** (6.7)	**89.6** (6.1)	**88.1** (7.1)	**.19** (small)
Sleep onset (hh:mm)	**23:37** (01:40)	**23:07** (01:21)	**00:00** (01:50)	**.50** (large)*
Sleep offset (hh:mm)	**07:08** (03:17)	**05:45** (00:30)	**08:57** (01:32)	**.85** (large)*
SOL (hr)	**0.08** (0.10)	**0.08** (0.09)	**0.08** (0.10)	**.08** (negligible)

Data presented as median (interquartile range). Abbreviations: TST = total sleep time; WASO = wake after sleep onset; SE = sleep efficiency; SOL = sleep onset latency
* Denotes significant difference between groups ($p < .05$). Effect sizes (*r*) interpreted using guidelines by Cohen (1988).

A statistically significant difference in cumulative sleep duration was observed based on the day of the week ($\chi^2(6) = 51.531$, p <.001; Figure 6.1). The post-hoc analysis identified significant differences in eight day-pairs. Furthermore, both sleep onset ($\chi^2(6) = 32.857$, p <.001) and sleep offset ($\chi^2(6) = 62.571$, p <.001) times significantly varied depending on the day of the week, with significant post-hoc differences observed between seven and twelve day-pairs for onset and offset respectively (Figure 6.2). Additional significant differences were found between eight day-pairs for the sleep period ($\chi^2(6) = 29.036$, p <.001), nine day-pairs for TST ($\chi^2(6) = 29.036$, p <.001), and four day-pairs for WASO ($\chi^2(6) = 18.429$, p = .005). No significant day-pairs were identified for SE following post-hoc analysis ($\chi^2(6) = 13.250$, p = .039) and SOL ($\chi^2(6) = 1.433$, p = .963). Complete results for post-hoc analysis assessing day-pair differences are presented in Appendix 25.

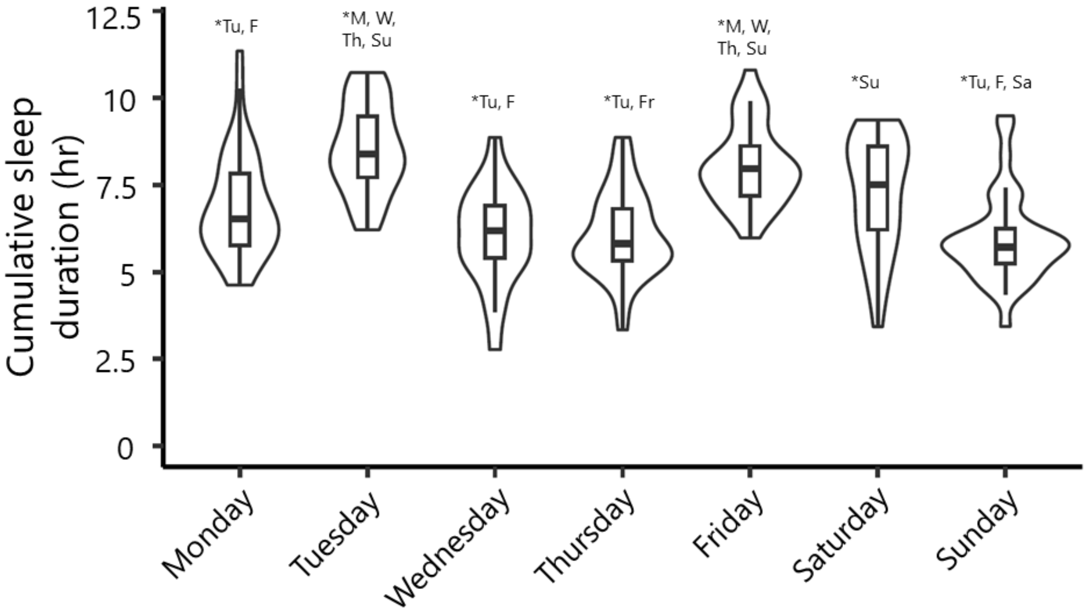

Figure 6.1. Violin plot demonstrating the distribution of cumulative sleep duration including napping.

Among the seven examined nocturnal sleep parameters, 37/41 (90.2%) day-pairs with a significant difference occurred between a night preceding morning training (Monday, Thursday, and Sunday) and a night preceding free mornings (Tuesday, Wednesday, Friday, and Saturday). When results are grouped accordingly, nights preceding morning training exhibited a shorter sleep period (2.13hr), shorter TST (1.80hr), shorter WASO (0.26hr), earlier sleep onset (00:53), and earlier sleep offset (03:12) compared to nights preceding free mornings (all p <.001; Table 6.2). No significant differences were observed between groups for SE (1.5% increase preceding morning training, p = .053). In total, 93/109 (85.3%)

of nights preceding morning training had a TST <7hr, compared to 41/121 (33.8%) of nights preceding free mornings.

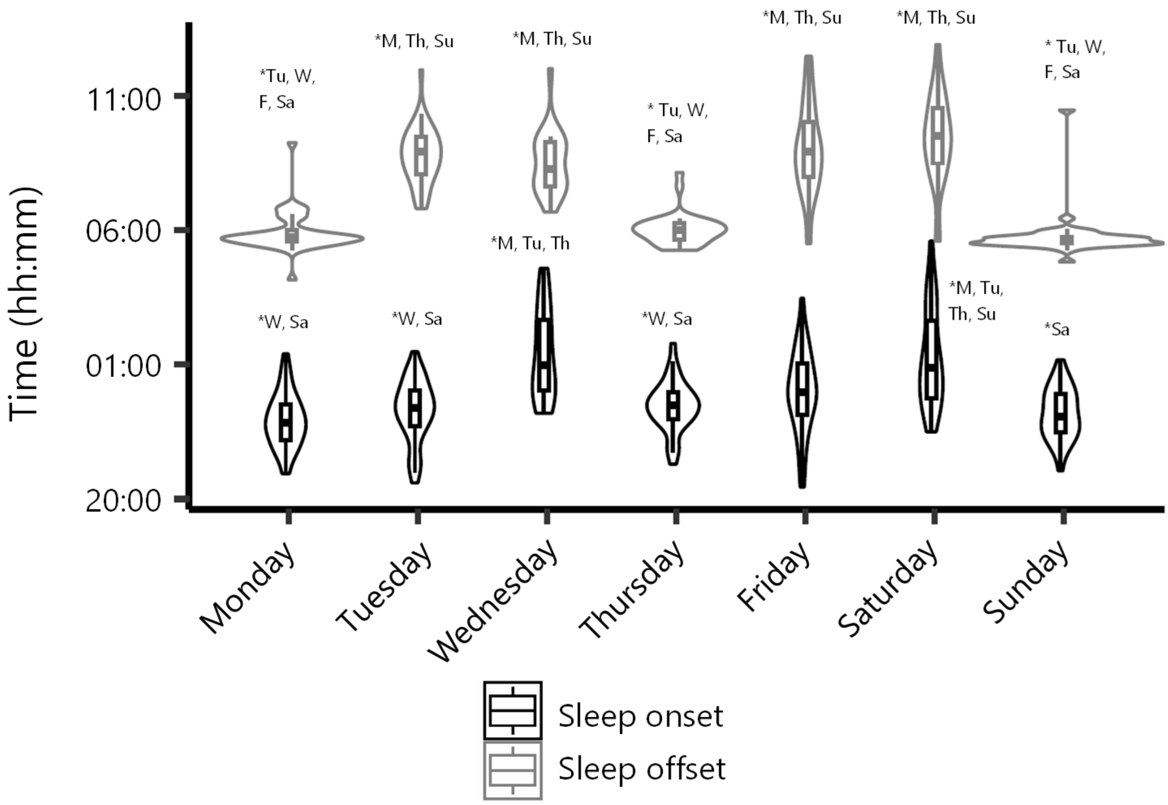

Figure 6.2. Violin plot demonstrating the distribution of nocturnal sleep onset and offset times, split by day of the week.
*Denotes statistically significant difference in post-hoc Wilcoxon rank-sum test with Bonferroni adjustment applied to the p-value for multiple tests (p <.00238). Abbreviations: M = Monday; Tu = Tuesday; W = Wednesday; Th = Thursday; F = Friday; Sa = Saturday; Su = Sunday.

6.4.3. Sleep regularity

The student-athletes exhibited a median (IQR) SRI of 67.0 (17.0), with scores ranging between 38.1 and 79.8. Participants who napped had a significantly lower median SRI of 57.9 (15.9) compared to a median of 73.6 (9.1) in non-nappers (z = -2.88, p = .004; Figure 6.3).

Pearson bivariate correlations revealed an inverse correlation between SRI and cumulative sleep duration (r = -.62, p = .003, 95%CI [-.79, -.44]; Figure 6.3). However, when considering only nocturnal sleep, TST was not associated with SRI (r = -.01, p = .949, 95%CI [-.64, .54]). Lower SRI scores were also significantly inversely associated with delayed sleep onset (r = -.50, p = .022, 95%CI [-.75, -.03]) and sleep offset (r = -.60, p = .004, 95%CI [-.82, -.37]), but not significantly associated with sleep period (r = .10, p = .662, 95%CI [-.52, .59]), SE (r = -

.34, p = .134, 95%CI [-.71, .12]), WASO (r = .33, p = .147, 95%CI [-.13, .65]), or SOL (r = -.17, p = .453, 95%CI [-.59, .38]). Concerning the ASSQ, SRI was positively associated with ASSQ-Chronotype score (r = .52, p = .016, 95%CI [.02, .81]), indicating lower SRI scores in student-athletes with more evening-type chronotypes. ASSQ-SDS was not associated with SRI (r = -.31, p = .172, 95%CI [-.57, .02]).

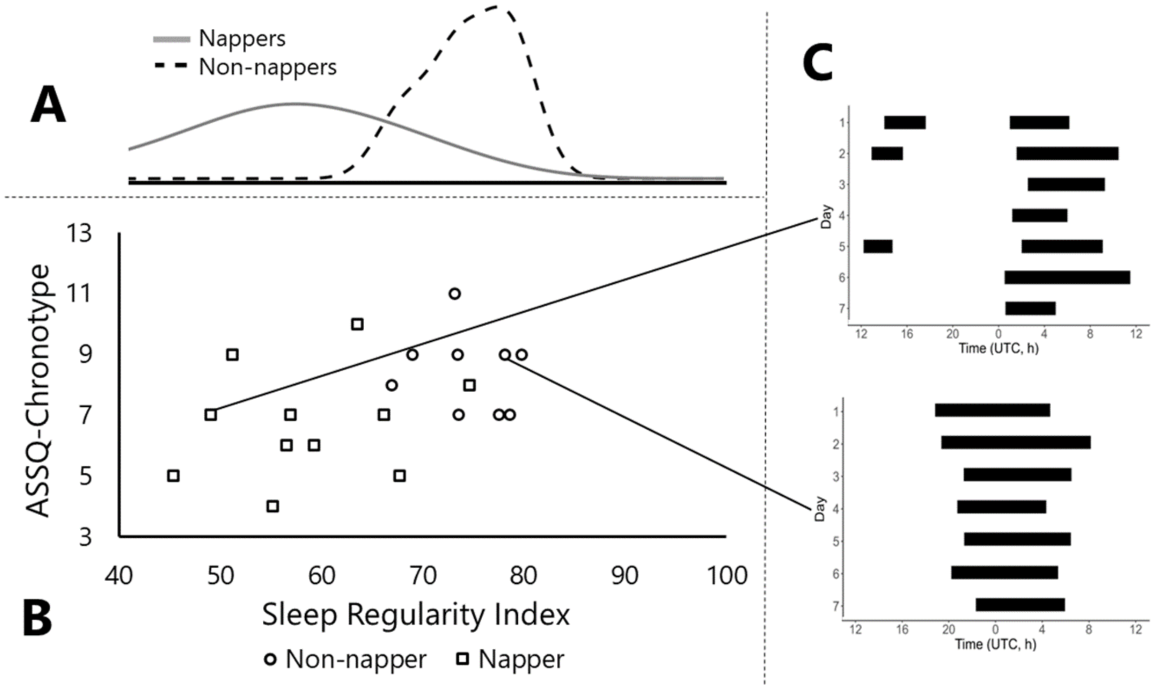

Figure 6.3. (A) Smoothed kernel density estimation of SRI student-athletes in the study classified as nappers and non-nappers; (B) Scatter plot highlighting the positive relationship between SRI and ASSQ-Chronotype, with data points split by napping status; (C) Example raster plots of two participants displaying differing SRI scores and napping status.

6.5. Discussion

The purpose of this study was to present the sleep parameters and SRI of a cohort of student-athletes, examine differences in sleep parameters when categorised by day of the week and the presence or absence of morning training, and examine the relationship between SRI and sleep parameters. A large significant difference between nights preceding morning training and free mornings was observed for actigraphy-derived sleep period, TST, sleep onset, and sleep offset. When assessed using the SRI, student-athletes displayed irregular sleep/wake patterns in response to changing daily training demands, with nights preceding morning training exhibiting advanced sleep onset and offset times, and shorter sleep durations. Additionally, SRI was significantly lower in student-athletes who napped compared to non-nappers, and a lower SRI was significantly associated with greater eveningness in chronotype assessed using the ASSQ, increased cumulative sleep duration, and delayed sleep onset and offset times.

The sleep parameters highlight a clear disparity between nights preceding morning training and free mornings. This observation aligns with previous findings in NCAA student-athletes that showed a significant reduction in TST on nights preceding morning training (Benjamin et al., 2019; Merfeld et al., 2022). While student-athletes attempted to compensate for the early start enforced by training by advancing sleep onset by 0.88 hours on nights preceding morning training, this adjustment did not fully compensate for the advance in sleep offset, which exceeded 3 hours. To fully compensate for morning training, a student-athlete wishing to wake at 05:30 in advance of training at 06:30 and achieve a sleep period of 8 hours would need to fall asleep by 21:30. However, this may not be feasible due to both homeostatic (insufficient sleep pressure) and circadian (high alertness) processes at this time (Borbély, 1982), in addition to any academic, social, or work demands in the late evening. With respect to sleep durations, both the median TST of 6.67 hours and cumulative sleep duration of 6.90 hours fall below public health recommendations for young adults (Hirshkowitz et al., 2015), indicating that many student-athletes may not be meeting their individual sleep need. The notable differences in sleep parameters between days reflect the unique scheduling of the student-athlete day, which involves sports training and competition distributed throughout the week, along with academic and social demands (Brauer et al., 2019). This contrasts with a more typical working schedule where demands are consistent over multiple consecutive days, creating a sleep pattern resembling social jetlag on multiple occasions each week in student-athletes. These increased levels of variability can prevent the establishment of consistent sleep/wake patterns, impacting healthy circadian regulation (Wittmann et al., 2006).

The SRI scores observed indicate that the student-athletes in this study exhibit some of the most irregular sleep/wake patterns among healthy populations. All participants had SRI scores below the median of 81.0 observed in the British population using data from the UK Biobank (Windred et al., 2021a), whilst 9/21 participants (42.9%) presented an SRI that would place them in the lowest 10th percentile (SRI <65.1). Previous studies on university students in Australia (mean SRI = 79.9) and the United States (mean SRI = 73) also demonstrated greater sleep/wake regularity (Phillips et al., 2017; Windred et al., 2021b). The low SRI observed also aligns with previous findings by Leduc et al. (2020), demonstrating greater sleep variability in British student-athletes compared to non-athlete peers, suggesting that the combination of performance sport and academic study can lead to sleep/wake irregularity. The SRI in this study was notably lower than observed by Halson et al. (2022b) in a cohort of elite athletes (median SRI = 85.1), although only nocturnal sleep episodes were considered in the elite population, and also lower than that observed in a professional rugby union team (median SRI = 76.4; Teece et al., 2024). However, Alves Facundo et al. (2022) demonstrated lower SRI scores in national (mean SRI = 68.7) and regional (mean SRI = 73.8) level athletes compared to international athletes (mean SRI = 80.1). The difference between groups may be attributed to the additional demands on sub-elite athletes, including work and/or education commitments, as is often the case for student-athletes (Brauer et al., 2019). Additionally, lower SRI values were found in team sports compared to individual sports and in male athletes compared to females (Alves Facundo et al., 2022), providing further rationale for the irregular sleep/wake patterns present within this study.

When considering the relationship between SRI and sleep parameters, we observed an inverse relationship between SRI and sleep onset, sleep offset, and cumulative sleep duration. However, no relationship was found between TST and SRI. This finding partially contrasts with previous research by Phillips et al. (2017), which showed greater daytime sleep and delayed sleep timing in irregular sleepers but found no relationship between daily sleep duration and SRI. Therefore, it appears that naps were used to add to nocturnal sleep, rather than compensate for lower nocturnal sleep than non-napping peers. However, this practice comes with the consequence of lower sleep regularity due to the variable placement and duration of naps during the day. While shorter naps of 10-20 minutes are recommended for adults with regular sleep/wake schedules (Milner & Cote, 2009), the longer naps observed in this study may result from restricted nocturnal sleep opportunity, as demonstrated by the advanced sleep offset times and shortened TST on nights preceding morning training.

SRI was also significantly associated with ASSQ-Chronotype, revealing that a later chronotype was associated with greater sleep/wake irregularity. While student-athletes may display a greater tendency towards early chronotypes than non-athlete students (e.g., Litwic-Kaminska & Kotysko, 2020), age-related changes in chronotype mean that a substantial number of student-athletes will still present with later chronotypes (Roenneberg et al., 2004). Although the ASSQ-Chronotype does not enable grouping of participants, the results do not indicate any skew towards morning-types, in contrast to other elite athlete groups that train in the morning in response to adaptation to early morning starts or being drawn towards sports that match their chronotype (Lastella et al., 2016). The impact of aligning the timing of sports training and competition to circadian preferences is currently unclear. However, current evidence suggests some favourable outcomes, such as reduced perceived exertion and improved performance on standardised physical tests (Lastella et al., 2021; Roveda et al., 2020).

6.6. Limitations

There are limitations to the present study that should be considered. Firstly, academic scheduling was not considered as lessons on all days except Thursday were preceded by sports training. However, earlier class start times have been associated with unfavourable changes to sleep/wake behaviours and poorer academic attainment (Swinnerton et al., 2021; Yeo et al., 2023), and as such could have influenced sleep on a Wednesday night. Secondly, all student-athletes resided off-campus during the study. Travelling to the training venue likely enforced an earlier sleep offset time than may have been present if residing on-site, and a comparison between accommodation locations warrants future research. Thirdly, the timing and location of Wednesday matches differed between the two weeks. This did not result in any significant change in sleep parameters between subsequent nights, although greater discrepancies in competition timing are present throughout the season and can influence sleep parameters in athletes (Sargent & Roach, 2016).

6.7. Conclusion

The current study has been the first to assess sleep/wake regularity using the SRI in a student-athlete population and revealed that student-athletes exposed to early morning training exhibited poor sleep regularity and undesirable sleep parameters on nights preceding training. These findings carry implications for both sports and academic performance, as well as for physical and mental health. Sleep regularity should be considered as a dimension of sleep health that is notably poorer in student-athletes exposed to early morning training sessions than in other non-clinical populations. Stakeholders in sports should carefully consider the timing of training and matches for student-athletes and consider the impact these structural factors have on sleep. Further research is warranted to explore the potential implications of irregular sleep/wake timing on circadian health and to investigate novel interventions targeted at improving sleep regularity in student-athletes.

6.8. Links to other studies

This study builds upon Chapter 5 and highlights that British student-athletes with early morning training experience suboptimal sleep health across multiple dimensions. Notably, this study reveals that a pattern akin to social jetlag occurs not only between weekdays and weekends but throughout the week depending on sports scheduling. This results in irregular sleep/wake patterns between consecutive days, which threatens to detrimentally impact not only academic and sporting performance but also overall health and wellbeing (Sletten et al., 2023; Windred et al., 2024). These findings underscore the pressing need to address sleep health across multiple dimensions – most notably sleep duration and regularity - in this student-athlete population.

These findings also reiterate the role of morning training as a crucial barrier preventing improved sleep health. However, it is important to understand the perceived impact of shortened sleep durations and irregular sleep/wake patterns from the student-athletes perspective. For example, if student-athletes are satisfied with their sleep and feel it does not affect their daytime performance, there may be less incentive to intervene. Conversely, if they perceive it as problematic, it is necessary to explore the impact on their sporting and academic performance, and other aspects of holistic wellbeing such as mood and emotions. This will be further investigated through interviews with participants in Chapter 7.

Moreover, it should be noted that morning training sessions are typically scheduled out of necessity to fit around academic commitments, rather than by choice. While universities could consider better integration between sports and academic schedules to avoid early starts, thus improving sleep regularity and performance in both areas, this presents a significant logistical challenge. Therefore, there is a need to explore other sleep-related risk factors at the individual and social levels of influence that are more readily modifiable within an intervention. These factors may also provide additional benefits to sleep health when combined with scheduling changes. These barriers will be elucidated further in Chapter 7 and within intervention design in Chapter 8.

CHAPTER SEVEN: A QUALITIATIVE EXPLORATION OF SLEEP IN THE STUDENT-ATHLETE

Author contribution: S. M. B. Wilson: conceptualisation, data curation, formal analysis, investigation, methodology, project administration, resources, writing (original draft preparation), and writing (review and editing) (all lead author); L. De Martin Silva: methodology and writing (review and editing); M. I. Jones: conceptualisation, methodology, supervision, and writing (review and editing); S. B. Draper: conceptualisation, methodology, supervision, and writing (review and editing); J. K. Parker: conceptualisation, methodology, supervision, and writing (review and editing).

7.1. Rationale

The study in Chapter 6 demonstrated that student-athletes display sub-optimal sleep health across several dimensions, including sleep duration and regularity. However, actigraphy-derived sleep parameters do not elucidate the underlying factors that underpin these findings. There is little evidence to suggest that student-athletes are at increased risk for sleep disorders (Emert et al., 2024), and sleep outcomes tend to improve when sporting and academic demands are reduced or removed (Astridge et al., 2021). This indicates that suboptimal sleep health in this population is situational and a consequence of the dual demands of sport and study, rather than a persistent problem. Using the social-ecological model of sleep health (Grandner, 2017), we can expect upstream factors at various levels of influence related to sport, study, or the interaction between both, to drive behaviours that underpin suboptimal sleep health. The identification of these influences can serve as a foundation for understanding how student-athlete sleep health can be better supported.

To understand the sleep-related behaviours in athlete populations, the Athlete Sleep Behaviour Questionnaire (ASBQ) was developed to identify maladaptive sleep practices (Driller et al., 2018). While effective at recognising problem behaviours, it does not enable an understanding of the upstream factors resulting in the behaviour. For example, an athlete reporting that they frequently 'get up at different times each morning with more than ±1 hour variation' could be the consequence of different upstream factors such as training schedules, inconsistent alarm use, or evening social events. Therefore, there is a need to use different methodologies that can provide contextual insight as to why these sleep-related behaviours occur.

Qualitative research methods may be appropriate to overcome the limitations of sleep questionnaires. Despite this, qualitative research exploring sleep in athlete populations either as standalone research or as part of a mixed-method approach is sparse (Nedelec et al., 2018). This is surprising as sleep can be considered a lived experience, where subjective perceptions do not always align with objective measurement (O'Donnell et al., 2009). This may stem from the prevailing view of sleep as primarily a biological process, despite its complex interaction with social and environmental factors (Grandner & Fernandez, 2021; Hale et al., 2020). Previous research that has adopted a mixed-method approach includes a study by de Blasiis et al. (2021). Student-athletes within the study identified factors including sleep environment, training schedules, and study demands through interviews, while actigraphy-derived outcomes showed the student-athletes to have shorter sleep durations, likely due to the addition of academic pressures (de Blasiis et al., 2021). While some studies have touched upon sleep as part of wider health behaviours in student-athletes (e.g., Linnér et al., 2021; Madrigal & Robbins, 2020; Rothschild-Checroune et al., 2012), most qualitative research that has focused on sleep has considered non-athlete university students. An online survey by Stores et al. (2023) that included open-ended questions and analysed using thematic analysis found that sleep disruption was perceived to be a strain on academic performance, and mental and physical wellbeing. Foulkes et al. (2019) also conducted a thematic analysis following interviews which revealed that sleep difficulties in first-year undergraduates were linked to adjusting to new lifestyles, the presence of peers, environmental noise, and academic stress. These university student studies illustrate how qualitative methods such as interviews can help to understand both the factors that underpin sleep health, and the perceived downstream consequences.

An additional advantage of using interviews to understand sleep health in a population is their role in behavioural diagnosis using behavioural frameworks, such as the Behaviour Change Wheel (Michie et al., 2011). Prior research has used interview content, analysed through methods including content and thematic analysis, to map against the COM-B behavioural model (the central behaviour model in the Behaviour Change Wheel) in different health contexts, such as physical activity in students (Brown et al., 2024). However, while this approach has been used in relation to clinical sleep or respiratory disorders (e.g., Zhu et al., 2023), there is no equivalent research on sleep health in a non-clinical population.

This study acts as a follow-on study to Chapter 6 as part of a mixed-method approach, where the actigraphy-derived outcomes are understood from the perception of the participants. This study aimed to explore student-athletes qualitative accounts of their current sleep-related behaviours, elucidating the perceived upstream influences and downstream consequences of their sleep practices. Then, the identified themes will be mapped against the COM-B model to understand how the upstream influences contributing to suboptimal sleep health can be addressed in future interventions.

7.2. Methods

7.2.1. Philosophical and methodological orientation

This study builds on Chapter 6, where wrist-worn actigraphy was used to assess sleep characteristics. In contrast, this second phase focuses on sleep as a lived experience, which cannot be fully understood through actigraphy-derived measures. The interviews were designed through an interpretative lens, using a constructivist epistemological approach and assuming a relativist ontology (Smith & Sparkes, 2016). This approach aligns with the pragmatic philosophical stance of the thesis and was deemed most suitable for exploring participants' subjective meanings and experiences, and understanding how the shared context of being a student-athlete shapes these experiences across individuals.

7.2.2. Participants

All 21 rugby union student-athletes who completed the study in Chapter 6 were invited to participate in interviews, with 12 agreeing to take part. Participants ranged in age from 18 to 25, with a split of backs (n = 5) and forwards (n = 7) playing positions. Ethnicity was reported as White (n = 10) or Black, Black British, Caribbean, or African (n = 2).

7.2.3. Procedure

Individual semi-structured interviews were conducted either in-person (n = 10) or online (n = 2), with all interviews recorded via Microsoft Teams. These were conducted between one and three weeks after the actigraphy recordings in Chapter 6 and lasted between 24 and 52 minutes (median = 40 min). The lead researcher, who was part of the rugby multidisciplinary team for the season, conducted all interviews. The study received institutional ethical approval (ETHICS2023-01), and the associated ethics application and forms are available in Appendix 20-23. All participants provided written consent before recording.

The interview guide was designed to enable participants to direct the conversation while maintaining a consistent structure across interviews (Kallio et al., 2016) and was refined following two pilot interviews conducted in May 2023. Initially, participants were asked to discuss their sleep, specifically in relation to being a student-athlete (e.g., the challenges involved, and differences compared to non-athlete peers), and to reflect on their satisfaction with their current sleep practices. Next, participants were shown their sleep data from the two-week actigraphy period as a prompt for further discussion. This data, presented visually using output from the GGIR R-package (Van Hees et al., 2015), included sleep onset and offset times and total sleep time (see Figure 7.1). No additional feedback was provided at this stage. Participants were asked to reflect on the data, share initial thoughts, and provide context for specific days (e.g., reasons for particularly short or long sleep). All points raised were noted by the interviewer.

Following this, each topic mentioned by the participant was explored in greater depth. Both perceived facilitators and barriers to sleep were revisited, with participants invited to elaborate or provide practical examples. For barriers, participants were asked what changes would be needed to improve their sleep. Any additional points that arose during the discussion were also noted. After the recording ended, the interviewer provided approximately 10 minutes of feedback on individual sleep data and the topics discussed, offering practical advice. The full interview guide is available in Appendix 26.

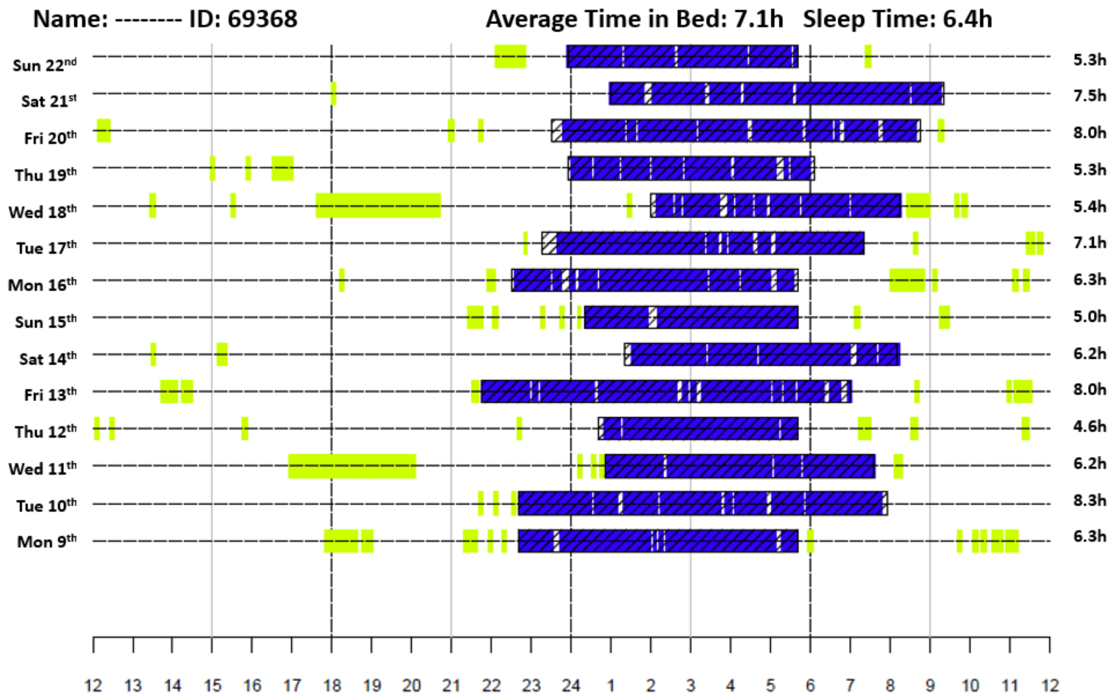

Figure 7.1. Example of visual sleep feedback provided to participants.
Note: Each hatched section represents the sleep episode, and blue sections within the episode were scored as sleep using actigraphy. Green sections are periods of low activity or device removal during the day and were not part of the study.

7.2.4. Data analysis and rigour

Audio recordings were transcribed using a two-step process: initial transcription was automated through Microsoft Teams, followed by manual verification to ensure accuracy. Each recording was carefully listened to, and the original transcript was edited as needed. Transcripts were then uploaded to NVivo 14 (Lumivero, Denver, CO) for analysis.

To explore student-athletes' perceptions of sleep and the factors underpinning sleep practices, reflexive thematic analysis (RTA) was selected as the analysis method (Braun & Clarke, 2021). RTA aligns with a relativist ontological assumption, recognising that reality is subjective and constructed through individual perceptions and experiences, consistent with a constructivist epistemology. This approach emphasises the active role of the researcher in theme development (Braun & Clarke, 2019). The six-step process of RTA offers flexible guidance rather than a rigid protocol.

In Step 1, transcripts were listened to and read twice to immerse the researcher in the data and enhance understanding. In Step 2, initial inductive, semantic codes were generated from each transcript, followed by a second round of coding to refine, expand, and collapse data. In Step 3, codes were grouped into potential themes based on patterns and shared meanings. Step 4 involved reviewing these themes to ensure they addressed the research question. Steps 3 and 4 were revisited iteratively until the lead researcher was confident the themes accurately reflected the interview content. Clear clusters of higher-level themes emerged, with earlier themes re-categorised as lower-level themes under these overarching themes. Step 5 involved naming and defining the higher-level themes, followed by the final write-up in Step 6.

To maintain a high level of reflexivity, a single author conducted the RTA, allowing for continuous reflection on their influence on the results. Although this approach may reduce consensus, the lead researcher's involvement with the players at the time of the interviews provided a nuanced understanding of the context, enabling semantic codes to reflect both explicit and implied meanings. Throughout the process, the lead researcher received support from fellow researchers as 'critical friends' who provided constructive feedback, challenged interpretations, and encouraged further reflexivity. For instance, they helped refine the interview guide after pilot testing to remove assumptions made by the lead researcher and ensure the conversation was participant driven.

After completing the RTA, each theme was deductively mapped against the COM-B (Capability, Opportunity, Motivation – Behaviour) model of behaviour change (Michie et al., 2011). The COM-B model, a diagnostic tool for understanding the factors underlying the current behaviour, was used as part of a behavioural diagnosis to guide the creation of targeted intervention using the Behaviour Change Wheel. Each of the six COM-B components were reviewed against the lower-order themes, with explanations provided for each coded factor.

7.3. Results

The inductive thematic analysis identified nine lower-order themes, which were organised into three higher-order themes: irregular patterns, focusing on social-level influences that create inconsistent sleep opportunities; sleep hygiene practices, highlighting individual-level factors with greater perceived control; and holistic health, examining the bidirectional relationships between sleep and aspects of health, wellbeing, and performance (Figure 7.2).

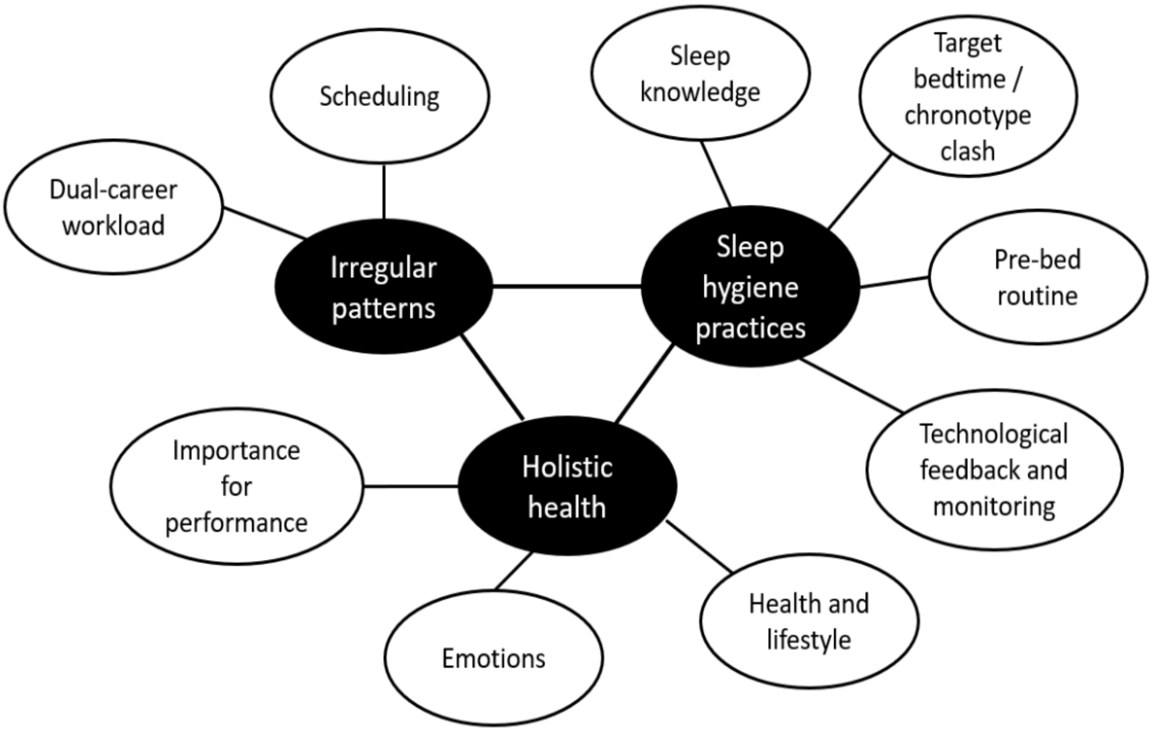

Figure 7.2. Thematic map of higher-order and lower-order themes.

7.3.1. Irregular patterns

The theme of irregular patterns reflects aspects of being a student-athlete that create a perceived inability to maintain regular sleep patterns in terms of timing and duration. These patterns are mainly influenced by social-level factors over which participants feel they have little control. As such, irregular sleep is considered 'part of the package' of being a student-athlete but remains a source of frustration amongst those interviewed.

Every participant highlighted the impact of early morning training sessions, typically scheduled before academic lessons (e.g., 06:30 start), as a key factor dictating their sleep patterns. The irregular placement of training sessions throughout the week (Monday, Tuesday, and Friday) caused athletes to alternate between training days and free days multiple times a week, leading to frequent changes in nocturnal sleep timing. While some participants felt they had adjusted to these early starts — *'Training in the morning is hard, like getting up, but you kind of get used to it'* (Participant H) – several reported ongoing tiredness due to the training schedule:

"So obviously for some boys it can be a bit of a challenge around maybe feeling quite tired a lot the day [after training]. Like that's maybe one thing that I do feel is like in the day I do

get a bit tired. So I do occasionally nap, or maybe some things I am less, less inclined to do" (Participant E).

Many participants reported replacement napping, which are daytime sleep episodes in response to previous sleep loss. These naps often lasted several hours and occasionally resulted in missed daytime activities, such as academic lectures. Some student-athletes noted that during holidays or when training sessions started later in the morning during pre-season, their sleep patterns became more regular, and the frequency of napping decreased. In addition to training schedules, the combined demands of sports and academics further affected perceived sleep. Many participants viewed this dual-career commitment as limiting their sleep opportunities on days with both training and lectures, resulting in extended days on campus *"until about 18:00, twelve hours later, at least"* (Participant H). This sleep debt was then compensated for with longer nocturnal sleep or naps when opportunities arose, typically on weekends. Participants who also worked part-time felt this balance further restricted sleep opportunities, adding a third role to manage:

'With a social life – like you play rugby, do uni[versity], and I am working weekends. So yeah, I don't really take a day off and sleep the next day to catch up' (Participant J).

The importance of socialising within the team outside of training was raised as a fundamental aspect of the student-athlete role, viewed as a 'third component' in addition to sport and study. This was seen as beneficial for psychosocial wellbeing with minimal impact on sleep, except for Wednesday night social events following matches. These nights out often resulted in non-restorative sleep due to shortened sleep opportunity and alcohol consumption, with lingering effects on sleep patterns for several days afterwards:

"If I go out on the Wednesday night I find, if I'm being honest, it's probably going to bed about 04:00 or 05:00 in the morning if l stay out. Like, if I'm really shattered then I'd probably be 01:00 to 02:00-ish. But the whole Thursday is like, even if it's not hungover I'm just fatigued and we'll have Friday. OK, I cope with it, but I think my main issue from like that lack of sleep." (Participant G).

7.3.2. Sleep hygiene practices

The theme of sleep hygiene practices relates to various sleep-related behaviours that can either support or hinder recommended sleep practices (Hauri, 1977). Unlike irregular patterns, student-athletes feel they have greater control over these factors and are aware of their impact on sleep health. However, they often engage in behaviours that counter typical sleep recommendations.

Several participants reported setting a target bedtime before training days to ensure adequate sleep. Despite this, irregular sleep patterns often resulted in participants going to bed earlier than usual but struggling to fall asleep. This difficulty was perceived as being worsened by contrasting sleep preferences on free days, with many student-athletes identifying as evening chronotypes:

"That's what I was saying, I don't really feel tired when you go to bed. So I'll just be like scrolling on my phone, trying to get tired to be able to fall asleep" (Participant C).

Using phones in bed was frequently mentioned as a pre-bed routine, despite contradicting typical sleep hygiene recommendations. While some participants reported this behaviour as hindering their ability to fall asleep, others experienced the opposite, with phone use helping to *"almost wind down and let me go to sleep"* (Participant H). Other reported sleep hygiene practices included limiting light exposure, practising breathing techniques, and enabling sleep modes (e.g., notification silencing) on devices. Some participants monitored their sleep using devices or smartwatches that provided biofeedback. However, this usage was infrequent and seen more as a curiosity checked occasionally. None of the participants used a sleep diary or reported any formal monitoring by their team. Instead, sleep was often gauged intuitively based on feelings of sleepiness and daytime performance:

"I feel like I won't go on to the app then like look and see because I've had this amount of sleep. I need a nap. My body will just naturally tell me that" (Participant I).

Perceptions of sleep knowledge varied among participants. While some felt they had sufficient understanding, often from discussions in their undergraduate studies, others felt differently: *'I can't say I know a lot about sleep and I can't say we speak about sleep enough.'* (Participant I). A few participants mentioned that sleep was almost a taboo subject within sport. While coaches did not necessarily doubt the importance of sleep, there was a lack of emphasis on it due to the gap between ideal sleep practices and what was realistically possible within their schedules.

7.3.3. Holistic health

The theme of holistic health represents the relationships between sleep and various aspects of health and performance, spanning physical health, psychological wellbeing, and daytime functioning. These relationships are often bidirectional, with poor sleep leading to unwanted consequences that prevent student-athletes from excelling in both academic and athletic roles.

An unexpected topic raised by eight student-athletes when discussing the downstream consequences of poor sleep was its relationship with diet. This was expressed in both directions: schedules often required eating close to bedtime, making it harder to initiate sleep – "*One night I might have ate too much as well, so I felt a bit sick, I couldn't go to sleep"* (Participant L) – while daytime tiredness from inadequate sleep led to poorer nutritional choices:

"I'm not picking bad foods, sometimes, it's just quick food. So like I would, I'll pick up a sandwich from the shop or something like that. But yeah, that's still costing me as well. So like, I'm probably sacrificing myself in cost and nutrition" (Participant F).

This created a vicious cycle, where poor sleep affected daily health, which then impacted sleep the following night. Participants also highlighted the relationship between sleep and physical activity. However, this was less about the amount of physical activity during training and more about how poor sleep made them feel *"less energized and it's more of a struggle"* (Participant D). The importance of sleep for athletic performance was universally acknowledged. Sleep was viewed primarily as a recovery tool, essential for muscle repair and growth, and providing energy and alertness for the following day. Fewer participants noted the relationship between sleep and academic performance, but similar disruptions were observed. Academic stress during high-pressure periods, such as exams, negatively impacted sleep, and poor sleep, in turn, made it difficult to stay attentive during lectures and retain information:

"Lectures like, I am trying to concentrate on what he's trying to say and I've never had it ever before. So like my heads, my heads tilting forwards and I'm like, 'oh, my God, I can't stay awake.' Like I'm rubbing my eyes trying to like snap out of this sort of thing." (Participant F).

Participants also identified a relationship between sleep and mood the following day. Short nocturnal sleep, often due to morning training or peer-related disruptions, was linked to increased irritability, frustration, and grogginess. These changes were attributed directly to the lack of sleep rather than other external factors, as they were not present on days following sufficient sleep. Mood typically improved after napping to recover from sleep loss:

"They've woken me up at like 5:00 o'clock in the morning and whatever shenanigans, gone back to bed and then like, they're up again at like 9:30, I'm stroppy the entire rest of the Sunday. And then even on, in a training session, if I've not had good night's sleep, I'm finding myself very, very snappy with people. And then it just ruins it, the same for the rest of the day… but the moment I've got nothing to do I'll have a nap and then I find having a nap does help me like, sort my mood out." (Participant G).

7.3.4. Linking themes to the COM-B model

Following the thematic analysis and theme generation, each of the lower-order themes was deductively mapped to one or more components of the COM-B model of behaviour change (Michie et al., 2011). This process aimed to identify the key factors that were perceived as barriers to healthy sleep practices and could serve as targets for intervention design. All COM-B components, except for physical capability, were coded against at least one lower-order theme (Table 7.1).

7.4. Discussion

This study aimed to explore the factors underpinning observed sleep characteristics and the downstream consequences of poor sleep in a cohort of student-athletes. The results from the RTA identified three higher-order themes: irregular patterns, sleep hygiene practices, and holistic health. These themes encompassed nine lower-order themes which, when mapped onto the COM-B model of behaviour change, related to five of the six factors that influence behaviour.

Table 7.1. Higher-order themes, and links between lower-order themes and COM-B components.

Higher-order theme	Lower-order theme	Link to COM-B components
Irregular patterns	Scheduling	Physical Opportunity: Scheduling (e.g., training) can restrict sleep opportunity on certain days
		Social Opportunity: Social norms and demands from coaches, lecturers, and peers influence sleep timing
	Dual-career workload	Physical Opportunity: Balancing academic and athletic responsibilities limits sleep opportunity
		Automatic Motivation: The stress and fatigue from managing dual roles can affect sleep patterns.
		Social Opportunity: Expectations and demands from academic, athletic, and social spheres create an environment conducive to irregular sleep patterns
Sleep Hygiene	Target bedtime / chronotype clash	Physical Opportunity: The misalignment between scheduled activities and natural sleep rhythms impacts the opportunity to sleep at preferred times
		Reflective Motivation: Adjusting schedules to align with chronotype requires conscious effort and planning.
		Psychological Capability: Understanding chronotype and how it impacts sleep regulation requires knowledge.
	Sleep Knowledge	Psychological Capability: Possessing the mental skills and understanding to manage and improve sleep health
	Pre-bed routine	Psychological Capability: Establishing effective pre-bed routines requires knowledge and understanding of sleep practices.
		Reflective Motivation: Creating and maintaining a pre-bed routine involves deliberate planning and effort.
		Social Opportunity: Social influences can impact the ability to establish and maintain a pre-bed routine.
	Technological monitoring and feedback	Reflective Motivation: Using feedback from technology to adjust sleep behaviours is a reflective process.
		Psychological Capability: Understanding and interpreting feedback from technology requires cognitive skills.
Holistic health	Emotions	Automatic Motivation: Emotions can influence sleep behaviours automatically and often subconsciously
	Importance for performance	Reflective Motivation: Recognising the importance of sleep involves conscious reflection and planning.
		Automatic Motivation: Recognition of sleep's importance can lead to automatic behaviours and habits geared towards optimising sleep
	Health and lifestyle	Automatic Motivation: Health and lifestyle choices, such as diet and physical activity, can become habitual and influence sleep.
		Physical Opportunity: Physical health and lifestyle factors create or limit opportunities for good sleep.

The irregular patterns theme primarily reflects social-level factors within the social-ecological model of sleep health (Grandner, 2017). This highlights that sleep behaviours are not solely individual but are influenced by contextual factors. Participants consistently cited early morning training as a cause of irregular sleep patterns, a known risk factor in athlete populations leading to shortened sleep durations (Sargent et al., 2014b). Morning training frequency has also been linked to poorer subjective sleep outcomes in student-athletes, as demonstrated in Chapter 5. However, participants emphasised that the issue is not just morning training, but the constant switching between early starts and preferred wake times, creating inconsistent sleep patterns. This supports previous evidence of greater sleep/wake irregularity in student-athletes compared to elite athletes by Leduc et al. (2020) and in Chapter 6 and may explain the pattern of long naps to compensate for lost sleep (Mah et al., 2018). Although the extent of these difficulties may be unique to this group, morning scheduling is common in student-athletes to accommodate academic timetables, positioning it as a key modifiable factor to improve sleep consistency.

The perceived workload of balancing sports and academics is often cited as restricting sleep, though the evidence is equivocal (Meridew et al., 2017). However, these interviews underscore the importance of considering other domains beyond sport and study. Many student-athletes work part-time jobs to support their studies, with typical shifts (e.g., bar work) further limiting sleep opportunities (Students, 2023). Additionally, participants highlighted the role of drinking as part of the social structure in university rugby, as previously examined by Harris et al. (2023). While this was perceived as important for team cohesion, such events could disrupt sleep patterns for multiple nights.

The sleep hygiene practices theme concerns behavioural and environmental strategies to promote sleep. These are mainly individual-level factors within the social-ecological model (Grandner, 2017), though influenced by higher-level factors, such as irregular schedules. Many participants reported setting target bedtimes to ensure adequate sleep opportunity but struggled to maintain these. This likely reflects a mismatch between required early bedtimes and the circadian phase delay seen in young adults (Roenneberg et al., 2004). Participants' lack of awareness of circadian rhythms may contribute to this issue. Research indicates athletes often lack the knowledge needed to apply sleep hygiene effectively (Driller et al., 2018; Dunican et al., 2024), and educational interventions have been shown to improve sleep hygiene understanding (Driller et al., 2019; Kloss et al., 2016)

Pre-bed routines varied, with many following common sleep hygiene guidelines (Bender & Lambing, 2024). However, participants frequently mentioned using electronics in bed, a common habit in athletes (Jones et al., 2019b). Although this behaviour was viewed negatively, evidence is inconclusive regarding the extent to which typical device use impacts sleep (Dunican et al., 2017; Jones et al., 2019a). Despite high technological literacy, few participants used devices to monitor sleep, even if they wore sleep trackers. Although such devices have accuracy limitations (Driller et al., 2023), the feedback from wearables can provide longitudinal data that can be used to understand current practices and promote healthier sleep behaviours. Instead, participants relied on intuition and how they felt during the day to assess their sleep.

The holistic health theme reflected how sleep affects various aspects of health and wellbeing, which, in turn, influence future sleep behaviours (Grandner, 2017). One key issue was the relationship between sleep and nutrition. Both are essential for life and functioning, and their reciprocal relationship has been highlighted in recent evidence. For example, participants noted poorer nutritional decisions following sleep loss, which has been documented in research (Zuraikat et al., 2021). The relationship between sleep and athletic performance was also unsurprising, given the participants' competitive level. While evidence on sleep and performance is mixed, cognitive performance is more sensitive to sleep loss than physiological performance (Fullagar et al., 2015). Similarly, participants linked sleep to academic performance, in line with research showing that shorter sleep durations are associated with poorer academic outcomes in student-athletes (Turner et al., 2021). Across interviews, there was also a sense of regret that participants were not able to obtain enough sleep to facilitate their performance, which aligns with previous research by Robbins et al. (2015) where insufficient sleep was retrospectively considered a common health regret at the end of a season. The emotional impact of sleep was another notable issue, with participants reporting more intense negative emotions, such as anger, after poor sleep. However, these emotions did not appear to affect sleep the following night, which aligns with findings that daily fluctuations in sleep quality impact emotional states the next day, but not vice versa (Simor et al., 2015).

Mapping the lower-level themes onto the COM-B model revealed that five of the six components were represented on at least one occasion, suggesting multiple influences can help explain why suboptimal sleep health is present in student-athletes. It is important to consider each of these components when designing an intervention with respect to the expected influence on sleep health, and the feasibility to implement. For instance, physical opportunity could be targeted by adjusting schedules, such as delaying training start times, a strategy proven effective in school settings (e.g., Minges & Redeker, 2016). However, widespread implementation has proven difficult due to the range of stakeholders involved in a large structural change (Illingworth et al., 2019). Ultimately, the process of mapping themes onto the COM-B model provides a foundation for developing targeted interventions that are specific to the target population and underpinned by a behavioural framework, which should enhance effectiveness (Mead & Irish, 2020).

7.5. Limitations

Participants were recruited through convenience sampling from those who completed the study in Chapter 6. While the number of respondents was deemed sufficient to provide enough depth to conduct the RTA, the sample may not be representative of the entire squad. For instance, individuals with poorer sleep may have been more motivated to seek feedback and advice compared to those with no sleep issues. However, the findings in Chapters 5 and 6 suggest that most student-athletes experience suboptimal sleep health. Additionally, the themes and their subsequent mapping onto the COM-B model are specific to this cohort. While many themes are likely shared across other student-athlete populations, there may be influences unique to specific sports or institutions, as discussed in Chapter 3. This reinforces the importance of conducting a behavioural diagnosis—such as the one performed here—that is specific to the target population, rather than relying on preconceived notions about barriers to desired behaviour (Mead & Irish, 2020).

7.6. Conclusion

This study is the first to use RTA to explore the lived experiences of sleep in a student-athlete population, identifying both upstream influences on sleep health and the downstream consequences of current sleep practices. The themes identified are broadly consistent with quantitative research findings, which indicate suboptimal sleep health among student-athletes. However, this study adds depth by detailing the lived experiences of student-athletes, including the challenges they face regarding sleep, their perceptions of sleep, and the impact of sleep on various aspects of daily life. By mapping these themes onto the COM-

B model, the research highlights the barriers to improved sleep behaviours, which can be addressed to facilitate behaviour change.

7.7. Links to other studies

This study identified a range of sleep-related themes within the student-athlete cohort, including those previously highlighted through quantitative methods in Chapters 5 and 6, such as sleep duration and regularity, as well as novel themes like emotional consequences. The mapping of these themes onto the COM-B model serves as part of a behavioural diagnosis for the development of a targeted sleep intervention in Chapter 8.

CHAPTER EIGHT: CREATION AND PILOT EVALUATION OF A BEHAVIOURAL SLEEP INTERVENTION FOR STUDENT-ATHLETES

Associated conference abstract (see Appendix 27): Wilson, S., Draper, S., Jones, M., & Parker, J. (2024). P1398 Evaluation of a targeted behavioural sleep intervention for student-athletes. *Journal of Sleep Research, 33*(S1), 594.
https://doi.org/10.1111/jsr.14291

Author contribution: S. M. B. Wilson: conceptualisation, data curation, formal analysis, investigation, methodology, project administration, resources, software, writing (original draft preparation), and writing (review and editing) (all lead author); M. I. Jones: conceptualisation, methodology, supervision, and writing (review and editing); S. B. Draper: conceptualisation, methodology, supervision, and writing (review and editing); J. K. Parker: conceptualisation, methodology, supervision, and writing (review and editing).

8.1. Rationale

The previous studies have shown student-athletes to display sub-optimal sleep health across multiple dimensions. Improvements in sleep health are associated with various positive downstream effects including better academic performance (Turner et al., 2021), improvements in some measures of sports performance (Han et al., 2022), reduced risk of injury and illness (Hamlin et al., 2021), and improved mental health (Grandner et al., 2021). Furthermore, improved sleep health has also been associated with eudaimonic wellbeing and positive affect in non-athlete populations (Steptoe et al., 2008). Therefore, there is a need to design interventions aimed at improving sleep health in student-athletes.

Previous sleep health interventions have been designed and tested in student-athletes. Sleep extension studies have resulted in improved sports performance (e.g., Mah et al., 2011; Schwartz & Simon, 2015), but these interventions are impractical outside of controlled experimental conditions. The provision of sleep education is widely recommended for all athletes (Walsh et al., 2020), and research by Harada et al. (2016) demonstrated that an educational leaflet could improve perceived sleep quality. However, while education is often considered a foundational component for behaviour change (Arlinghaus & Johnston, 2018), education alone may be insufficient to drive long-term behavioural changes (Halson, 2019). This would indicate that education should be combined with other behaviour change techniques for more effective results. An example of this was a multi-component workshop combining education with interactive tasks that resulted in improved daytime functioning and reduced daytime sleepiness in American collegiate athletes (Kaier et al., 2016). Additionally, research on a similar multi-component sleep health intervention indicated favourable changes to sleep outcomes (Grandner et al., 2017). These studies highlight the potential of multi-component behavioural sleep interventions in improving sleep health among student-athletes, although these have not been further examined in the empirical literature.

A criticism of current sleep health interventions in athlete populations is the apparent absence of integrated behaviour change theory during their development (Halson, 2019) and this was further apparent in the scoping review conducted in Chapter 4. Performing a behavioural diagnosis specific to the population is a critical step at the start of intervention development to ensure that the intervention components are targeting the desired behaviour, and interventions incorporating health behaviour theory into their development are more effective at improving the target outcome (Glanz & Bishop, 2010). The Behaviour Change Wheel (BCW) is a structured approach to health intervention development that includes several steps: defining the problem in behavioural terms, selecting and specifying the target behaviour, identifying what needs to change using the COM-B behavioural model (Capability, Opportunity, Motivation - Behaviour), and evaluating the best delivery options along with the specific behaviour change techniques (BCTs) to integrate into the intervention (Michie et al., 2013; Michie et al., 2011).

The themes identified and mapped against the COM-B components in Chapter 7 have highlighted several factors that may contribute to suboptimal sleep health in student-athletes and may serve as appropriate targets within a targeted intervention. Despite the widespread use of the BCW in the design of other behavioural health interventions, no previous sleep health intervention in university students or athletes has adopted this approach. The unique demands of student-athletes necessitate this targeted approach, and therefore this study sought to design and pilot test a behavioural sleep intervention targeted towards student-athletes using the BCW, and evaluate the impact on sleep parameters, wellbeing, and affect.

8.2 Intervention design

This section details the process used for intervention development using the BCW framework (Michie et al., 2011). Further details on the creation and function of the BCW are presented in Chapter 3.

8.2.1 Defining the target behaviour

Adopting the view of sleep health as a multidimensional concept (Buysse, 2014), the studies presented in Chapters 5-7 showed that a high prevalence of student-athletes present with difficulties in relation to sleep duration and regularity. While these studies also presented evidence of poor satisfaction (Chapter 7) and alertness (Chapter 5), these dimensions were both less apparent and harder to directly target within an intervention. Furthermore, as the dimensions of sleep health are inherently linked, improvements in one may yield benefits across several dimensions. These studies have also made it apparent that suboptimal sleep health is driven by a confluence of upstream influences and behaviours rather than a single identifiable behaviour, and likely differs between individuals. Therefore, the defined target for this intervention was the modification of any sleep-related behaviour(s) that increase sleep duration and/or improve sleep regularity.

8.2.2 COM-B behavioural diagnosis

The COM-B model serves as the central behavioural model within the BCW and facilitates the performance of a behavioural diagnosis that is essential for intervention design through the identification of the potential levers of change (Michie et al., 2011). Each COM-B component is defined and explained within Chapter 3. Table 8.1 elaborates on the necessary changes for the target behaviour concerning each COM-B component, and whether there is a need for change through the intervention. Of the five COM-B components identified through interviews in Chapter 7, all were considered suitable to change apart from Social Opportunity, which was considered less readily modifiable through intervention (Table 8.1).

Table 8.1. Identification of COM-B components to target within the intervention.

Component	What needs to happen for the target behaviour to occur?	Need for change
Physical Capability: Physical skill, strength, or stamina	Student-athletes need to have physical characteristics to be able to fall asleep and stay asleep when desired.	No – there is limited evidence that poor sleep in student-athletes is driven by physical characteristics. Pain associated with sport may hinder physical capability, but this can be unavoidable or required for physical adaptation.
Psychological Capability: Knowledge or psychological skills, strength, or stamina	Student-athletes need to understand what sleep health is, and have the necessary knowledge to implement healthy sleep practices	Yes – Interviews indicated that while student-athletes valued healthy sleep, they may not always possess the skills and/or knowledge required to implement change
Physical Opportunity: Opportunity afforded by the environment involving time, resources, locations	Student-athletes must be presented with sufficient sleep opportunity each night that aligns with their chronotype	Yes – Early morning training has been identified as a factor that is predictive of poorer sleep characteristics, and reiterated by student-athletes during interviews
Social Opportunity: Opportunity afforded by interpersonal influences, social cues and cultural norms that influence the way we think about thing	Student-athletes need to be in an environment that supports good sleep habits.	No – There are social factors that influence sleep as identified in Chapter 7, but these are considered part of the wider student-athlete lifestyle (e.g., social life) where interference may have unwarranted effects on other facets of health (e.g., mental wellbeing)
Reflective Motivation: Reflective processes involving plans (self-conscious intentions) and evaluations (beliefs about what is good and bad)	Student-athletes need to consciously value sleep and its benefits	Yes – Interviews revealed that many student-athletes do not reflect on sleep practices in the same manner that they may do for other aspects of health such as physical activity
Automatic Motivation: Automatic processes involving reactions, processes emotional desires, inhibitions, drive states and reflex responses	Student-athletes need to develop habitual behaviours that support good sleep (e.g., sleep hygiene)	Yes – There is evidence from interviews and questionnaires that poor sleep duration and/or regularity may be exacerbated by the lack of habitual sleep-related behaviours.

8.2.3 Intervention functions and policy categories

Intervention functions are strategies or approaches adopted to alter behaviour. The BCW identifies nine intervention functions (defined in Appendix 28), which link to the identified COM-B components. A matrix of links between intervention functions and COM-B components is available in Appendix 29. Each of the nine intervention functions was considered viable to address one or more COM-B component and was assessed against APEASE criteria which evaluate the acceptability, practicability, effectiveness, affordability, side effects, and equity. The intervention functions deemed suitable were education, enablement, and environmental restructuring (Appendix 28).

The BCW also identifies seven policy categories related to broader systemic and structural strategies that support behaviour change interventions (Michie et al., 2011), as defined in Appendix 30. These categories are linked to the selected intervention functions, with a matrix of links between policy categories and intervention functions available in Appendix 31. Each of the policy categories was considered viable for at least one of the three identified intervention functions and again was assessed against APEASE criteria to select the most effective and realistic policy categories (Public Health England, 2020). Service provision and environmental/social planning were determined to be the most suitable policy options (Appendix 30).

8.2.4 Behaviour change techniques

Following the COM-B diagnosis and selection of intervention functions and policy categories, the specific BCTs (the observable and replicable components of behaviour change interventions) were selected from the Behaviour Change Technique Taxonomy v1 (BCTTv1; Michie et al., 2013). Specification of BCTs within an intervention is important as preliminary evidence suggests that a greater number of BCTs is associated with increased sleep durations in previous athlete interventions (Baron et al., 2021). However, these are infrequently reported within the empirical literature. Like the intervention functions and policy categories, BCTs are linked to the COM-B model whereby certain BCTs are more frequently used within interventions addressing each COM-B component (Michie et al., 2014). Ten BCTs were selected for inclusion in the intervention. These are detailed in Table 8.2 with their links to COM-B components and intervention functions.

Table 8.2. BCTs selected for inclusion within the intervention, and the links to COM-B component and intervention function.

Intervention function	COM-B component	BCT selected
Environmental restructuring	Physical opportunity Automatic motivation	12.1 Restructuring the physical environment
Education	Psychological capability Reflective motivation	5.1 Information about health consequences 5.2 Salience of consequences 2.6 Biofeedback 4.1 Instruction on how to perform a behaviour 5.6 Information about emotional consequences 9.1 Credible source
Enablement	Automatic motivation	1.1 Goal setting (behaviour) 1.9 Commitment 9.2. Pros and cons

8.3. Intervention structure

To integrate the selected BCTs into a deliverable intervention, two separate interventions were specified based on the level of influence within the social-ecological model of sleep health (Grandner, 2017). The first intervention was an education and enablement intervention targeting individual-level factors, and the second intervention was an environmental restructuring intervention targeting social-level factors.

8.3.1. Education and enablement intervention

The first component was an in-person interactive workshop delivered by the lead researcher. The workshop lasted approximately 45 minutes and included:

- A discussion on the pros and cons of good sleep
- Information on the impact of sleep on health, mood and emotions, sports performance, and academic performance
- A simulated driving task using fatigue goggles (Alcovista, Spain)
- A discussion on the main barriers to sleep identified during baseline questionnaire data collection and recommendations on how to overcome these

- Self-selection of a discussed sleep-related behaviour that the individual struggles with, and a personal commitment to change this behaviour over the remaining intervention period

This was followed by individual feedback from the baseline actigraphy data collection, including a visual image and breakdown of sleep onset, sleep offset, total sleep time for each night, and the Sleep Regularity Index (SRI) score across the week. Individualised advice was provided to improve sleep outcomes over the remainder of the intervention period. An example of the individual feedback provided is available in Appendix 32. An explanation of how each BCT was integrated into the workshop or feedback components is provided in Table 8.3.

Table 8.3. The BCTs incorporated into the education and enablement intervention.

BCT	Definition from BCTTv1	How the BCT was delivered
1.1 Goal setting (behaviour)	Set or agree on a goal defined in terms of the behaviour to be achieved	Individual feedback: Participants were provided a recommendation in relation to a component of sleep health (e.g., duration or regularity) based on actigraphy-derived outcomes at baseline
1.9 Commitment	Ask the person to affirm or reaffirm statements indicating commitment to change the behaviour	Interactive workshop: At the end of the workshop participants, each participant was asked to select one sleep-related behaviour discussed and make a personal commitment to attempt to address one of these over the intervention period
2.6 Biofeedback	Provide feedback about the body (e.g. physiological or biochemical state) using an external monitoring device as part of a behaviour change strategy	Individual feedback: Feedback from the first actigraphy data collection in relation to current sleep practices was provided
4.1 Instruction on how to perform a behaviour	Advise or agree on how to perform the behaviour (includes 'Skills training')	Interactive workshop: Five key problems around sleep (taken from ASBQ at baseline) were highlighted with recommendations to help overcome these

BCT	Definition from BCTTv1	How the BCT was delivered
5.1 Information about health consequences	Provide information (e.g. written, verbal, visual) about health consequences of performing the behaviour	Interactive workshop: Information on the relationship between sleep and health outcomes was presented
5.2 Salience of consequences	Use methods specifically designed to emphasise the consequences of performing the behaviour with the aim of making them more memorable (goes beyond informing about consequences)	Interactive workshop: Fatigue-simulation goggles were used to emphasise the impact of sleep restriction on functioning
5.6 Information about emotional consequences	Provide information (e.g. written, verbal, visual) about emotional consequences of performing the behaviour	Interactive workshop: Information on the relationship between sleep, mood, and emotion was presented
9.1. Credible source	Present verbal or visual communication from a credible source in favour of or against the behaviour	Interactive workshop: session was run by the lead researcher with experience in delivering sleep workshops
9.2 Pros and cons	Advise the person to identify and compare reasons for wanting (pros) and not wanting to (cons) change the behaviour (includes 'Decisional balance')	Interactive workshop: Participants were asked at the start of the session to reflect on previous sleep practices, and the benefits or drawbacks related to these

8.3.2. Environmental restructuring intervention

The environmental restructuring component involved delaying morning training to increase sleep opportunity, aligning better with age-related changes in chronotype during young adulthood. This approach has been examined within schools in previous research and has generally been successful at increasing sleep duration on nights preceding school (Minges & Redeker, 2016). It is probable that sleep regularity was also improved in these interventions through a reduction in social jetlag, although this has not been examined.

This delay in training timing was to be implemented using two separate teams. After a baseline period where both teams trained at the same time (Monday 08:30, Tuesday 08:30, Friday: 07:30), one team would have the timing change implemented for the remainder of the intervention (Monday 09:15, Tuesday 09:15, Friday: 08:15), while the other team would continue to train at the baseline times.

8.3.3. Intervention format

The intervention was designed to be delivered using a 2x2 factorial design, with two teams for the environmental restructuring intervention (control or delayed timing) pre-allocated based on coaching logistics. Participants from each team were allocated to the education and enablement intervention (control or intervention) using simple random sampling. However, the environmental restructuring intervention was postponed due to localised flooding reducing pitch availability, requiring both teams to train on the same all-weather pitch at the same time. Consequently, the team allocated to the delayed training timing condition was moved to match the control team. Additionally, the control condition for the education and enablement intervention was removed due to poor adherence to actigraphy data collection during baseline (<50% completion). Participants in this condition were removed from the study and were not required to participate in post-intervention data collection. Consequently, the study design was amended to a quasi-experimental pre-post design, assessing only the education and enablement intervention without a control group.

8.4. Methods

8.4.1. Participants

Student-athletes were recruited from two university rugby teams. Both teams were composed solely of first-year university students and followed the same training schedule during the study period. Student-athletes were excluded from participation if they reported any previous history of a sleep-related disorder, current medication that may interfere with sleep, or any concussion in the prior month. Participants were required to provide valid actigraphy for all days during the baseline and post-intervention data collection periods. Four participants were excluded for providing insufficient data during post-intervention data collection.

Fifteen participants completed the protocol and were included in statistical analyses, with a mean (± SD) age of 19 ± 1 years. The self-identified ethnicities in the sample were: White (*n* = 12), Black, Black British, Caribbean, or African (*n* = 2), and Mixed or multiple ethnic groups (*n* = 1). Playing positions were divided among forwards (*n* = 12) and backs (*n* = 3). All participants were enrolled in a sport-related university course. Most participants resided in university accommodation either on-site (*n* = 5) or off-site (*n* = 6), with two residing in private rentals and two at family homes.

The study received approval from the Hartpury University ethics committee (ETHICS2023-83), and the associated application and forms are attached as Appendix 33-36. All participants provided informed consent before study commencement. To incentivise participation, participants were entered into a prize draw for 1 x £50 and 5 x £25 gift vouchers upon successful completion of the protocol. As the reward was not related to the outcome (sleep), this was not considered an active part of the intervention and none of the BCTs in the grouping ‘reward and threat’ were considered.

8.4.2. Procedure

The intervention took place over a six-week period between January and March 2024. Participants completed a questionnaire and one-week actigraphy data collection at baseline (week 1) and post-intervention (week 6), with an interactive workshop at the start of week 2 and individual feedback at the start of week 3 (see Figure 8.1). The sport schedule during the data collection was training on Monday and Tuesday (both 08:30 start) and Friday (07:30 start), with matches on Wednesday afternoons (between 13:00 to 15:00 start). Changes to training start times (± 1 hour) occurred between actigraphy collection periods due to reduced pitch availability from localised flooding.

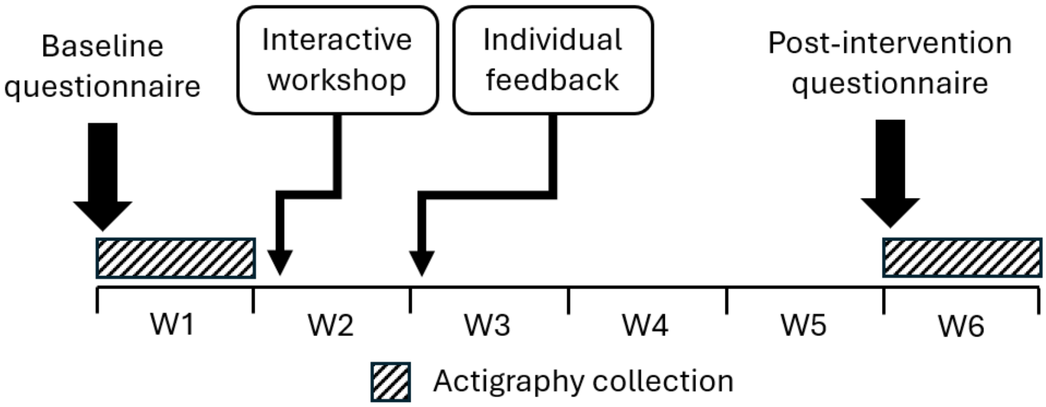

Figure 8.1. Summary of study procedure.

8.4.3. Measures

The Athlete Sleep Screening Questionnaire was used as a measure of subjective sleep difficulty that has been validated as a screening tool for athlete populations (Bender et al., 2018; Samuels et al., 2016). Five Likert scale questions are summed to provide a sleep difficulty score (ASSQ-SDS) from 0-17, with higher scores indicating greater sleep difficulty. Other components of the ASSQ were not used in further analyses. Details on the validation of the ASSQ are presented in Chapter 6.

The Athlete Sleep Behaviour Questionnaire (ASBQ) was used to assess sleep-related behaviours that can facilitate or hinder sleep (Driller et al., 2018). The ASBQ comprises of 18 Likert scale questions and summed for a global score from 18-90 with higher scores indicating poorer sleep-related behaviours. The initial validation of the ASBQ by Driller et al. (2018) demonstrated questionable internal consistency (α = .63) and good test-retest reliability (*r* = .88) in performance athletes, while a meta-analysis has similarly shown acceptable internal consistency (α = .73) and good test-retest reliability (intraclass correlation coefficient = .88). A recent confirmatory factor analysis in student-athletes found that the original ASBQ did not meet recommended model fit indices and instead supported a nine-item questionnaire (Miley et al., 2023). However, in the absence of alternative validated instruments for this population, the ASBQ was deemed the most suitable option to capture sleep-related behaviours, although this potential limitation is considered during the interpretation of results.

The Warwick-Edinburgh Mental Well-being Scale (WEMWBS) was used as a measure of mental wellbeing focused on the positive aspects of mental health (Tennant et al., 2007). The WEMWBS consists of 14 Likert scale questions that are summed for a global score from 14-70, with higher scores indicating greater positive mental health. Initial validation demonstrated good internal consistency (α = .89) and good test-retest reliability (r = .83) in a sample of British university students (Tennant et al., 2007).

The Positive and Negative Affect Schedule (PANAS) was used as a measure of feelings and emotions over the previous week (Watson et al., 1988). The PANAS has two sub-scales for positive and negative affect consisting of ten Likert scale questions that sum for a score from 10-50, with higher scores indicating greater positive and negative affect respectively. The validation in American students demonstrated good internal consistency (positive: α = .88, negative: α = .85). However, test-retest reliability when asked to reflect over the course of a week was low (both r = .47), reflecting the tendency for affect to fluctuate over shorter periods (Watson et al., 1988).

Actigraphy-derived sleep parameters were collected using GENEActiv monitors (Activinsights, Cambridge, United Kingdom). Monitors sampled at 40Hz to match that used in Chapter 6. Participants were asked to always wear monitors on the non-dominant wrist at all times except for contact training and to use to event marker button to denote sleep onset and offset. Data was extracted and saved in raw format files (.bin) using GENEActiv PC software v3.3 and processed using the GGIR v3.0 R-package in RStudio v2022.12.0.353 (Migueles et al., 2019; Posit Team, 2022).

The actigraphy-derived sleep parameters examined for each sleep episode were *sleep onset*, *sleep offset*, and *total sleep time* (TST), *sleep period*, *wake after sleep onset* (WASO), *sleep efficiency* (SE). The *cumulative sleep duration* across each 24-hour from 12:00 to 12:00, and the *Sleep Regularity Index* (SRI) across each one-week data collection period, were also calculated. *Sleep onset latency* was not calculated due to low adherence to sleep diary completion in some participants. Further details on the actigraphy analysis approach and definitions for sleep parameters are presented in Chapter 3.

8.4.4. Statistical analysis

Statistical analyses were performed in RStudio v2022.12.0.353 (Posit Team, 2022). Descriptive statistics are presented as median and interquartile ranges as the distribution of sleep onset, sleep offset, TIB, TST, WASO, and SE were considered non-normal at baseline and post-intervention when nights were aggregated (Shapiro-Wilk, p <.05), whilst SRI is typically considered to follow a non-normal distribution in research using larger samples (Windred et al., 2021a). Differences in actigraphy-derived sleep parameters and questionnaire scores between baseline and post-intervention were assessed using paired t-tests as the differences were all considered to be normally distributed (Shapiro-Wilk, p >.05), and homoscedastic following visual inspection of residuals.

The magnitude of differences was interpreted using effect sizes with Hedges' g correction for small sample sizes and following guidelines by Cohen (1988) as negligible ($|g|$ ≤0.2); small ($|g|$ ≤0.5); medium ($|g|$ ≤0.8); and large ($|g|$ >0.8), with bias-corrected and accelerated 95% confidence intervals (1000 samples) reported.

8.5. Results

Table 8.4 presents sleep outcomes at baseline and post-intervention, and the magnitude of differences between timepoints. No statistically significant differences were observed in sleep parameters (all p >.05), with small effect sizes indicating increased TST including naps and earlier sleep onset times. Ten out of 15 participants increased their TST including naps post-intervention. However, nocturnal TST was only increased in 7/15 student-athletes.

ASBQ global scores indicated a small increase in scores between baseline (Mdn: 43, IQR: 41 to 45.5) and post-intervention (Mdn: 44, IQR: 41.5 to 49; t(14) = 1.90, g = 0.46 (-0.05, 1.02)), indicating poorer sleep hygiene behaviours. There was a small decrease in ASSQ global scores from baseline (Mdn: 7, IQR: 6 to 8) to post-intervention (Mdn: 6, IQR: 4.5 to 7.5; t(14) = -1.23, g = -0.30 (-0.79, 0.20)), reflecting an improvement in perceived sleep.

There was negligible difference in WEMWBS score from baseline (Mdn: 48, IQR: 45 to 53) to post-intervention (Mdn: 50, IQR: 46 to 52; t(14) = 0.29, g = 0.07 (-0.41, 0.55)). Concerning PANAS scoring, there was a medium effect size indicating a reduction in positive affect from baseline (Mdn: 37, IQR: 34 to 41) to post-intervention (Mdn: 32, IQR: 31 to 39; t(14) = -2.08, *g* = -0.51 (-1.01, 0.01)), and negligible in negative affect from baseline (Mdn: 19; IQR: 17 to 22) to post-intervention (Mdn: 20, IQR: 18 to 22; $t(14) = -0.78$, $g = 0.19$ (-0.30, 0.67)).

Table 8.4. Sleep outcomes at baseline and post-intervention presented as median (interquartile range), and effect size between timepoints.

Variable	Baseline	Post-intervention	Effect size (BCa 95% CI)
Sleep period (hr)	**7.51** (6.98 to 8.03)	**7.78** (7.08 to 8.30)	**0.07** (-0.41, 0.55)
Total sleep time (hr)	**6.43** (5.97 to 6.99)	**6.47** (5.92 to 7.17)	**0.17** (-0.32, 0.64)
Total sleep time incl. naps (hr)	**6.69** (6.24 to 7.08)	**7.06** (6.31 to 7.42)	**0.25** (-0.24, 0.73)
Wake after sleep onset (hr)	**1.09** (0.87 to 1.31)	**1.04** (0.93 to 1.20)	**-0.14** (-0.62, 0.35)
Sleep efficiency (%)	**85.9** (83.2 to 88.0)	**86.5** (83.7 to 89.0)	**0.19** (-0.29, 0.67)
Sleep onset (hh:mm)	**01:06** (00:42 to 01:54)	**01:08** (00:44 to 01:31)	**-0.35** (-0.83, 0.16)
Sleep offset (hh:mm)	**08:36** (08:29 to 08:53)	**09:01** (08:15 to 09:09)	**-0.16** (-0.64, 0.32)
Sleep Regularity Index (units)	**70.5** (66.1 to 73.6)	**69.5** (63.1 to 79.6)	**0.09** (-0.39, 0.57)

8.6. Discussion

This study aimed to evaluate a tailored behavioural sleep intervention for student-athlete populations designed using the BCW, and evaluate the changes in sleep parameters, wellbeing, and affect between baseline and post-intervention. Participants displayed undesired sleep parameters at baseline, including short sleep durations and irregular sleep/wake timings. However, no statistically significant differences were observed in any outcome.

The baseline sleep parameters observed align with previous research indicating that student-athletes are prone to poor sleep. For example, the high frequency of total sleep time (TST) under 7 hours has been documented in prior studies using actigraphy (Carter et al., 2020; Goldman et al., 2024), whilst the ASSQ, SDS, and ASBQ scores reflect a high prevalence of sleep difficulties and poor sleep hygiene behaviours, consistent with earlier findings (Rebello et al., 2022). The SRI score also highlights irregular sleep/wake patterns that are common among student-athletes and linked to adverse health outcomes (Sletten et al., 2023), even when training timing is later in the morning than the cohort used in Chapter 6. These findings emphasise the need for targeted sleep health interventions in student-athlete populations.

While no statistically significant differences were observed between baseline and post-intervention sleep parameters, the results provide preliminary evidence that the intervention may have elicited some changes in sleep behaviour. Paradoxically, the increase in ASBQ scores indicates poorer sleep hygiene practices post-intervention. However, this may reflect increased awareness of sleep hygiene behaviours rather than a deterioration of personal practices, as observed in previous interventions where perceived sleep hygiene worsened despite a reduction in daytime sleepiness (Kaier et al., 2016). Actigraphy-derived outcomes suggest minimal changes in nocturnal sleep, aside from a small phase advance in sleep timing. Some participants increased their TST through napping, a common practice among student-athletes, with 68-80% reporting napping at least once per week (Mah et al., 2018; Rebello et al., 2022). Increased napping may explain the lack of improvement in sleep regularity, as the SRI is sensitive to daytime sleep episodes (Phillips et al., 2017). This reliance on napping could indicate an inability to extend nocturnal sleep, often attributed to the time demands of balancing university studies and sports. However, this notion has been challenged and was not predictive of self-reported sleep outcomes in Chapter 5. A more compelling explanation for the difficulty in extending nocturnal sleep is the age-related shift in chronotype observed in young adulthood (Roenneberg et al., 2004), which may prevent substantial advances in sleep onset regardless of intentions.

While no significant differences were observed for mental wellbeing (WEMWBS) or affect (PANAS), unfavourable changes in both constructs were apparent between the baseline and post-intervention periods. This aligns with previous research showing worsening mental health and mood states in first-year university students over an academic semester (Doyle-Baker et al., 2018). These changes in mental wellbeing and affect are likely related to poor sleep (Steptoe et al., 2008). Although the strength and direction of these relationships remain equivocal, previous studies have also reported worsening sleep durations and variability over a semester in student-athletes (Bolin, 2019; Hamlin et al., 2021). Similarly, Astridge et al. (2021) found substantial variations in subjective sleep quality among British student-athletes across a calendar year, with the number of academic assessments each month being the strongest predictor of sleep quality. Therefore, it is feasible that this intervention served a protective effect, mitigating the negative changes in sleep outcomes that are typically over the progression of a semester. This underscores the need to include a control condition in future studies, a limitation of previous comparable interventions (Grandner et al., 2017; Kaier et al., 2016).

These findings indicate that addressing individual-level barriers may be insufficient to significantly improve sleep health. An alternative approach to enhancing sleep in student-athletes might involve targeting social-level barriers, such as delaying sports schedules. It is well established that wake times in young adults are influenced by social factors, such as educational schedules, which in turn affect sleep outcomes (Yeo et al., 2023). During the intervention design, barriers to sleep were identified in the COM-B model for physical opportunity, particularly concerning the scheduling of morning training sessions as demonstrated in Chapter 5. Previous studies have consistently shown that delaying school start times leads to positive changes in sleep, extending sleep episodes rather than merely shifting them (Minges & Redeker, 2016). Furthermore, while the effects of chronic changes to training schedules are unclear, acute delays in training times can increase sleep durations the previous night (Dunican et al., 2017). The proposed social-level environmental restructuring intervention in this study sought to examine the effect of delayed training times but was halted due to logistical challenges related to pitch conditions. This highlights the difficulty of addressing barriers beyond the individual level, which are more susceptible to external influences, and the general difficulties in changing health behaviours (Kelly & Barker, 2016). Despite this, the potential benefits for sleep outcomes suggest that future research should explore similar adjustments to sports scheduling.

The logistical challenges encountered during the implementation of this study, which will be discussed in the broader context of this thesis in Chapter 9, parallel the experiences of the Oxford Teensleep research project (Illingworth et al., 2019). This planned study, conducted in British secondary schools, proposed a 2x2 factorial design incorporating both a sleep education intervention and a delayed school start time (10:00) across 100 schools. Despite significant media coverage, only two schools agreed to participate. The study was consequently simplified to a single pre-post design with only the sleep education programme delivered (Illingworth et al., 2020). This simplified intervention showed small improvements in actigraphy-derived sleep measures, such as a mean increase of 9 minutes in total sleep time (TST), far less than the improvements anticipated from a delayed start time (Minges & Redeker, 2016). Feedback from schools highlighted several key issues that are relevant to this research, including difficulties in securing stakeholder support within narrow timeframes, limited resources, concerns about changes to staffing and facilities, and challenges with transportation logistics. Similarly, the reduction of available facilities due to localised flooding was cited by coaches as the primary reason for the inability to maintain the planned delay to training start times in this study. These issues underscore the complexities of implementing interventions targeting upstream factors at the social level of influence, as such changes often have wide-reaching implications and require comprehensive stakeholder buy-in. At Hartpury, practical examples of these challenges include the need for a coordinated delay to lectures if training start times are postponed, as well as potential changes to bus schedules, external facility bookings, and catering service times for breakfast. While the planned intervention could still be implemented as designed with a small number of teams, scaling up such initiatives across the academy would necessitate significant logistical adjustments and a concerted effort to address the needs and concerns of all stakeholders. This highlights the inherent difficulties in scaling interventions aimed at social-level factors, even when their potential benefits for sleep health are well-evidenced.

This study is the first to employ the BCW to design a targeted sleep health intervention for a student-athlete population and, to our knowledge, the first to do so in any performance sport or university student cohort. The absence of behaviour change theory in previous sleep interventions represents a significant limitation in the existing literature (Halson, 2019). Although sleep is often viewed as primarily biologically driven, the social-environmental context is intertwined with human biology and plays a crucial role in sleep health (Grandner, 2017). The BCW provides several advantages for intervention design by integrating multiple behaviour change theories into a systematic yet flexible framework that can be tailored to specific populations (Michie et al., 2011). It also incorporates the BCTTv1 to select specific behaviour change techniques aligned with the behavioural diagnosis (Michie et al., 2013). As highlighted in the scoping review in Chapter 4, these techniques have not been clearly specified in previous literature, limiting replicability and refinement. Employing the BCW allows for greater transparency and adaptability, enabling future iterations or modifications to suit different target populations. Therefore, the application of the BCW or similar evidence-based frameworks has the potential to significantly improve the effectiveness and replicability of future intervention designs.

8.7. Limitations

The exploratory nature of this study presents several limitations. The small sample size, due to equipment constraints, reduced the statistical power and limited the ability to detect smaller changes between baseline and post-intervention. Additionally, the absence of a control group hindered the assessment of changes outside the intervention and whether the intervention provided a protective effect against the expected deterioration in sleep outcomes over a semester. Therefore, repeating this study with a larger sample size and a control condition would be required to determine the intervention's effectiveness. While the use of a behavioural diagnosis ensures that the intervention is tailored to the target population, different sub-groups of student-athletes may face unique barriers to sleep health. Factors such as sport, culture, and gender can influence sleep in student-athletes (Charest et al., 2023). Consequently, the intervention used in this study may need to be modified for other student-athlete groups. Lastly, the timing of demands outside of sport (e.g., academic lessons or employment) was not recorded, which could influence individual sleep outcomes. Therefore, assessing and controlling for these factors in future interventions would be prudent.

8.8. Conclusion

This exploratory study is the first to utilize the BCW to design a targeted sleep intervention for student-athletes. The intervention consisted of an interactive workshop and individualised feedback, with a total of nine behaviour change techniques incorporated. No statistically significant differences were observed between baseline and post-intervention for sleep outcomes, mental wellbeing, and affect. However, the intervention demonstrated the potential to mitigate the typical worsening of sleep outcomes during the academic semester. This intervention was designed to be practical to implement within existing university sports structures. However, more substantial changes in sleep behaviour may only be possible by addressing structural factors such as training timing. Furthermore, this study provides a blueprint for how evidence-based intervention design frameworks can be used to design future sleep health interventions to ensure they are specific to the target population.

8.9. Links to other studies

This intervention has drawn on evidence from previous studies to inform development. This includes the need to implement behaviour change theory into development and specify intervention content using BCTs based on limitations in previously published literature (Chapter 4), the need to consider intervention outcomes across multiple dimensions of sleep health (Chapters 5 and 6), and the use of interviews to identify the COM-B components that are perceived barriers to improving sleep health behaviours in student-athletes (Chapter 7).

CHAPTER NINE: DISCUSSION, RECOMMENDATIONS, AND CONCLUSION

9.1. Introduction

The purpose of this thesis was to examine sleep within a British student-athlete population. Following the literature review presented in Chapter 2, three primary research objectives were outlined in Chapter 3: To assess sleep health amongst British student-athletes; to identify the upstream influences that underpin suboptimal sleep health in student-athletes; and to design and evaluate a behavioural sleep intervention targeted towards British student-athletes. To address these research objectives, five primary studies were conducted: (a) a scoping review to map the existing evidence of behavioural sleep interventions in athletes and specify the behaviour change techniques used (Chapter 4); (b) a cross-sectional survey in British student-athletes to examine sleep health and understand the impact of training timing and time demands as upstream factors influencing sleep health (Chapter 5); (c) a longitudinal assessment of sleep in student-athletes exposed to early morning training to understand how this influences sleep patterns across the week and sleep regularity (Chapter 6); (d) semi-structured interviews to explore perceived upstream influences and downstream consequences of sleep health, and map against the COM-B model to act as a behavioural diagnosis preceding intervention design (Chapter 7); and (e) the design and pilot testing of a targeted behavioural sleep intervention designed using the Behaviour Change Wheel (Chapter 8). Each study has contributed to generating new knowledge in the field and identified areas for future research. This chapter will discuss how each study has addressed one or more research objectives, evaluate the strengths and limitations of the thesis, and outline the theoretical implications and practical recommendations derived from these findings.

9.2. Research objectives

9.2.1. Assess sleep health amongst British student-athletes

The literature review conducted in Chapter 2 showed that when considered as a homogenous population, student-athletes demonstrate suboptimal sleep health across multiple dimensions (e.g., duration), while other dimensions (e.g., regularity) remain under-researched. However, there are likely to be different upstream factors influencing sleep health in different subgroups of student-athletes. Most previous research has focused on American student-athletes, although differences relating to sport (e.g., performance level) and study (e.g., academic structure) provide a rationale for differences in sleep health between cohorts to exist. Only one study has assessed some dimensions of sleep health among British student-athletes (Leduc et al., 2020), and therefore this thesis sought to further understand sleep health in this cohort and how it compares to international counterparts.

In Chapter 5, a cross-sectional survey of Hartpury sports academy student-athletes used multiple validated sleep questionnaires to examine how this cohort's sleep health compares to previous research. Results showed a high prevalence of undesired sleep characteristics, such as poor perceived sleep quality (with 49% of participants scoring >5 on the Pittsburgh Sleep Quality Index (PSQI)) and a high prevalence of daytime napping. These findings broadly align with previous studies on student-athletes (e.g., Mah et al., 2018), echoing similar trends observed in elite athletes and university students, where suboptimal sleep health is common despite associations with downstream consequences for sports performance, academic attainment, and health. This reinforces the need to better understand and improve sleep health within this population. Additionally, the study observed a pattern of social jetlag, where weekday sleep onset and offset times were advanced and sleep duration was shortened, supporting previous research (e.g., Mah et al., 2018) and indicating some level of disrupted sleep regularity because of the shift between weekday and weekend timings. A unique challenge for student-athletes is the variability in sport (e.g., training) and academic (e.g., lectures) schedules across the week, potentially adding further variation to weekday sleep patterns, which this study could not fully investigate.

To gain insight into these between-day variations, a longitudinal study was conducted in Chapter 6, monitoring sleep with actigraphy over two weeks in a rugby union team exposed to frequent early morning training sessions. The study revealed significant differences across various sleep outcomes when comparing nights before morning training sessions to those preceding non-training days, consistent with earlier findings in student-athletes (e.g., Benjamin et al., 2019; Merfeld et al., 2022). Sleep regularity was assessed using the Sleep Regularity Index (SRI; Phillips et al., 2017), a metric that captures between-day variation.

The median SRI score of 67.0 was notably lower than previously observed in university students and elite athletes (e.g., Halson et al., 2022b; Windred et al., 2021), reflecting more irregular sleep/wake timing. Poor sleep regularity is associated with a range of adverse health outcomes (Sletten et al., 2023; Windred et al., 2024), marking it as a critical dimension of sleep health where student-athletes with early morning training schedules face particular challenges—a finding not previously demonstrated in empirical literature (see Chapter 2, Table 2.3).

9.2.2. Identify the upstream influences that underpin suboptimal sleep health in British student-athletes

The social-ecological model of sleep health suggests multiple upstream influences on sleep health at the individual, social, and societal levels (Grandner, 2017). However, it remained unclear which of these influences most significantly contributes to suboptimal sleep health in British student-athletes and whether their relative impact differs from other student-athlete populations.

In Chapter 5, the cross-sectional survey included assessments of common upstream factors identified in the literature review, specifically the frequency of early morning or late evening training and weekly hours dedicated to sport and academics. Total time demands for British student-athletes were approximately 30 hours per week, significantly lower than their American counterparts where this often exceeds 60 hours (NCAA, 2019). This suggests that cumulative time demands may not restrict sleep opportunity for British student-athletes, reinforcing the need to consider them as a distinct subgroup in the first research objective. Regression analyses identified that a higher frequency of morning training sessions significantly predicted poorer perceived sleep quality (PSQI global score), poorer sleep hygiene (Sleep Hygiene Index global score), reduced total sleep time on weekdays, and earlier weekday wake times. Although academic schedules necessitate certain training times, early morning training is misaligned with the age-related shift toward eveningness in young adults, leading to poorer sleep outcomes. This misalignment was identified as an important upstream influence warranting further investigation in subsequent studies.

The longitudinal study in Chapter 6 reinforced that early morning training is detrimental to sleep health. Findings showed a significant disparity in sleep outcomes between nights preceding morning training and those preceding free days. Median total sleep time on free nights was 7.66 hours, aligning with public health recommendations for young adults (Hirshkowitz et al., 2015), but dropped to 5.86 hours on nights before morning training. These between-night variations contributed to irregular sleep/wake patterns, as discussed in the previous objective.

In Chapter 7, semi-structured interviews with the same population explored perceived upstream factors impacting sleep health and associated downstream consequences. Reflexive thematic analysis identified three higher-order themes and nine lower-order themes. The higher-order theme ‘irregular patterns’ encompassed the impact of training schedules but also highlighted the challenges of balancing academic and athletic responsibilities, despite the relatively lower combined time demands compared to American student-athletes, as observed in Chapter 5. The interviews also surfaced other potential upstream influences with limited previous empirical investigation, including sleep knowledge, pre-bed routines, technological monitoring, and emotional factors. This illustrates the wide array of upstream factors that can contribute to sleep health and provides several feasible intervention targets which were incorporated into the designed intervention.

9.2.3. Design and evaluate a behavioural sleep intervention targeted towards British student-athletes

As discussed in Chapter 3, adopting a behavioural approach to improve sleep health in student-athletes is well-founded, given that observed sleep challenges appear to be driven by upstream influences related to academic and sporting demands. Reductions or removals of these demands have been associated with improvements in sleep (e.g., Astridge et al., 2021). Calls have been made for the integration of behaviour change theory in sleep interventions (Halson, 2019) to align with health research practices in other domains, ensuring that interventions use appropriate techniques to drive sleep behaviour change in specific populations.

The scoping review in Chapter 4 aimed to identify and map existing behavioural sleep interventions in athletes, assess their impact on sleep outcomes, and retrospectively classify the behaviour change techniques (BCTs) utilised. Across 33 studies, various intervention types were employed, showing mixed results. Importantly, most studies did not clearly specify the BCTs used, which impeded understanding, comparison, and replicability. Furthermore, few studies demonstrated evidence of a behavioural diagnosis to ensure the intervention's suitability for the target population. Addressing these limitations, this thesis incorporated behaviour change theory during intervention development and implementation.

The first step in applying this approach was conducting a behavioural diagnosis using the interview study in Chapter 7. Lower-order themes from the interviews were mapped onto the COM-B model, with five of the six components associated with at least one theme. These findings provided the basis for designing a targeted intervention using the Behaviour Change Wheel (Michie et al., 2013). Two intervention components were developed. The first involved environmental restructuring at the social level, with a plan to delay training start times by 45 minutes, which findings from Chapters 5 and 6 suggested would benefit sleep health. However, logistical challenges prevented the implementation of this component, highlighting the complexities involved in modifying higher-level social influences. The second component involved education and enablement, in which student-athletes participated in an interactive workshop and received individualised feedback on their sleep. Assessed via a pre-post design, the follow-up measurement showed no significant improvements in actigraphy-derived or self-reported sleep outcomes, mental wellbeing, or affect. However, the intervention may have helped to stabilise sleep outcomes across the semester, countering the usual decline in sleep health previously reported (e.g., Bolin, 2019). Although this could not be confirmed due to the lack of a control condition, this finding suggests potential benefits worth exploring in future studies.

9.3. Limitations

The research presented in this thesis offers novel insights into sleep health within British student-athletes but carries inherent strengths and limitations that must be considered when interpreting the findings. Institutional, sporting, and temporal considerations, as outlined in Chapter 3, section 3.3.3, remain particularly relevant when evaluating the generalisability of these results. This section revisits those considerations alongside additional limitations identified throughout the research, while individual study limitations are discussed in their respective chapters.

This thesis applied the concept of sleep health (Buysse, 2014) and the socio-ecological model of sleep health (Grandner, 2017) to understand both the upstream influences and downstream consequences related to sleep health and explain why a behavioural approach to intervention design was appropriate for this population. While this approach has been justified (Chapter 3), it differs from the traditional physiologically focused lens often employed in sleep research. For instance, the studies did not fully address how changes in sleep dimensions, such as duration and regularity, might impact homeostatic or circadian regulation under the two-process model. Nonetheless, improvements in these dimensions could support physiological regulation, for example by promoting more consistent sleep/wake patterns. While behaviourally focused intervention design may be more complex due to the interplay of physiological and social-environmental factors (Grandner & Fernandez, 2021), future research could benefit from a more holistic framework incorporating both physiological and psychological principles.

A notable limitation is the generalisability of findings. This research was conducted at a single institution with unique characteristics, such as a rural campus requiring transport and differences in academic structure compared to other countries (e.g., Kerckhoff et al., 2001). In relation to sport, the studies in Chapters 6–8 focused on men's rugby union student-athletes, a group with potentially distinct sleep health characteristics due to factors such as physical demands and schedules (e.g., Mah et al., 2018). Likewise, temporal factors all data were collected during the in-season academic semester, limiting insights into sleep health during off-season periods when academic and sporting demands are reduced. Ultimately, sleep health operates at the individual level, as each person will have different upstream factors that influence their own sleep health. However, the more shared characteristics there are, the greater the number of shared upstream influences acting upon sleep health, and subsequently the greater the generalisability of results. Therefore, it is likely that the findings from these research studies are more applicable to other sub-groups of student-athletes than research conducted on elite athletes or non-athlete university students, thus contributing to a relatively underexplored population.

One limitation was the lack of female representation, as research from Chapter 6 onwards was conducted exclusively with men's rugby union players. While this decision was made for pragmatic reasons based on academy needs and the number of available participants, this reflects a broader trend of underrepresentation of female athletes in sports science research (Cowley et al., 2021). Furthermore, only 25% of published sleep research reports female-specific sleep data (Power et al., 2023). While the literature review in Chapter 2 highlighted mixed findings on the effect of sex on sleep health, there is evidence to suggest potential differences due to both physiological factors, such as menstruation (Koikawa et al., 2020), but also potential cultural differences around social norms and attitudes. Teece et al. (2023) highlighted that there are specific challenges that differ between male and female players in relation to sleep, in what is one of the first studies to consider sleep in female rugby union players. With increasing professionalism and public interest in women's rugby, future research should address sleep health in female student-athletes to support their development and transition into elite sport.

Participant recruitment and retention posed challenges throughout the research, impacting statistical power and external validity. For instance, the survey in Chapter 5 achieved a response rate of approximately 30%, slightly below the average for online surveys (Wu et al., 2022), This raises the possibility of non-respondent bias, as it is unclear whether non-respondents had systematically better or worse sleep health. Similarly, adherence issues were noted in longitudinal studies (Chapters 6 and 8), with 6 out of 28 participants excluded due to insufficient adherence in Chapter 6. Such challenges have been observed in other sleep studies involving student-athletes (Bretzin et al., 2022; Maguire et al., 2018), suggesting that there are unique challenges in conducting sleep research in student-athletes, and there is a need to understand the barriers to adherence to ensure future studies have a final sample that is reflective of population, minimise wasted resources, and increase statistical power. Adherence issues also contributed to the loss of a control condition in the intervention study, limiting the ability to determine whether the intervention mitigated the typical decline in sleep health observed during the semester.

9.4. Theoretical implications

9.4.1. Sleep in the British student-athlete

As discussed in section 9.2, there is limited research on sleep in British student-athletes, despite a clear rationale for potential differences in sleep health compared to international peers due to distinct upstream influences. This thesis has shown that, while many self-reported sleep outcomes are similar across student-athlete groups (Chapter 5), substantial differences exist in the combined academic and sporting workload. Training schedules emerged as a primary upstream that was considered a viable intervention target. However, other factors identified in interviews (Chapter 7) warrant further research on British student-athletes, including post-match social events and balancing student-athlete commitments with part-time employment. Additionally, as this research focused on a single institution, it is crucial to investigate how these findings may compare across different institutions.

More broadly, this research underscores the need to treat student-athletes as a distinct population, separate from elite athletes, as findings in one group cannot necessarily be generalised to the other. For instance, the irregular sleep/wake patterns observed in Chapter 6 exceeded those typically seen in elite athletes (e.g., Halson et al., 2022b). Given the large international population of student-athletes and the evidence of suboptimal sleep health that may surpass other non-clinical populations, further empirical research on sleep in student-athletes is essential.

9.4.2. Sleep health and the social-ecological model

The concept of sleep health across multiple dimensions (Buysse, 2014) and the social-ecological model of sleep health (Grandner, 2017) have been applied throughout this thesis. While these are relatively novel developments, they indirectly apply to much previous research. For instance, studies using actigraphy typically report on dimensions such as efficiency, timing, and duration, while behavioural interventions often aim to modify at least one upstream factor affecting sleep health. Applying these concepts to a population with a high prevalence of suboptimal sleep health, driven primarily by student-athlete demands rather than clinical issues, is especially relevant.

This research has highlighted that not all dimensions of sleep health have been thoroughly examined in student-athletes, with sleep regularity emerging as a particular challenge, especially due to early morning training schedules. This thesis has collected sleep outcomes related to each of the six dimensions outlined by Buysse (2014) at least once. While the concept of sleep health was only explicitly integrated after the cross-sectional survey in Chapter 5, it became clear later in the research process how the study objectives aligned with this concept. Given the findings of suboptimal sleep health across multiple dimensions, as established in the literature review in Chapter 2 and further clarified in this thesis, future research would benefit from adopting the concept of sleep health across multiple dimensions, whether using Ru-SATED (Buysse, 2014) or alternative dimensions (e.g., Knutson et al., 2017), from the outset.

9.4.3. Implementation of behaviour change theory

Despite the role of behaviour in linking upstream influences to observed sleep health, sleep research in athlete populations has rarely adopted a behaviour-focused approach to understanding and improving sleep health (Halson, 2019). Examining sleep through a behavioural lens is complex, given its strong biological underpinnings compared to other health behaviours like physical activity. However, sleep research in other populations has begun to adopt this approach (e.g., Pegado et al., 2023), aligning well with the concept of sleep health and is particularly relevant for student-athletes, a non-clinical population with prevalent suboptimal sleep health. This gap was further highlighted in the scoping review in Chapter 4, where various studies used interventions with identifiable behavioural components but without clear application of behaviour change theory or tailoring for the target population. As discussed in section 9.2, this thesis utilised the Behaviour Change Wheel (Michie et al., 2013) to design a targeted behavioural sleep intervention informed by a behavioural diagnosis using the COM-B model. Although the pilot study in Chapter 8 did not significantly change any sleep outcome, it may have helped mitigate the typical decline in sleep health observed in student-athletes over the semester, suggesting a potential area for further investigation. Future research should consider using behaviour change theory in designing sleep interventions for student-athletes, and this approach may also apply to performance athletes and university students, who represent similar non-clinical populations.

9.4.4. Additional research directions

In addition to the points discussed above, several findings from this thesis present considerations for future research in student-athlete populations:

- **Measure daytime napping within longitudinal studies:** Chapters 5 and 6 demonstrated a high prevalence of daytime napping among student-athletes, with nap durations substantial enough to potentially impact nocturnal sleep regulation. Without data on napping, assessments of sleep dimensions such as duration and regularity may offer an incomplete view. Further research is needed to validate the use of actigraphy for napping assessment, as overlooking naps could lead to misleading findings about overall sleep health.
- **Further research examining scheduling changes:** This thesis identified sport scheduling as a key upstream factor in student-athlete sleep health. While the implications for stakeholders are discussed in section 9.5, the research community would benefit from studies that examine the outcomes of scheduling adjustments, not only in terms of sleep health improvements but also in their downstream impacts on factors such as academic performance and lecture attendance. Furthermore, understanding potential trade-offs, such as effects on travel, part-time work, and environmental factors, is essential for a well-rounded perspective on scheduling changes.
- **Adoption of mixed methods approaches to sleep*:*** This thesis illustrates the benefits of combining methodologies to offer a more comprehensive view of sleep health. Mixed methods approaches can capture the lived experiences of sleep in ways that quantitative data alone may miss. For example, the interviews in Chapter 7 contextualised findings from earlier chapters and underscored why sleep is perceived as an essential health behaviour to address, supported by both self-reported and actigraphy-derived data. Additionally, while COM-B behavioural diagnoses have been attempted through questionnaires (Keyworth et al., 2020), interviews remain a preferred method, allowing for in-depth responses from the target population and providing valuable insight directly from student-athletes.

9.5. Practical recommendations

The findings from this thesis suggest several actionable recommendations for stakeholders in sports and education to help address sleep health challenges in student-athletes. These recommendations build on existing research and provide initial steps toward establishing a more robust evidence base that can be practically applied.

9.5.1. Adjust scheduling to prevent early morning starts

The most compelling recommendation from this research is to address early morning sports scheduling as a modifiable factor contributing to suboptimal sleep health in student-athletes. Evidence from self-reported (Chapter 5) and actigraphy-derived (Chapter 6) measures, as well as student-athletes perceptions (Chapter 7), consistently highlights early training as a key barrier. Additionally, the behavioural intervention in Chapter 8, while addressing most COM-B components, showed no significant change in sleep without addressing the physical opportunity element of scheduling. This underscores training timing as a critical barrier that is unlikely to be mitigated through other intervention methods alone.

While existing research, including this thesis, does not provide a definitive recommendation on the ideal start time for student-athletes, findings from school settings have led the American Academy of Sleep Medicine to recommend lesson start times no earlier than 08:30 (Watson et al., 2017). However, greater delays are likely to yield further beneficial effects – for a typical 18-year-old, alignment with their biological wake time of 09:00 would require lesson start times to be as late as 11:00 (Kelley et al., 2015). Although such a delay may not be feasible given the demands of academic and athletic schedules, stakeholders need to reconsider the early starts seen in this study (as early as 06:30) and the resulting misalignment with student-athletes' biological rhythms. A practical application of this would be an embargo on early morning training sessions, creating a standardised, later start time for academic lessons that aligns more closely with most student-athletes biological clocks. This shift could not only increase sleep duration but also promote better sleep regularity across the week.

9.5.2. Implement a culture that values sleep health

While working in the university it became clear that despite recognising suboptimal sleep among student-athletes, sleep was culturally undervalued compared to other health aspects like physical activity or nutrition. For example, a board in the gym promoted targets such as a specific sleep duration, napping, and regular wake times—recommendations that align with sleep health guidelines but conflicted with many student-athletes training schedules (see Figure 9.1). This conflict was raised by participants in Chapter 7 when discussing sleep hygiene practices; many felt that sleep was a taboo topic, either undervalued by staff or hindered by an inability to make changes that could improve sleep health. Furthermore, the undervaluing of sleep may result in a reluctance from student-athletes to take proactive control of their sleep health, as regardless of any active effort to improve sleep health, the environmental barriers at the institutional level remain. Additionally, the cancellation of the environmental restructuring component of the intervention in Chapter 8, driven by external factors, revealed a lack of willingness to explore alternatives to continue the study. This decision, made without consulting the research team, reflected sleep as a lower-priority health issue rather than one actively promoted.

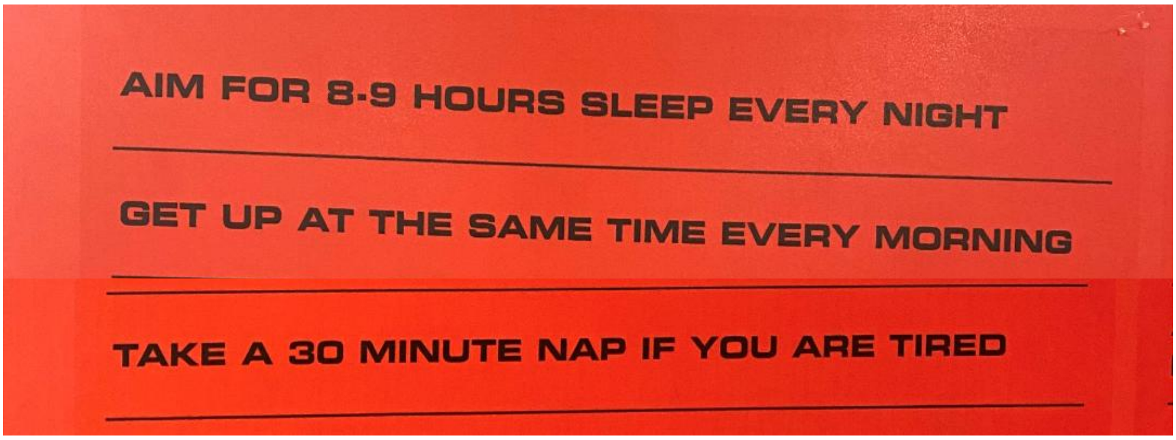

Figure 9.1. Recommendations for maximising performance related to sleep in the Hartpury Performance Gym

To support future research and intervention development for student-athletes, there is a need for a cultural shift among stakeholders that elevates sleep as a core component of student-athlete health. Espie (2022) asserts that valuing sleep as a foundational health behaviour is essential, and for those working with student-athletes, sleep should be regarded with the same importance as other health practices to ensure wellbeing. The education and enablement intervention delivered in Chapter 8 offers a straightforward approach to achieving this shift, with regular sleep education recommended for all performance athletes (Walsh et al., 2020). The implementation of these practices can also have widespread advantages for the institution, with sleep health programmes in universities improving graduation rates and future earnings that exceed the cost of implementation multiple times over (Prichard & Hartmann, 2019). Similarly, providing sleep education to staff could help them appreciate the role of sleep, foster discussions on supporting student-athlete sleep, and potentially improve their own sleep health (Dunican et al., 2021). This could take the form of having a workplace 'sleep ambassador' that can promote a culture that supports sleep health at the institutional level (e.g., Sleep Well Academy, 2024).

9.5.3. Regular sleep screening in student-athletes

The study in Chapter 5 reveals a high prevalence of suboptimal sleep health within the student-athlete population. Without a screening process like that conducted in this study, there is no method to identify individuals who may need further support to improve their sleep health. The consensus recommendations for elite athletes by Walsh et al. (2020) suggest conducting sleep screening both pre- and post-season. This screening would categorise athletes into groups: those with no sleep problems, those with mild issues who could benefit from a better understanding of sleep behaviours and occasional monitoring, and those who may have clinical sleep difficulties and should be referred to medical professionals. Given the high rates of suboptimal sleep health observed in Chapter 5, many individuals would likely benefit from such screening and support. Additionally, while the prevalence of sleep disorders in student-athletes is likely comparable to the general population (Emert et al., 2024), identifying these individuals would help them access medical support and could enhance both their athletic performance and academic success.

Tools such as the Athlete Sleep Screening Questionnaire (Samuels et al., 2016), which may be suitable for use in student-athlete populations pending further validation (Charest, 2022), could facilitate a low-burden screening process. Screening could easily be integrated into current practices, such as alongside concussion assessments. For effective implementation, organisations would need practitioners with knowledge of sleep and experience in interpreting such data. Currently, such expertise is rare in both professional and student-athlete sport, despite the clear evidence of sleep's importance for performance and overall wellbeing, underscoring the need for dedicated sleep practitioners within these settings.

9.5.4. Actionable advice for student-athletes

While this thesis has highlighted scheduling as a potentially modifiable upstream factor influencing sleep health, the challenges in implementing the environmental restructuring intervention in Chapter 8 underscore the significant difficulty in making changes at the social level, even within a supportive institution. Many student-athletes across the UK and beyond will continue to face similar schedules in the foreseeable future. Thus, student-athletes must have access to scientifically supported information about sleep, such as the educational content discussed earlier, as well as actionable strategies to enhance sleep health despite the structural challenges they face.

A key recommendation from this research is to minimise shifts in sleep timing between consecutive days. Maintaining a consistent sleep schedule can be especially beneficial for student-athletes with variable training demands. This research identified social jetlag between weekdays and weekends (Chapter 5), irregular sleep/wake patterns that are more pronounced than those in other non-clinical populations (Chapter 6), and a high frequency of daytime napping (Chapters 5 and 6). Additionally, irregular patterns emerged as a core theme from interviews with all participants (Chapter 7). For some student-athletes, adjusting their sleep on free days to more closely align with their training days may support improved sleep regularity. However, this may be particularly challenging for intermediate or evening chronotypes, who find it harder to maintain earlier bedtimes, especially in the context of social events that typically occur later in the evening. This approach emphasises the importance of providing tailored, flexible strategies for student-athletes, allowing them to make small but impactful adjustments to their routines where possible.

9.6. Conclusion

To conclude, this thesis aims to further understanding of sleep in student-athlete populations, addressing the limited prior research in this area. Three research objectives guided a series of studies, designed pragmatically to advance knowledge in this field. The first objective was to assess sleep health among British student-athletes, a subgroup with little empirical evidence available. Findings revealed suboptimal sleep health across multiple dimensions, with a particular focus on sleep regularity, which appeared poorer than in other non-clinical populations, especially in those exposed to early morning training sessions. The second objective sought to identify upstream influences contributing to suboptimal sleep health in British student-athletes. Early morning training sessions, scheduled before academic commitments, emerged as a primary factor impacting sleep health and should be adjusted where possible. Additional upstream influences also contribute to the observed poor sleep health, presenting a range of viable intervention targets. Lastly, the thesis aimed to design and evaluate a behavioural sleep intervention tailored to British student-athletes. The scoping review highlighted a lack of behaviourally informed interventions in athlete populations, guiding the development of an intervention using the Behaviour Change Wheel and a COM-B behavioural diagnosis to ensure relevance to British student-athletes. Although the pilot study did not show significant changes in sleep outcomes, likely due to the inability to modify training times, it provides a framework for future interventions to incorporate behaviour change theory effectively. These findings address key literature gaps and offer potential avenues for future research, as well as practical recommendations for stakeholders to support student-athlete sleep health.

9.7. Claim to meet the qualification descriptor

Doctoral criteria and how they are fulfilled by the studies within this thesis.

(i) **Have conducted enquiry leading to the creation and interpretation of new knowledge through original research, shown by satisfying scholarly review by accomplished and recognised scholars in the field**.

Chapter 4: Scoping review to retrospectively examine the behavioural content of previous sleep interventions. Accepted and published after double-blind peer review.

Chapter 5: Cross-sectional survey in British student-athlete cohort. Accepted and published after double-blind peer review, and partly presented at a national conference.

Chapter 6: Longitudinal assessment of sleep patterns in student-athletes exposed to early morning training. Undergoing double-blind peer review, and pilot study presented at national conference.

Chapter 8: Design and pilot testing of behavioural intervention. Undergoing double-blind peer review and presented at continental conference.

(ii) **Can demonstrate a critical understanding of the current state of knowledge in the field of theory and/or practice.**

Demonstrated through the narrative literature review in Chapter 3, the scoping review in Chapter 4, and within the rationale and discussion sections of subsequent chapters. These highlighted the knowledge gaps in the field which in turn determined the thesis objectives and the purpose of each study in answering these objectives, and the behavioural approach to intervention development.

(iii) **Show the ability to conceptualise, design and implement a project for the generation of new knowledge at the forefront of the discipline or field of practice including the capacity to adjust the project design in light of emergent issues and understandings.**

Chapter 4: The scoping review retrospectively examined the behavioural content of previous intervention studies and highlighted various limitations that informed the approach taken to intervention development in this thesis.

Chapter 5: New knowledge generated on the sleep characteristics in British student-athletes, with the frequency of morning sports sessions as a significant predictor of multiple sleep outcomes.

Chapter 6: This study is the first to assess sleep regularity in student-athletes using a consecutive measure with the Sleep Regularity Index and provided evidence of greater sleep/wake irregularity than other athlete or student populations.

Chapter 7: Utilised an underrepresented method in sleep research (interviews), and served as a COM-B behavioural diagnosis for intervention development.

Chapter 8: The first study in sleep health to utilise the Behaviour Change Wheel as a framework for the design of a targeted intervention. The intervention was amended in response to external factors and highlighted an important consideration for future interventions in this population.

(iv) **Can demonstrate a critical understanding of the methodology of enquiry**

The thesis has implemented a mixed-method approach. This includes the use of methods that are uncommon in the field such as interview studies and the use of the Behaviour Change Wheel framework, but the use of which is justified in this population and aligns with the research objectives. This is expanded upon in the methodology section of Chapter 3 and reflected upon in the discussion chapter.

(v) **Have developed independent judgement of issues and ideas in the field of research and/ or practice and are able to communicate and justify that judgement to appropriate audiences**

The research studies presented have been developed over the course of the thesis in response to thesis, through personal development as a researcher, and considering emerging literature, where each study is linked to multiple previous or subsequent studies. Communication to external audiences is demonstrated by the associated peer-reviewed publications and conference presentations of multiple studies in both sleep and sports science fields.

(vi) **Can critically reflect on their work and evaluate its strengths and weaknesses including validation procedures**

Both strengths and limitations are acknowledged and discussed to inform future research directions, while the discussion chapter considers the collective strengths and limitations of the thesis and how findings can be interpreted. Validation procedures are demonstrated through various including (but not limited to) the adherence to PRISMA guidelines and use of multiple reviewers in Chapter 4, assessing questionnaire internal consistency and the use of bootstrapping in Chapter 5, and the use of critical friends during reflexive thematic analysis in Chapter 7.

Table 9.1. The list of objectives of the thesis outlined in Chapter 3 and how they link to each study and satisfy the doctoral criteria and taken from the UWE Postgraduate handbook.

Objective	**Relevant chapters**	**Doctoral criteria I**	**II**	**III**	**IV**	**V**	**VI**
Assess sleep health amongst British student-athletes	3, 5, 6, 9	X	X	X	X	X	X
Identify the upstream influences that underpin suboptimal sleep health in British student-athletes	3, 5, 6, 7, 9	X	X	X	X	X	X
Design and evaluate a behavioural sleep intervention targeted towards British student-athletes	3, 4, 7, 8, 9	X	X	X	X	X	X

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Appendix

Appendix 1. Behavioral interventions and behavior change techniques used to improve sleep outcomes in athlete populations: A scoping review (Wilson et al., 2024).

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Behavioral interventions and behavior change techniques used to improve sleep outcomes in athlete populations: A scoping review

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ABSTRACT

Background: Athletes display a high prevalence of undesired sleep characteristics that may affect both performance and wellbeing.
Objectives: This scoping review aimed to identify and map the existing evidence of behavioral sleep interventions and their effects on sleep outcomes in athletes, and retrospectively code the behavior change techniques (BCTs) implemented using the Behavior Change Technique Taxonomy (BCTTv1).
Methods: Conducted following the JBI methodology for scoping reviews, four online databases were used to identify prospective interventions with at least one behavioral component in competitive athletes, and reporting a sleep outcome pre- and post-intervention.
Results: Thirty-three studies met the inclusion criteria, encompassing 892 participants with a median age of 23. Five intervention categories were identified (education, mind-body practices, direct, multi-component, and other), with each demonstrating mixed efficacy but the potential to improve sleep outcomes. The BCTs varied in type and frequency between each category, with only 18 unique BCTs identified across all studies.
Conclusions: The varied efficacy of previous studies at improving sleep outcomes may be attributed to the lack of behavior change theory applied during intervention development. Designing interventions following a targeted specification of the behavioral problem, and the integration of corresponding BCTs should be considered in future research.

Introduction

Sleep has garnered significant interest within athlete populations due to the high prevalence of undesired sleep characteristics, such as nocturnal sleep durations under seven hours and sleep efficiencies below 85% (Gupta et al., 2017; Lastella et al., 2015). These findings can be attributed to sport-specific sleep risk factors, including those relating to training, travel, and competition, in addition to non-sporting factors (Gupta et al., 2017). The impact of poor sleep on sport performance outcomes is equivocal and dependent on the type of task; for example, while gross physical and motor performance appears to be relatively robust to acute sleep loss, cognitively demanding sporting tasks might experience impairment (Kirschen et al., 2020). Furthermore, the downstream effects of poor sleep over extended periods could result in undesired outcomes such

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as poorer physiological recovery and increased injury risk, which may have implications for sport performance (Milewski et al., 2014). Therefore, a need exists to develop targeted sleep health interventions for athletes to improve sleep and mitigate against any negative performance outcomes such as closed-skill accuracy and reaction time (Jarraya et al., 2014; Mah et al., 2011).

While sleep regulation is primarily grounded in biological processes, there is a complex interaction with the social-environmental context that influences observed sleep practices (Grandner, 2017). Little evidence exists to indicate a higher prevalence of sleep disorders in athletes compared to the general population (Tuomilehto et al., 2017). Therefore, much athlete research has viewed sleep through a behavioral lens. This has included interventions designed to catalyze a personal transformation in sleep practices by implementing changes at the individual (e.g., personal beliefs), social (e.g., the workplace), and societal levels (e.g., public policy), rather than direct manipulation of biological sleep control such as light therapies or pharmacological sleep aids (Grandner, 2017; Halson, 2019). Behavioral sleep interventions across the wider population have adopted diverse approaches to improve sleep outcomes, but have demonstrated mixed effectiveness (Baron et al., 2021). Past systematic reviews evaluating sleep interventions in athletes have incorporated both behavioral and non-behavioral interventions within their scope, and provide preliminary evidence to support the use of both intervention types on outcomes including sport performance, mood, and recovery (Bonnar et al., 2018; Gwyther et al., 2022; Silva et al., 2021). However, the extent of changes in sleep outcomes in behavioral interventions, and the behavioral components driving the observed sleep changes remain unclear.

The complexity of behavioral interventions and the diverse terminology used when reporting intervention content have posed challenges in separating and pinpointing the specific behavioral components that drive behavioral change. In response, there has been a push to categorize intervention content into standardized components termed behavior change techniques (BCTs; Abraham & Michie, 2008). A BCT is considered to be the "active ingredient" of an intervention, constituting an observable, replicable, and irreducible element that aims to modify or redirect the causal processes governing behavior (Michie & Johnston, 2013; Michie et al., 2011). Drawing upon previous behavior change taxonomies, the Behavior Change Technique Taxonomy (BCTTv1) was developed following Delphi-type exercises by field experts as a comprehensive, hierarchically-structured classification system(Michie et al., 2013). The BCTTv1 consists of 93 non-overlapping and clearly defined BCTs, further grouped into 16 clusters. For example, within the grouping *"1. Goals and planning"* sits the BCT *"1.1 Goal setting (behavior)"*, which is defined as *"set or agree on a goal defined in terms of the behavior to be achieved"*.

While the adoption of the BCTTv1 is now increasingly common, the majority of studies incorporating behavior change within interventions do not utilize the BCTTv1 or other standardized nomenclature when describing behavioral intervention content. Nevertheless, the BCTTv1 allows retrospective coding of previously published research, facilitating meaningful comparisons between intervention components (Michie et al., 2013). The absence of integrated behavior change theory in previous athlete sleep research has been identified as a limitation of current literature, with no research assessing the long-term efficacy of specific BCTs within interventions (Halson, 2019). Consequently, there exists a need to systemize previous interventions using a standardized framework such as the BCTTv1. This would allow for assessment of the specific BCTs and frequency of use, enable comparisons between studies, and ascertain the most effective BCTs at improving sleep in athletes that should be incorporated into future research.

In light of the inherent limitations of previous reviews, the objectives of this scoping review were: (1) to identify and map the existing evidence of behavioral sleep interventions and their impact on sleep outcomes in athletes, and (2) retrospectively classify the BCTs employed in the identified interventions using the BCTTv1. A scoping review was identified as the most suitable synthesis approach to address these objectives, given the relative novelty of the research area and variations in intervention design. These factors necessitate the identification of available evidence types and an examination of the research methodologies employed (Munn et al., 2018).

Methods

Overview

This review was conducted in accordance with the JBI methodology for scoping reviews (Peters et al., 2020), and followed the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis Extension for Scoping Reviews(PRISMA-ScR; Tricco et al., 2018). The methodology outlined below was defined *a priori* and registered prospectively as a review protocol on the Open Science Framework on 24 March, 2023, and updated on 11 September, 2023 (DOI: 10.17605/OSF.IO/BFZWX).

Inclusion criteria

The review inclusion criteria were defined using the Population, Content, and Context framework (Peters et al., 2020), and are summarized in Table 1. A broad definition of sport was applied to encompass all physically demanding activities including non-traditional sports (e.g., mountaineering and dance). Inclusion based on performance level was defined using the framework outlined by McKay et al. (2022), with athletes participating in a sport at Tier 2 (Trained/Developmental) or above, encompassing ~12%–19% of the global population.

Due to challenges in accurately classifying performance levels from study manuscripts, studies were categorized into professional, student-athlete, or amateur groups. The exclusion of athletes aged <18 years and para-athletes was imposed due to the impact of age and certain disabilities on sleep regulation (Grade et al., 2023; Hagenauer et al., 2009). A broad definition of behavior was applied, constituting "anything a person does in response to internal or external events, that may be overt and directly measurable or covert and indirectly measurable, and are physical events that occur in the body and controlled by the brain" (Davis et al., 2015). Direct interventions where sleep schedules or targets are specified were included alongside indirect interventions (e.g., education), reflecting the approach used in a previous review by Baron et al. (2021). Studies solely published in English were included, as the translation from other languages into English could result in the inadvertent exclusion or misinterpretation of BCTs. No restrictions were placed on the publication date of studies to ensure the identification of a wide range of evidence.

Table 1. Study inclusion criteria using the population, concept, context framework.

Study Component	Inclusion	Exclusion
Population	Athletes currently engaged in sport at any level from trained/developmental to world class (Tier 2–5 of McKay et al. (2022) framework)* Mean age ≥18 years	Non-athlete population, para-athlete* Participants inclusion contingent on diagnosed sleep disorder at baseline
Concept	Prospective sleep intervention with ≥ 1 behavioral component Report ≥1 sleep outcome pre- and post-intervention, no restriction on type of outcome	Intervention including medication or pharmacological component Intervention including circadian realignment following travel between time zones Outcomes related to, but not directly assessing, sleep (e.g., daytime sleepiness or attention)
Context	No restriction on context or setting	
Types of sources	Experimental and quasi-experimental study designs	Descriptive observational study designs, qualitative studies, and text and opinion papers Systematic reviews, meta-analyses and other review types Any gray literature

*The McKay et al. (2022) framework was specified following the pilot exercise to allow retrospective classification of performance level using standardized definitions. The exclusion of studies with para-athletes were specified following the pilot exercise as certain disabilities can impact sleep regulation (Grade et al., 2023).

Search strategy

A systematic search strategy was employed to identify research articles, conference papers, and abstracts for inclusion. An initial limited search of MEDLINE (PubMed) was undertaken to identify relevant studies on the subject. Article text words and index terms from this preliminary search were used to develop a simple search strategy using Title/Abstract keywords: [(sleep*) AND (athlete* OR sport* OR athletic* OR player) AND (intervention OR hygiene OR education* OR behavior* OR behaviour* OR extension OR counseling OR optimization OR optimization OR workshop)] and restricted to the English language. MEDLINE (PubMed), EMBASE (Ovid), APA PsycInfo, and SCOPUS databases were searched, with the full search term for each database available in the appendix (Table S1). The initial literature search was run on March 21, 2023, and then rerun on September 6, 2023. Additionally, backward citation searching of the included studies was performed to identify any further relevant studies.

Study selection

Following the search, all identified studies were collated and imported to Rayyan online review software (Rayyan Systems Inc, Cambridge, MA, USA; Ouzzani et al., 2016). Duplicate studies were manually removed, and a pilot calibration exercise was performed with a random selection of 25 full-text studies screened by two reviewers in accordance with the JBI pilot framework to increase inter-reviewer consistency (Peters et al., 2020). The level of agreement between reviewers was almost perfect (agreement = 96.0%, Cohen's $\kappa = 0.83$; Landis & Koch, 1977). Adjustments to the inclusion criteria relating to performance level classification and studies including para-athletes were made at this stage (Table 1). Both reviewers then independently evaluated the titles, abstracts, and then the full texts of each study. Agreement between reviewers was substantial (agreement = 98.3%, Cohen's $\kappa = 0.61$; Landis & Koch, 1977). Disparities or disagreements were resolved through reviewer discussion.

Data extraction

Data from the included studies were extracted by the lead reviewer and verified by a second reviewer. The extracted data encompassed study aims, study format (e.g., journal article or abstract), study design, participant characteristics (country, sport, performance level, sample size, age, and gender), intervention components (e.g., any inclusion criteria, direct or indirect intervention, and any control groups), study duration, sleep outcomes, and key findings, and was documented in a data-charting form based on recommendations from the JBI scoping review methodology (Peters et al., 2020; Appendix Table S2). Authors of papers were contacted once to request any missing or supplementary data where required.

For the coding of behavioral intervention content, two reviewers who had completed prior online training (www.bct-taxonomy.com) independently performed the coding for the included studies. All 93 BCTs outlined in the BCTTv1 were considered for each study, with both reviewers explaining their rationale for assigning the BCT in each instance. Fourteen discrepancies (i.e., the BCT was only coded by one reviewer) were resolved through discussion; if a consensus could not be reached, the proposed BCT was not included.

Quality appraisal

Quality appraisal was conducted to support the study objective of mapping the available evidence by providing an assessment of the methodological quality and possibility of bias in each study to enable an understanding of the current strengths and limitations in this research area. Quality appraisals were conducted using the nine-question quasi-experimental, and thirteen-question randomised controlled trial JBI critical appraisal checklists corresponding to the study design employed (Tufanaru et al., 2020). No inclusion criteria were applied in relation to quality appraisal scores. Quality appraisal was not performed on conference abstracts. The level of agreement between the two independent reviewers was substantial (agreement = 83.5%, Cohen's $\kappa = 0.64$; Landis & Koch, 1977), with discrepancies resolved through discussion. Following quality appraisal, the overall score for each study was incorporated into data synthesis alongside the data extraction form and coded BCTs.

Results

The PRISMA flowchart highlighting the study selection process is presented in Figure 1. A total of 33 studies were identified, and are summarized in Table 2.

Study characteristics

The predominant study locations by region were Oceania ($n = 11$), Europe ($n = 9$), and North America ($n = 9$). Professional athletes were used in 17 studies, with 10 using student-athletes and six using amateur athletes (one unknown). Five studies encompassed participants from multiple sports, with rugby union ($n = 5$) and football ($n = 3$) the most prevalent sports in single-sport studies. Amongst the included studies, 19 used all-male participants, with five all-female and eight using mixed-gender samples. The collective participant count across studies was 892, with a median sample size of 21 (IQR: 15), and a median age of 23 (IQR: 4) where reported.

Study design

Studies were categorized into five groups for narrative synthesis based on similarities in extracted intervention characteristics before the coding of BCTs: education ($n = 11$), mind-body practices ($n = 5$), direct ($n = 7$), multi-component ($n = 7$), and other ($n = 3$). Pre-post study designs were utilized in 23 studies (single-group: $n = 21$, non-randomized parallel groups: $n = 2$), while ten studies utilized randomized designs (RCT: $n = 5$; randomized cross-over, $n = 4$; quasi-randomized trial, $n = 1$). Intervention durations spanned from acute one-day studies to multiple weeks. Assessment of sleep outcomes was typically performed during or immediately post-intervention, with only ten studies

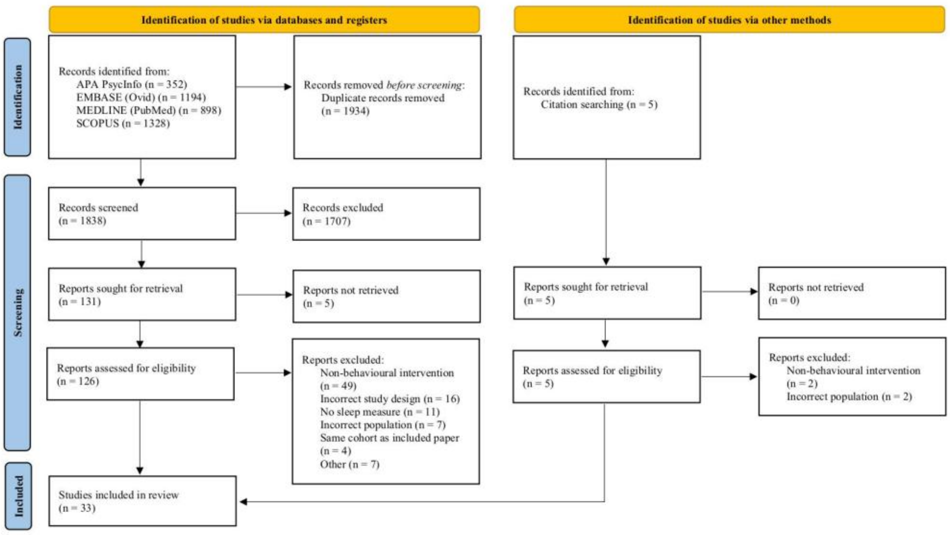

Figure 1. Search results and study selection and inclusion process (Page et al., 2021).

Table 2. Characteristics of included studies.

Study	Country, Sport, and Level	Intervention Components	Design and duration	Participant Characteristics	Sleep Parameters	Outcomes	QA	BCT Total
Education								
Caia et al. (2018)	Australia, rugby league, professional	Group education sessions (2×30-min) during competitive season. 50% with shortest TST assigned to INT. CON = no education sessions	Non-randomized parallel groups pre-post 14-d BL, 14-d INT, 14-d FU at 1-m post-INT	n: 24 age: 27 ± 4 (INT), 25 ± 3 (CON) gender: all M	Actigraphy: SE, SOL, SOT, TIB, TST, WUT,	↑ TIB (25-min), ↑ TST (20-min), advanced SOT (23-min) post-INT vs BL. ↑ TIB (51-min), delayed WUT (3-min), ↓ SE (4.2%) at FU vs BL.	5/9	3
Driller et al. (2019)	New Zealand, cricket, professional	Group education session (50-min), personalized feedback and recommendations from 1-to-1 consultation (30-min)	Single group pre-post 3-wk BL, 3-wk INT	n: 9 age: 23 ± 4 gender: all M	Actigraphy: SE, SOL, SOT, SOV, TIB, TST, WASO, WE, WED, WUT, WV Questionnaire: PSQI	↑ SE (5%), ↓ SOL (29-min), SOV (28-min), ↓ PSQI global (2-pt)	7/9	4
Dunican et al. (2021)	Australia, basketball, professional	Group education session (2-hr) during competitive season, and personalized feedback and recommendations from 1-to-1 consultation (20-min)	Single group pre-post (Athlete sub-study) 1-m BL, 1-m INT	n: 12 age: 25 ± 2 gender: all F	Actigraphy: SE, SOL, SOT, TIB, TST, WASO, WUT,	No significant findings	7/9	2
Dunican et al. (2023)	Australia, swimming, amateur	Group education session (2.5-hr) with recommendations during training programme	Single group pre-post 7-wk BL, 7-wk INT	n: 24 age: 39 ± 11 gender: 54% F	Actigraphy: FI, SE, SOL, SOT, TIB, TST, WASO, WUT	Delayed SOT and WUT (both 12-min)	7/9	2
Harada et al. (2016)	Japan, football, student-athlete	Educational leaflet with 8 sleep hygiene recommendations	Single group pre-post 1-m INT, FU at 3-m post-INT	n: 84 age: 18–22 gender: all M	Questionnaire: Undefined sleep quality questionnaire	↑ sleep quality at FU vs pre-INT	7/9	1

(*Continued*)

Table 2. (Continued).

Study	Country, Sport, and Level	Intervention Components	Design and duration	Participant Characteristics	Sleep Parameters	Outcomes	QA	BCT Total
Jenkins et al. (2021)	UK, rugby union, professional	Group education session (30-min) during competitive season and daily actigraphy feedback	Single group pre-post 3-wk BL, 3-wk INT, 2-wk FU	n: 14 age: 24 ± 4 gender: all M	Actigraphy: SE, sleep quality (1–10 derived from actigraph), SOL, SOT, SOV, TST, TIB, WASO, WE, WED, WUT, WV	No significant findings	7/9	3
Kaier et al. (2016)	USA, multiple, student-athlete	Group workshop: education, simulated sleep deprivation, brainstorming, recommendations	Single group pre-post BL, 1-d INT, FU within 14-d (FU1) and 3-to-4-m (FU2) post-INT	n: 104 age: 19 ± 2 gender: 69% F	Questionnaire: PSQI, SHI	No significant findings	6/9	6
O'Donnell and Driller (2017)	New Zealand, netball, professional	Group sleep hygiene education (50-min) with recommendations and daily reminders	Single group pre-post 1-wk BL, 1-wk INT	n: 26 age: 23 ± 6 gender: all F	Actigraphy: SE, SOL, SOT, SOV, TIB, TST, WE, WED, WUT, WV	↑ TST (22-min), ↓ WED (3-min), ↓ WV (21-min)	8/9	3
Sargent et al. (2021)	Australia, cricket, professional	Group workshop: feedback, education, individual target setting, encouraged to nap CON = no workshop	Randomised control trial 1-wk BL, 1-wk INT	n: 15 age: 22 ± 2 (INT), 26 ± 4 (CON) gender: all M	Actigraphy: SE, SOL, SOT, TIB, TIB (incl. naps), TST, TST (incl. naps), WUT,	↑ TIB (42-min) and ↑ TST (36-min) (both incl. naps) in INT. ↓ TIB (incl. naps; 24-min) in CON	8/13	5
Van Ryswyk et al. (2017)	Australia, Australian football, professional	Group education sessions (2 × 1-hr) with written and verbal information. Weekly group feedback and optional individual consultation. Additional individual	Single group pre-post 6-wk INT	n: 25 age: 23 ± 2 gender: all M	Actigraphy: TIB, TST (incl. naps), SE, SOL, WASO Sleep diary: SE, TIB, TST (incl. naps) Questionnaire: PSQI	↑ sleep diary TST (incl. naps; 20-min) and sleep diary SE (2%)	4/9	3

(Continued)

Table 2. (Continued).

Study	Country, Sport, and Level	Intervention Components	Design and duration	Participant Characteristics	Sleep Parameters	Outcomes	QA	BCT Total
		feedback if < 7-hr self-report sleep duration						
Vitale et al. (2019)	Italy, football, amateur	Group education session (45-min) with recommendations following evening training. CON: no session	Randomised control trial 2-d BL, 1-d INT, 1-d FU	n: 29 age: 26 ± 6 (INT), 25 ± 7 (CON) gender: all M	Actigraphy: FI, SE, SOL, SOT, TST, WASO, WUT Questionnaire: sleep quality (0–10 Likert scale)	Group x time interactions: ↓ SOL, ↑ sleep quality	10/13	2
Mind-body practices								
Chen et al. (2018)	Taiwan, baseball, amateur	Mindfulness training protocol (4 × 2.5 to 3-hr sessions) including breathing, yoga, and meditation	Single group pre-post 28-d INT, FU at 28-d post-INT	n: 21 age: 26 ± 3 gender: all M	Questionnaire: PSQI (Chinese version)	↓ PSQI (Chinese version) global (0.9-pt) at FU vs pre-INT	7/9	1
Datta et al. (2022)	India, multiple, unknown	Yoga nidra or progressive muscle relaxation training protocol (3–4 × supervised sessions, daily self-led practice). Individual sleep education session pre-protocol	Randomised control trial 14-d BL, 28-d INT, 14-d FU	n: 45 age: 21 ± 4 gender: all M	Actigraphy + EEG module (n = 20):SE, sleep stages (S1-S3), SOL, TIB, TST, WASO Sleep diary:SE, sleep quality (undefined), SOL, TIB, TST, WASO	Actigraphy: ↓ SOL (26-min) and ↓ TIB (31-min) at FU vs BL Sleep diary: ↑ SE, ↑ TIB, ↓ SOL in yoga nidra vs progressive muscle relaxation at FU vs BL	6/13	5
Jones et al. (2020)	USA, rowing, student-athlete	Mindfulness-based stress reduction protocol (8 × 75-min supervised sessions, self-practice). CON: no protocol	Quasi-randomized control trial 3-to-7-d BL, 56-d INT, 7-d FU at 42-d post-INT	n: 27 age: 18–23 gender: all F	Actigraphy:SE, TST, WASO Questionnaire: PSQI	↑ SE in INT and ↓ SE in CON at FU vs BL, ↓ PSQI global (group x time interaction) at FU vs BL	7/13	3
L. J. McCloughan et al. (2016)[3]	Australia, dance, student-athlete	Daily self-led progressive muscle relaxation (8.5-min audio). Analysis split by	Single group pre-post 7-d BL, 7-d INT	n: 12 age: 20 ± 1 gender: all F	Actigraphy:SE, SOL, SOT, TIB, TST, WASO, WUT, Questionnaire: sleep quality (1–5 Likert scale)	↓ SOL (4-min) in high SOL/high trait social evaluation anxiety group, ↑ sleep quality (0.2 units) in high SOL/high trait social evaluation anxiety group	7/9	4

(*Continued*)

Table 2. (Continued).

Study	Country, Sport, and Level	Intervention Components	Design and duration	Participant Characteristics	Sleep Parameters	Outcomes	QA	BCT Total
		SOL and trait anxiety at BL						
Rijken et al. (2016)	Netherlands, multiple, professional	Mental coaching protocol (4 × 2.5 hr sessions) including stress awareness, breathing techniques, and mindfulness. Additional heart rate variability feedback training using app (INT1) or alpha power feedback using EEG system (INT2)	Non-randomized parallel groups pre-post 35-d INT, FU at 42-d post-INT	n = 21 age: 21–32 (INT1), 16–38 (INT2) gender: all M (INT1), 80% M (INT2)	Questionnaire: PSQI	No significant findings	7/9	1
Direct								
O. A. Famodu et al. (2017)[#] [2]	USA, athletics, student-athlete	Target increase in TIB of 1-hr above individual baseline	Single group pre-post 7-d BL, 7-d INT	n: 21 age: 20 ± 2 gender: all F	Actigraphy: TST	↑ TST (22-min)	–	1
Leduc et al. (2022)	UK, rugby union, student-athlete	Target 10 hr TIB after evening training session at the expense of a recovery session the following morning. CON: no sleep extension, attended recovery session	Randomised cross-over 2-d BL, 1-d INT, 2-d FU, 48-hr washout	n: 10 age: 21 ± 1 gender: all M	Actigraphy: FI, SE, SOL, SOT, WUT, TIB, TST, WASO	Delayed WUT (3.5-hr), ↑ TIB (3.3-hr), ↑ TST (2.5 hr), ↑ WASO(3-min) in INT vs CON	11/13	2
Mah et al. (2011)	USA, basketball, student-athlete	Target 10 hr TIB	Single group pre-post 14-to-28-d BL, 35-to-49-d INT	n: 11 age: 19 ± 1 gender: all M	Actigraphy: TST Sleep diary: napping, TIB, TST, WASO, WUT	Actigraphy: ↑ TST (1.8-hr) Sleep diary: ↑ TST (2.6-hr)	7/9	1
Mah et al. (2017)[#]	USA, baseball, professional	Target 10 hr TIB. CON: maintain habitual sleep	Randomised control trial 2-d BL, 5-d INT	n: 17 age: - gender: all M	Actigraphy: TST Sleep diary: TST	Actigraphy: ↑ TST (0.6-hr) Sleep diary: ↑ TST (1.2-hr)	–	1
							7/13	1

(*Continued*)

Table 2. (Continued).

Study	Country, Sport, and Level	Intervention Components	Design and duration	Participant Characteristics	Sleep Parameters	Outcomes	QA	BCT Total
Roberts et al. (2019)[4]	Australia, cycling, amateur	Target 30% extension of TIB, with SOT and WUT tailored to chronotype. CON: maintain habitual sleep (additional 30% restriction of TIB condition present but not reported)	Randomised cross-over 3-d INT, >1-wk washout	n: 9 age: 30 ± 6 gender: all M	Actigraphy: SE, TST Questionnaire: sleep quality (1–5 Likert scale)	↑ TST on all nights (1.3–1.8 hr), ↓ SE on night 2 and 3 (3–4%) in INT vs CON, ↓ sleep quality on night 3 (0.6-units) in INT vs CON		
Schwartz and Simon (2015)	USA, tennis, student-athlete	Target 9 hr sleep duration including naps	Single group pre-post 1-wk BL, 1-wk INT	n: 12 age: 18–22 gender: 58% F	Sleep diary: napping, SOT, TST, WUT,	↑ TST (1.7-hr)	6/9	1
Swinbourne et al. (2018)	New Zealand, rugby union, professional	Target 10 hr TIB, and sleep education (format and duration unclear)	Single group pre-post 3-wk BL, 3-wk INT	n: 25 age: 25 ± 3 gender: all M	Actigraphy:SE, SOL, TIB, TST, WASO Questionnaire: PSQI	↑ TST (1-hr), ↓ PSQI global (1.9-pt)	6/9	2
Multi-component								
Charest et al. (2017) #	Canada, speed skating, professional	Daily napping, increased target TIB, sleep hygiene routine including electronic device removal and blue light glasses	Single group pre-post 2-wk INT	n: 7 age: 24 ± 4 gender: 57% M	Sleep diary: sleep satisfaction, SOL, TST, WE Questionnaire: ASSQ	↑ TST, ↓ SOL, ↑ sleep satisfaction, ↓ ASSQ sleep difficulty score	–	0
de Mello et al. (2020)	Brazil, swimming, professional	Daily light therapy (30-min) and sleep hygiene recommendations during competition period	Single group pre-post 10-d INT	n: 14 age: 27 ± 2 gender: 71% M	Actigraphy: TST, SE, SOL, WE	↑ TST (51-min)	4/9	1
Duffield et al. (2014)	Australia, tennis, professional	Acute cold water immersion, compression garments and sleep hygiene	Randomised cross-over 1-d INT, >1-d washout	n: 8 age: 21 ± 4 gender: all M	Actigraphy: SE, SOL, TIB, TST	No significant findings (Large ES for ↑ TST and ↑ TIB in INT vs CON)	7/13	1

(*Continued*)

Table 2. (Continued).

Study	Country, Sport, and Level	Intervention Components	Design and duration	Participant Characteristics	Sleep Parameters	Outcomes	QA	BCT Total
		recommendations following high physical loading. CON = 15-min stretching post-session						
Fullagar et al. (2016)	Germany, football, amateur	Acute environmental changes, electronics curfew, and set time in bedroom/lights out post-match. CON = usual post-match routine, time in bedroom delayed	Randomised cross-over 1-d BL, 1-d INT, 7-d washout	n: 20 age: - gender: all M	Actigraphy:napping,SOL, SOT, TST, WE, WED, WUT	↑ TST (1.7-hr) post-match and ↑ WE (4.6 episodes) in INT vs CON	8/13	1
Grandner et al. (2017)[# 1]	USA, Unknown, student-athlete	Initial sleep education session (1.5-hr), sleep/fitness tracking, text reminders, peer and researcher support	Single group pre-post 10-wk INT	n: 35 age: - gender: -	Questionnaire: PSQI (and PSQI-derived SOL, SOT, TST, WUT)	↓ PSQI global (1.3-pt), ↓ SOL (12-min), advanced WUT (32-min)	–	5
Vachon et al. (2022)	France, rugby union, professional (U21)	Sleep education, relaxation strategies, mattress change, foam rolling, and cold water immersion during training taper.	Single group pre-post 3-wk BL, 7-d INT	n: 18 age: 19 ± 1 gender: all M	Questionnaire: PSQI	↓ PSQI global (1.3-pt) with greatest ↓ in participants classified as functional overreaching training status	6/9	4
Vachon et al. (2023)	France, rugby union, professional (U21)	Group education sessions (2 × 1.5-hr) and mind-body practice sessions (3 × 45-to -60-min) including hypnosis, progressive	Single group pre-post 4-wk INT, 4-wk BL	n: 11 age: 19 ± 1 gender: all M	Actigraphy: SE, SOL, SOT, TIB, TST, WASO, WE	↓ SOL and ↑ SE at BL vs pre-INT	4/9	5

(Continued)

Table 2. (Continued).

Study	Country, Sport, and Level	Intervention Components	Design and duration	Participant Characteristics	Sleep Parameters	Outcomes	QA	BCT Total
		muscle relaxation, and paradoxical interventions						
Other								
Bender et al. (2018)	Canada, multiple, professional	Standardised clinical sleep interview, follow-up interview if classed as moderate/ severe sleep difficulty, general recommendations (sleep education sheet) and individualized treatment (e.g., travel/jet-lag management, CBT-Insomnia program, light therapy)	Randomised single-group pre-post (Clinical validation sub-study) 1-d BL, INT duration variable, FU at ~ 151-d post-INT start	n: 44 age: 24 ± 4 gender: 62% F (age and gender from full study, *n* = 199)	Questionnaire: ASSQ	↓ ASSQ sleep difficulty score (1.5-pt) at FU vs pre-INT, greatest ↓ in participants with greater sleep difficulty at BL	5/9	2
Jakowski and Stork (2022)	Germany, multiple, student-athlete	Downloaded either Sleep Score (INT1) or Sleep Cycle (INT2) app, used sleep tracking and reports in week 1 then added smart alarm in week 2 alongside sleep diary. CON1: no INT, CON2: sleep diary only.	Randomised control trial 2-wk INT	n: 98 age: 21 ± 2 gender: 62% F	Sleep diary: SE,SOL, SOT, TIB, TST, WE, WED, WUT Questionnaire: PSQI	No significant findings	7/13	1
Tuomilehto et al. (2017)	Finland, ice hockey, professional	Group education session (2-hr). If potential sleep disorder at BL (*n* = 14), additional polysomnography	Single group pre-post (sub-study) INT duration variable, FU at 12-m post-INT start	n: 40 age: 17–40 (from main study, *n* = 109) gender: all M	Questionnaire: sleep quality (1–10 Likert scale)	↑ sleep quality (0.6-units) at FU with greatest ↑ in those with lower BL sleep quality	5/9	2

(*Continued*)

Table 2. (Continued).

Study	Country, Sport, and Level	Intervention Components	Design and duration	Participant Characteristics	Sleep Parameters	Outcomes	QA	BCT Total
		assessment and individual treatment plan (e.g., typical treatment for clinical insomnia or sleep disordered breathing)						

#Presented as an abstract.
Additional studies identified presenting the same research: [1]Alfonso-Miller et al. (2017) and Athey et al. (2017); [2]O. Famodu et al. (2014); [3]L. McCloughan et al. (2014); [4] Roberts et al. (2022)
Duration abbreviations: BL: baseline; CON: control; FU: follow-up; INT: Intervention.
Measure abbreviations: ASSQ: Athlete Sleep Screening Questionnaire; FI: fragmentation index;; PSQI: Pittsburgh Sleep Quality Index; SE: sleep efficiency; SOL: sleep onset latency; SOT: sleep onset time; SOV: sleep onset variance; TIB: time in bed; TST: total sleep time; WASO: wake after sleep onset; WE: wake episodes; WV: wake variance; WUT: wake up time.

conducting a follow-up ≥ 7-d post-intervention. Sleep outcomes were evaluated using actigraphy ($n = 21$), questionnaires ($n = 15$), and sleep diaries ($n = 7$), with 11 studies utilizing two or more assessment methods.

Behavior change techniques

Across the 33 studies, a total of 18 distinct BCTs were identified, occurring in 79 separate instances. The most frequently employed BCTs were " 4.1 *Instruction on how to perform a behavior*" (20), *"9.1 Credible source"* (12), and *"1.1 Goal setting (behavior)"* (9). When categorized into the 16 BCT groupings, 12 groupings were identified on at least one instance (Figure 2). Four BCT groupings were not found in any study: *"6. Comparison of behavior"*, *"14. Scheduled consequences"*, *"15. Self-belief"*, and *"16. Covert learning"*. A comprehensive breakdown of the coded BCTs for each intervention and their definitions can be found in Appendix Tables S3 and S4.

Narrative synthesis

Educational

Twelve studies were categorized as educational studies and were primarily focused on the change in sleep behaviors through the dissemination of sleep-related knowledge. Except for Harada et al. (2016), where educational information was conveyed through a text-based information leaflet, all other studies delivered education via one or more group sessions, ranging in duration from 30 to 150 minutes. In four studies, this was complemented by the delivery of an individual session and/or feedback (Driller et al., 2019; Dunican et al., 2021; Jenkins et al., 2021; Van Ryswyk et al., 2017). Eight educational studies demonstrated at least one favorable change in sleep outcomes, while three revealed no significant findings (Dunican et al., 2021; Jenkins et al., 2021; Kaier et al., 2016), and one solely demonstrated a phase delay in sleep timing (Dunican et al., 2023). Notable outcomes included significant improvements in actigraphy-derived total sleep time ranging between 20–36 minutes

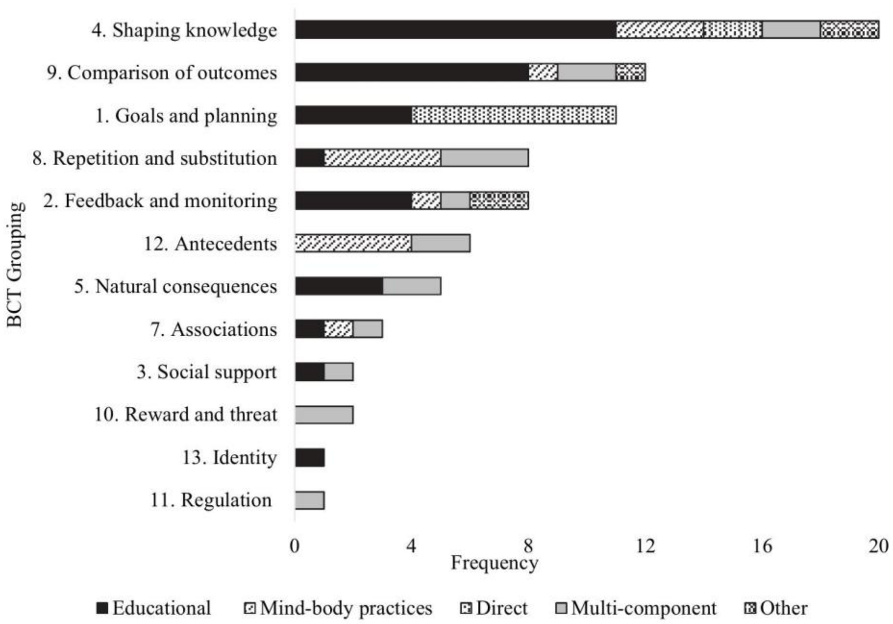

Figure 2. Frequency of coded BCTs by BCT grouping and split by intervention category.

(Caia et al., 2018; O'Donnell & Driller, 2017; Sargent et al., 2021) and improvements in subjective measures of sleep quality (Driller et al., 2019; Harada et al., 2016; Vitale et al., 2019). The only unfavorable outcome observed was a lower sleep efficiency at the one-month follow-up in the study by Caia et al. (2018).

Educational studies exhibited the highest frequency of BCT usage (mean: 3 ± 1), and also displayed the greatest heterogeneity in content, encompassing nine BCT groupings across the studies. The BCT *"4.1 Instruction on how to perform a behavior"* was present in all studies due to the nature of education delivery. Additionally, the utilization of sleep experts and healthcare professionals to deliver education sessions resulted in the inclusion of the BCT *"9.1 Credible source"* in eight educational studies.

Mind-body practices

Five studies were categorized as mind-body practices, where a holistic approach was taken to improve health outcomes through relaxation and mental awareness. These interventions encompass practices including yoga, progressive muscle relaxation, mindfulness, and breathing techniques. Amongst the five studies, three incorporated multiple mind-body practices within the delivered intervention, with two of them demonstrating some favorable changes in sleep outcomes (Chen et al., 2018; Jones et al., 2020) and one showing no change (Rijken et al., 2016). While a comparison between different mind-body practices was not feasible, a comparative study suggested that yoga may yield more favorable changes to sleep outcomes than progressive muscle relaxation (Datta et al., 2022).

The mean number of BCTs used in mind-body practice studies was 3 ± 2. The BCTs *"12.6 Body changes"* and "*8.1 Repetition and Substitution"* were each identified in four of the five studies, reflecting the impact of mind-body practices on body awareness and the repeated performance of the practice. Additionally, the BCT *"4.1 Instruction on how to perform a behavior"* was present in three mind-body practice studies.

Direct

The seven direct studies sought to increase sleep duration above baseline values by establishing a goal to increase sleep by a specific amount or toward a predefined target. This typically occurred as part of an intervention where the change in sleep duration served as an independent variable to assess the effect on a non-sleep dependent variable (e.g., sport performance). In all studies, either actigraphy-derived total sleep time or self-reported sleep duration was increased. However, in each study, the increase fell short of the predetermined goal. An unintended outcome of increased sleep duration can be a corresponding reduction in sleep efficiency, as was observed by Roberts et al. (2019). Only one study augmented a direct intervention with a non-direct behavioral intervention component, where the addition of sleep hygiene education demonstrated improvements in self-reported sleep quality and an increase in actigraphy-derived total sleep time (Swinbourne et al., 2018).

Direct studies exhibited the lowest frequency of BCT usage (mean: 1 ± 0). Furthermore, the BCTs used were the most homogenous; *"1.1 Goal setting (behavior)"* was present in all the direct studies due to the inherent goal-setting aspect, while *"4.1 Instruction on how to perform a behavior"* was the only other BCT identified, appearing in two instances.

Multi-component

Seven studies integrated two or more distinct components within the delivered intervention. In five studies, behavioral components such as education or sleep hygiene strategies were integrated to support the utilization of non-behavioral components including light therapies, cold water immersion, and environmental modifications (Charest et al., 2017; de Mello et al., 2020; Duffield et al., 2014; Fullagar et al., 2016; Vachon et al., 2022). The remaining two studies included the amalgamation of education and mind-body practices (Vachon et al., 2023), and a cluster of behavioral components including education, tracking, and social support (Grandner et al., 2017). All studies exhibited a significant change in one or more assessed sleep outcome with the exception of Duffield et al. (2014), where large effect sizes were demonstrated within a limited sample size.

The mean number of BCTs utilized per study was 2 ± 2, yet a distinct division was apparent. Three studies featured four or five BCTs present, spanning a diverse range of nine BCT groupings (Grandner et al., 2017; Vachon et al., 2022, 2023). Conversely, the remaining four studies either employed *"8.1 Behavioral practice/substitution"* as the sole BCT, or in the case of Charest et al. (2017), no BCTs were identified.

Other

Three studies did not align with the previously discussed categories. In Bender et al. (2018) and Tuomilehto et al. (2017), the intervention components delivered were contingent on a sleep assessment performed at baseline and thus varied in content and duration between participants. Both studies featured 2 BCTs, though the use of the BCTTv1 framework was limited to the intervention components delivered to all participants. Jakowski and Stork (2022) employed a combination of app feedback and smart alarms using the BCT *"2.2 Feedback on behavior"*, yet no significant changes in sleep outcomes were observed.

Quality appraisal

Twenty studies underwent appraisal using the nine-item assessment tool for quasi-experimental studies, yielding a mean study score of 6 ± 1. The poorest scored items pertained to the inclusion of a control group (Q4, 1/20 studies) and appropriate statistical analysis (Q9, 8/20 studies). Nine studies were assessed using the 13-item appraisal tool for randomized controlled trials, producing a mean study score of 8 ± 2. The poorest scored items concerned insufficient blinding of participants (Q4) and researchers (Q5) to treatment allocation (both 1/9 studies). A comprehensive breakdown of the quality appraisal scores for each study is presented in Appendix Tables S5 and S6.

Discussion

The objectives of this scoping review were to identify and map the existing body of evidence on behavioral sleep interventions in athletes and their effect on sleep outcomes, and retrospectively code the BCTs employed in identified interventions using the BCTTv1 framework. This review identified a total of 33 studies, all published within the last decade, reflecting the burgeoning interest in athlete sleep. Diverse behavioral strategies were employed within the included interventions, coalescing into five categories: educational, mind-body practices, direct, multi-component, and other. These categories exhibited distinctions concerning the individual BCTs used and the frequency of usage. However, only 18 of the 93 BCTs specified in the BCTTv1 were identified across the 33 studies. This finding indicates there are alternative behavioral strategies that remain currently unexplored within athletes that could potentially prove effective in instigating favorable changes in sleep outcomes.

The sleep outcomes extracted from the included studies indicate that each category of behavioral intervention can be effective at improving sleep outcomes. This reaffirms the viability of behavioral interventions to improve athlete sleep indicated in previous reviews (Bonnar et al., 2018; Gwyther et al., 2022; Silva et al., 2021). However, there are important considerations beyond changes in sleep outcomes for each intervention category that should be noted. Direct interventions exhibited the most notable changes in sleep outcomes, with multiple studies achieving an increase in total sleep time exceeding an hour. Yet, the application of a direct intervention outside a controlled intervention poses challenges when the wider impact of the social-environmental context on sleep is considered (Grandner, 2017). For instance, sport-related factors impinge the ability to increase sleep opportunity, such as that noted by Mah et al. (2011) where travel schedules impaired the ability to maintain a consistent sleep-wake pattern. Educational interventions emerged as the most prevalent intervention type. A recent consensus statement advocates the use of sleep education multiple times a year as a first-line tool to improve sleep in athletes, irrespective of baseline sleep characteristics (Walsh et al., 2020). However, concerns over the long-term efficacy of sleep education as a standalone tool have been raised (Halson, 2019), and were exemplified in the study by Caia et al. (2018) where improvements in sleep outcomes were not maintained post-intervention. This observation aligns with the core components of the COM-B behavior change model (Michie et al., 2011), as while education can bolster psychological capability, it is unable to overcome deficits in opportunity or automatic motivation that may prevent sleep behavior change. Therefore, the inclusion of education as part of a multi-component intervention may be more prudent. Mind-body practices and multi-component interventions demonstrated efficacy at changing sleep outcomes, however quantifying the contribution of behavioral driven changes poses certain challenges for both categories. In mind-body practices, behavioral changes are inherently intertwined with bodily changes. Furthermore, the purpose of these interventions is not solely to change sleep behavior, but to enhance holistic health. This is highlighted by the inclusion of sleep as one of multiple health outcomes assessed in several studies (Chen et al., 2018; Jones et al., 2020; Rijken et al., 2016). Similarly, in multi-component interventions, dissecting the effect of each component is complex in the absence of a comparison condition, where a single component is delivered in isolation. Lastly, while studies involving individually tailored studies are highly applicable to real-world practice (Bender et al., 2018; Tuomilehto et al., 2017), the level of detail provided in a journal article format restricts the evaluation of behavioral components only delivered to select participants.

While the biological regulation of sleep introduces a layer of complexity to the implementation of behavior change theory within sleep health interventions when compared to more traditional health intervention targets like physical activity, many facets of sleep remain under behavioral control (Mead & Irish, 2020). This study aligns with previous reviews that view sleep through a behavioral lens and have applied the BCTTv1 framework to specify the BCTs employed within sleep interventions across diverse populations.The average use of BCTs within the journal articles included in this review (mean: 2.7) is notably higher than a previous review on sleep extension interventions for ages ≥ 12 (mean: 1.8; Baron et al., 2021), yet falls short of those found in a review focused on interventions in emergent adults aged 18–29 (mean: 4.25; Pegado et al., 2023). The diversity of BCT groupings used in this review (12 out of 16 BCT groupings) sits above the eight BCT groupings identified by Baron et al. (2021) and the 11 groupings identified by Pegado et al. (2023), however, the latter was observed across only eight studies. This suggests there is scope to incorporate more BCTs within future behavioral sleep interventions tailored toward athletes, with specific literature gaps evident. For instance, the group sessions performed in all but one educational intervention could provide a "blank canvas" to incorporate multiple BCTs beyond the scope of education delivery. This was demonstrated in two studies that incorporated five and six unique BCTs into a multifaceted workshop format (Kaier et al., 2016; Sargent et al., 2021). The incorporation of multiple BCTs has been shown to improve the extent of increases in total sleep times, but conversely, interventions with a large number of curriculum components showed smaller increases in TST compared to those with fewer curriculum components (Baron et al., 2021). Hence, ensuring workshops are designed to be concise but targeted and impactful regarding BCT implementation is an important consideration, and provides an avenue to enhance the efficacy of future interventions. Table 3 highlights examples of such BCTs that were not identified in any studies within this review, but could be incorporated into a workshop format.

While the rationale behind the inclusion of specific BCTs within studies cannot be determined through retrospective coding, the justification for intervention design lacks clarity, and in certain instances, empirical substantiation. The mixed efficacy of sleep health interventions has been in part attributed to the absence of behavior theory as a foundation for intervention design (Mead & Irish, 2020), while health interventions that embed behavior change theory within development tend to demonstrate more consistently positive outcomes (Glanz & Bishop, 2010). As an illustration, the integration of the BCT *"4.1 Instruction on how to perform a behavior"* within an educational sleep intervention would be strengthened by prior evidence demonstrating that the targeted athletes possess insufficient knowledge regarding sleep behaviors. Various behavioral theories can be applied to sleep health research (Mead & Irish, 2020). The use of the BCTTv1 taxonomy in conjunction with the COM-B behavioral

Table 3. Example BCTs for integration into group sessions.

BCT Grouping and BCT	Definition	Example
Shaping knowledge 4.3 Re-attribution	Elicit perceived causes of behavior andsuggest alternative explanations (e.g.external or internal and stable or unstable)	Ask athletes to reflect on what they believe drives their current sleep behaviors (e.g. lack of time) and offer alternatives to consider and reflect upon (e.g., electronics use before bed)
Natural consequences 5.6 Information about emotional consequences	Provide information (e.g. written, verbal, visual) about emotional consequences of performing the behavior	During a group session, shift the focus away from sport and highlight the relationships with sleep, mental wellbeing, and mood outcomes
Comparison of behavior 6.3 Information about others' approval	Provide information about what other people think about the behavior. The information clarifies whether others will like, approve or disapprove of what the person is doing or will do	Collate information from coaches and sport practitioners on how they value sleep as a recovery modality to share with athletes
Comparison of outcomes 9.2 Pros and cons	Advise the person to identify and compare reasons for wanting (pros) and not wanting to (cons) change the behavior (includes "Decisional balance")	Have athletes come up with and discuss the pros and cons of their current sleep practices
Self-belief 15.3 Focus on past success	Advise to think about or list previous successes in performing the behavior (orparts of it)	Ask athletes to reflect on a time that they engaged with healthy sleep practices, and the downstream effects they experienced when doing so

BCT definitions from Michie et al. (2013).

model provides a potential avenue to bridge the existing gap between a behavioral diagnosis and intervention development (Michie et al., 2011). The COM-B can be used to identify which of the core components of capability, opportunity, and motivation are underpinning the undesired behavior, and can then be mapped onto the BCTTv1 such that only relevant BCTs are incorporated within a precisely targeted intervention (Michie et al., 2013). There exists a plausible rationale for any combination of the COM-B components to underpin desired and undesired sleep behaviors in athletes, and likely differ contingent on the unique attributes of the athlete group being addressed, such as age, sex, and performance level amongst other variables. This underscores the need to specify the problem in behavioral terms before attempting to resolve it.

The quality appraisal conducted on the included studies showed that study quality was generally satisfactory, but highlighted some limitations within the current literature. The inclusion of control conditions within quasi-experimental study designs is undoubtedly challenging, with methodological constraints including participant availability and the cost and availability of measurement tools. Nevertheless, with various sport-related and non-sport-related factors acting as extraneous variables that can influence observed sleep outcomes (e.g., Astridge et al., 2021), control conditions should be implemented where possible to ensure changes can be attributed to the intervention and enhance the robustness of findings. Furthermore, the lack of blinding of both participants and researchers surfaced as a limitation in randomized controlled trials. This is a common issue within applied behavioral research, however, recommendations such as the use of an additional unblinded research coordinator can minimize bias (Friedberg et al., 2010).

A component of quality appraisal not evaluated by the JBI assessment tools is the pre-registration of studies. No studies referenced pre-registration within the manuscript, and a search of Open Science Framework and PubPsych online repositories returned only a handful of studies included in this review (Jakowski & Stork, 2022; Jones et al., 2020; Rijken et al., 2016; Schwartz & Simon, 2015). Furthermore, some studies omitted the *a priori* outcomes and/or definitions of extracted sleep outcomes within the methods section. In the future, behavioral sleep interventions in athletes should preregister studies in a public repository to increase transparency and confidence in findings (Hardwicke & Wagenmakers, 2023).

Limitations

An important limitation of this scoping review is that, whilst the coding of BCTs was facilitated by the BCTTv1, there remains a subjective element contingent upon the philosophical standpoint of the coders. The coders in this review adopted a more liberal approach to BCT coding, and as such identified a slightly greater number of BCTs in several studies that were also included in a previous review (Baron et al., 2021). This process is further complicated by the restrictive word count imposed upon most journal articles, which often prevents the inclusion of comprehensive methodological details, and in turn, creates ambiguity regarding the application of specific BCTs. Two key strategies can be incorporated into future research to overcome this limitation: (1) the publication of study intervention manuals as an appendix or in an open repository, and (2) the employment of standardized terminologies, such as those defined within the BCTTv1 when describing behavioral components within an intervention.

There also exist limitations related to the search parameters employed in this review, most notably related to age. Although this restriction was applied in response to the differences in biological sleep regulation during childhood and adolescence (Hagenauer et al., 2009), it is noteworthy that recent research has employed behavioral sleep interventions within athletes in this age group, and contain BCTs that could apply to adult athletes and warrant further exploration (e.g., Aben et al., 2023; Edinborough et al., 2023; Lever et al., 2021). Finally, there are inherent methodological limitations concerning the search strategy employed. These include the non-consideration of gray literature and unpublished studies, the reliance on only five databases for literature searching, and the inclusion of English-only studies. While these choices were pragmatic, they may have resulted in the inadvertent exclusion of relevant studies.

Conclusion and future directions

To summarize, this scoping review sheds light on the wide range of behavioral sleep interventions that have been performed in athlete populations within the last decade. The identified intervention categories – educational, mind-body practices, direct, multi-component, and other – differed concerning the prevalence and diversity of BCTs implemented. While each category contained studies demonstrating some favorable changes to sleep outcomes, there was no clear study type or BCT that showed consistent changes. Furthermore, the limited range of BCTs used would indicate that there are alternative behavioral components that have yet to be examined in athletes. The included studies appear to exhibit an insufficient integration of behavior change theory during intervention development, which could partially explain the mixed effectiveness observed concerning sleep outcomes. Moving forward, future studies should prioritize the completion of a behavioral diagnosis before intervention development that is specific to the athlete cohort the intervention is targeting. Furthermore, any behavioral components incorporated into interventions should be specified using standardized terminology, such as those outlined in the BCTTv1. This would facilitate more effective cross-study comparisons, and pave the way for a future meta-analysis that could identify the most potent BCTs for driving sleep behavior change in athlete populations.

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SMBW acted as the reviewer at each stage and wrote the review. KVS acted as a reviewer for screening and study selection. JKP acted as a reviewer for quality appraisal and data extraction. AC acted as a reviewer for the coding of behavior change techniques. SBD, MIJ, and JKP were involved in the direction and revision of the manuscript. All authors read and approved the final manuscript.

Data availability statement

Data supporting the findings of this study are available within the article and its supplementary materials.

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Appendix 2. Application for ethical approval (ETHICS2022-10)

This appendix has been removed as it contains personal information

Appendix 3. Research data management plan (ETHICS 2022-10)

This appendix has been removed as it contains personal information

Appendix 4. Risk assessment (ETHICS2022-10)

HARTPURY RISK ASSESSMENT

ACTIVITY / PROCESS ASSESSED: ………Research Study……………… DATE: ………07/11/2022…………

DEPARTMENT: ………Sport…………… ASSESSORS: ………………Alexander Wilson………………..

HAZARD	AT RISK	CONTROLS	RISK RATING	OTHER PRECAUTIONS
Risk of eye strain	Researcher	Regular scheduled breaks, limit continuous work period per day, wear prescription glasses	1	N/A
Discomfort from sitting (upper limb, back)	Researcher	Regular scheduled breaks, limit continuous work period per day	1	N/A
Stress	Researcher	Regular scheduled breaks, discontinue work for the day if required	1	N/A
			Review Date:	

Hazard and severity (1 = minor, 2 = serious, 3 = very serious / fatal)
Risk (likelihood: 1 = very unlikely, 2 = unlikely, 3 = likely / very likely)
Hazard x Risk = Hazard severity (1,2,3, = low, 4 = medium, 6+ = high)

Appendix 5. Search strategy

Search	Query (Title/Abstract)	Database APA PsycInfo	 EMBASE (Ovid)	 MEDLINE (PubMed)	 SCOPUS
#1	Sleep*	86,936	347,411	235,638	314,831
#2	Athlete* OR sport* OR athletic* OR player	68,690	213,020	176,389	517,437
#3	Intervention OR hygiene OR education* OR behavior* OR behaviour* OR extension OR counselling OR optimisation OR optimization OR workshop	1,828,236	4,100,226	3,344,802	10,934,993
#4	#1 AND #2 AND #3, Limited to English language	352	1,194	898	1,328

APA PsycInfo search: (TI Sleep* OR AB Sleep*) AND (TI (Athlete* OR sport* OR athletic* OR player) OR AB (Athlete* OR sport* OR athletic* OR player)) AND (TI(Intervention OR hygiene OR education* OR behavior* OR behaviour* OR extension OR counselling OR optimisation OR optimization OR workshop)) OR AB ((Intervention OR hygiene OR education* OR behavior* OR behaviour* OR extension OR counselling OR optimisation OR optimization OR workshop)), Narrow by Language: -english
EMBASE (Ovid) search: (Sleep*.ti. or Sleep*.ab.) AND ((Athlete* or sport* or athletic* or player).ti. or (Athlete* or sport* or athletic* or player).ab.) AND ((Intervention or hygiene or education* or behavior* or behaviour* or extension or counselling or optimisation or optimization or workshop).ti. or (Intervention or hygiene or education* or behavior* or behaviour* or extension or counselling or optimisation or optimization or workshop).ab.) AND English.lg.
Medline (PubMed) search: ("sleep*"[Title/Abstract] AND ("athlete*"[Title/Abstract] OR "sport*"[Title/Abstract] OR "athletic*"[Title/Abstract] OR "player"[Title/Abstract]) AND ("Intervention"[Title/Abstract] OR "hygiene"[Title/Abstract] OR "education*"[Title/Abstract] OR "behavior*"[Title/Abstract] OR "behaviour*"[Title/Abstract] OR "extension"[Title/Abstract] OR "counselling"[Title/Abstract] OR "optimisation"[Title/Abstract] OR "optimization"[Title/Abstract] OR "workshop"[Title/Abstract])) AND (english[Filter])
SCOPUS search: ((TITLE(sleep*) OR ABS(sleep*))) AND ((TITLE(athlete* OR sport* OR athletic* OR player) OR ABS (athlete* OR sport* OR athletic* OR player))) AND ((TITLE(intervention OR hygiene OR education* OR behavior* OR behaviour* OR extension OR counselling OR optimisation OR optimization OR workshop) OR ABS(intervention OR hygiene OR education* OR behavior* OR behaviour* OR extension OR counselling OR optimisation OR optimization OR workshop))) AND (LIMIT-TO(LANGUAGE, "English"))

Appendix 6. Data extraction grid with example

Category	**Example**
Author/Year	*Caia et al. (2017)*
Aim	*Impact of sleep hygiene education during the competitive season*
Format (Journal article/Abstract)	*Journal article*
Study design	*Parallel groups (median split) pre-post*
Country	*Australia*
Sport	*Rugby League*
Performance level	*Professional*
Sample Size	*24*
Age (mean ± SD unless specified)	*27 ± 4 y (INT), 25 ± 3 y (CON)*
Gender split	*all male*
Inclusion criteria (if applicable, any related to pre-intervention sleep)	*50% with shortest TST at baseline assigned to INT group*
Direct/indirect	*Indirect*
Intervention summary	*2 x 30min sleep hygiene education sessions one week apart. Outline importance of sleep, regularity of sleep patterns, prebed routine, electronics use, bedroom environment, caffeine and alcohol use before bed. Daily access to practitioner with sleep expertise.*
Duration	*14-d baseline, 14-d intervention, 14-d follow-up at 1-m post-intervention*
Control condition (if applicable)	*No intervention*
Sleep outcomes	*Actigraphy: SOT, SOL, WUT, TIB, TST, SE*
Key findings	*Post-intervention increase in TIB (25-min) and TST (20-min) and earlier SOT (23-min). At follow-up, increased TIB (51-min) and later WUT (34-min) but lower SE (4.2%). Control group had no changes in sleep. Limited efficacy at follow-up*

Appendix 7. Coded BCTs for included studies

	Study BCTs	1. Goals and Planning	2. Feedback and Monitoring	3. Social support	4. Shaping knowledge	5. Natural consequences	6. Comparison of behaviour	7. Associations	8. Repetition and	9. Comparison of outcomes	10. Reward and threat	11. Regulation	12. Antecedents	13. Identity	14. Scheduled consequences	15. Self-belief	16. Covert learning
Grouping BCTs		*11*	*8*	*2*	*20*	*5*	*0*	*3*	*8*	*12*	*2*	*1*	*6*	*1*	*0*	*0*	*0*
Educational																	
Caia et al. (2018)	*3*			3.1	4.1					9.1							
Driller et al. (2019)	*4*		2.2		4.1	5.1				9.1							
Dunican et al. (2021)	*2*				4.1					9.1							
Dunican et al. (2023)	*2*				4.1					9.1							
Harada et al. (2016)	*1*				4.1												
Jenkins et al. (2021)	*3*		2.6		4.1	5.1											
Kaier et al. (2016)	*6*	1.9	2.2		4.1	5.2				9.1				13.2			
O'Donnell & Driller (2017)	*3*				4.1			7.1	8.1								
Sargent et al. (2021)	*5*	1.1 1.4	2.6		4.1					9.1							
van Ryswyk et al. (2017)	*3*	1.1			4.1					9.1							
Vitale et al. (2019)	*2*				4.1					9.1							
Mind-body practices																	
Chen et al. (2018)	*1*												12.6				
Datta et al. (2022)	*5*				4.1			7.1	8.1	9.1			12.6				

	Study BCTs	1. Goals and Planning	2. Feedback and Monitoring	3. Social support	4. Shaping knowledge	5. Natural consequences	6. Comparison of behaviour	7. Associations	8. Repetition and	9. Comparison of outcomes	10. Reward and threat	11. Regulation	12. Antecedents	13. Identity	14. Scheduled consequences	15. Self-belief	16. Covert learning
Jones et al. (2020)	*3*				4.1				8.1				12.6				
McCloughlin et al. (2016)	*4*		2.3		4.1				8.1				12.6				
Rijken et al. (2016)	*1*								8.1								
Direct																	
Famodu et al. (2017)	*1*	1.1															
Leduc et al. (2022)	*2*	1.1			4.1												
Mah et al. (2011)	*1*	1.1															
Mah et al. (2017)	*1*	1.1															
Roberts et al. (2019a)	*1*	1.1															
Schwartz & Simon (2015)	*1*	1.1															
Swinbourne et al. (2018)	*2*	1.1			4.1												
Multi-component																	
Charest et al. (2017)	*0*																
de Mello et al. (2020)	*1*								8.1								
Duffield et al. (2014)	*1*								8.1								
Fullagar et al. (2016)	*1*								8.1								
Grandner et al. (2017)	*5*		2.3	3.1		5.1		7.1			10.2						
Vachon et al. (2022)	*4*				4.1					9.1	10.11		12.6				

	Study BCTs	**1. Goals and Planning**	**2. Feedback and Monitoring**	**3. Social support**	**4. Shaping knowledge**	**5. Natural consequences**	**6. Comparison of behaviour**	**7. Associations**	**8. Repetition and substitution**	**9. Comparison of outcomes**	**10. Reward and threat**	**11. Regulation**	**12. Antecedents**	**13. Identity**	**14. Scheduled consequences**	**15. Self-belief**	**16. Covert learning**
Vachon et al. (2023)	*5*				4.1	5.1				9.1		11.4	12.6				
Other																	
Bender et al. (2018)	*2*		2.2		4.1												
Jakowski & Stork (2022)	*1*		2.6														
Tuomilehto et al. (2017)	*2*				4.1					9.1							

Appendix 8. Definitions of coded BCTs

BCT	Frequency	Definition
1.1 Goal setting (behaviour)	9	Set or agree on a goal defined in terms of the behaviour to be achieved.
1.4 Action planning	1	Prompt detailed planning of performance of the behaviour (must include at least one of context, frequency, duration, and intensity). Context may be environmental (physical or social) or internal (physical, emotional or cognitive).
1.9 Commitment	1	Ask the person to affirm or reaffirm statements indicating commitment to change the behaviour
2.2 Feedback on behaviour	3	Monitor and provide informative or evaluative feedback on performance of the behaviour (e.g. form, frequency, duration, intensity).
2.3 Self-monitoring of behaviour	2	Establish a method for the person to monitor and record their behaviour(s) as part of a behaviour change strategy
2.6 Biofeedback	3	Provide feedback about the body (e.g. physiological or biochemical state) using an external monitoring device as part of a behaviour change strategy
3.1 Social support (unspecified)	2	Advise on, arrange or provide social support (e.g. from friends, relatives, colleagues,' buddies' or staff) or noncontingent praise or reward for performance of the behaviour. It includes encouragement and counselling, but only when it is directed at the behaviour
4.1 Instruction on how to perform a behaviour	20	Advise or agree on how to perform the behaviour (includes 'Skills training')
5.1 Information about health consequences	4	Provide information (e.g. written, verbal, visual) about health consequences of performing the behaviour
5.2 Salience of consequences	1	Use methods specifically designed to emphasise the consequences of performing the behaviour with the aim of making them more memorable (goes beyond informing about consequences)
7.1 Prompts/cues	3	Introduce or define environmental or social stimulus with the purpose of prompting or cueing the behaviour. The prompt or cue would normally occur at the time or place of performance
8.1 Behavioural practice/ rehearsal	8	Prompt practice or rehearsal of the performance of the behaviour one or more times in a context or at a time when the performance may not be necessary, in order to increase habit and skill
9.1 Credible source	12	Present verbal or visual communication from a credible source in favour of or against the behaviour
10.2 Material reward (behaviour)	1	Arrange for the delivery of money, vouchers or other valued objects if and only if there has been effort and/or progress in performing the behaviour (includes 'Positive reinforcement')
10.11 Future punishment	1	Inform that future punishment or removal of reward will be a consequence of performance of an unwanted behaviour (may include fear arousal) (includes 'Threat')
11.4 Paradoxical instructions	1	Advise to engage in some form of the unwanted behaviour with the aim of reducing motivation to engage in that behaviour
12.6 Body changes	6	Alter body structure, functioning or support directly to facilitate behaviour change
13.2 Framing/reframing	1	Suggest the deliberate adoption of a perspective or new perspective on behaviour (e.g. its purpose) in order to change cognitions or emotions about performing the behaviour (includes 'Cognitive structuring')

Appendix 9. Quality appraisal scores for quasi-experimental studies

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Study score
Question score	20/20	18/20	16/20	1/20	18/20	14/20	19/20	13/20	8/20	-
Bender et al. (2018)	Y	Y	N	N	Y	N	N	Y	Y	5/9
Caia et al. (2017)	Y	N	Y	Y	Y	Y	Y	Y	Y	8/9
Chen et al. (2018)	Y	N	Y	N	Y	Y	Y	Y	Y	7/9
De Mello et al. (2022)	Y	Y	Y	N	N	N	Y	N	N	4/9
Driller et al. (2019)	Y	Y	N	N	Y	Y	Y	Y	Y	7/9
Dunican et al. (2021)	Y	Y	Y	N	Y	Y	Y	Y	N	7/9
Dunican et al. (2023)	Y	Y	Y	N	Y	Y	Y	Y	N	7/9
Harada et al. (2016)	Y	Y	Y	N	Y	Y	Y	Y	N	7/9
Jenkins et al. (2021)	Y	Y	Y	N	Y	Y	Y	Y	N	7/9
Kaier et al. (2016)	Y	Y	Y	N	Y	N	Y	N	Y	6/9
Mah et al. (2011)	Y	Y	Y	N	Y	Y	Y	N	Y	7/9
McCloughlin et al. (2016)	Y	Y	Y	N	Y	Y	Y	Y	N	7/9
O'Donnell & Driller (2017)	Y	Y	Y	N	Y	Y	Y	Y	Y	8/9
Rijken et al. (2016)	Y	Y	Y	N	Y	Y	Y	Y	N	7/9
Schwartz & Simon (2015)	Y	Y	Y	N	Y	Y	Y	N	N	6/9
Swinbourne et al. (2018)	Y	Y	Y	N	Y	Y	Y	N	N	6/9
Tuomilehto et al. (2017)	Y	Y	N	N	Y	N	Y	Y	N	5/9
Vachon et al. (2022)	Y	Y	Y	N	Y	N	Y	N	Y	6/9
Vachon et al. (2023)	Y	Y	Y	N	Y	Y	Y	N	N	6/9
Van Ryswyk et al. (2017)	Y	Y	N	N	N	N	Y	Y	N	4/9

Question summary: Q1, Is it clear in the study what is the 'cause' and what is the 'effect' (i.e. there is no confusion about which variable comes first)? Q2, Were the participants included in any comparisons similar? Q3, Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest? Q4, Was there a control group? Q5, Were there multiple measurements of the outcome both pre and post the intervention/exposure? Q6, Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analyzed? Q7, Were the outcomes of participants included in any comparisons measured in the same way? Q8, Were outcomes measured in a reliable way? Q9, Was appropriate statistical analysis used? Full checklist explanations are available on the JBI website (https://jbi.global/critical-appraisal-tools)

Appendix 10. Quality appraisal scores for randomised controlled trials

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Study score
Question score	5/9	4/9	6/9	1/9	1/9	5/9	8/9	9/9	9/9	5/9	7/9	5/9	6/9	-
Datta et al. (2022)	Y	Y	N	N	N	Y	Y	Y	Y	N	N	N	N	6/13
Duffield et al. (2014)	Y	N	Y	N	N	N	Y	Y	Y	Y	Y	N	N	7/13
Fullagar et al. (2016)	Y	N	Y	N	N	N	Y	Y	Y	N	Y	Y	Y	8/13
Jakowski & Stork (2022)	Y	N	N	N	N	Y	Y	Y	Y	N	Y	Y	N	7/13
Jones et al. (2020)	N	N	Y	N	N	Y	Y	Y	Y	Y	N	N	Y	7/13
Leduc et al. (2022)	N	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	11/13
Roberts et al. (2019a)	N	N	Y	N	N	Y	N	Y	Y	Y	Y	N	Y	7/13
Sargent et al. (2021)	N	Y	N	Y	N	N	Y	Y	Y	N	Y	Y	Y	8/13
Vitale et al. (2019)	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	10/13

Question summary: Q1, Was true randomization used for assignment of participants to treatment groups? Q2, Was allocation to treatment groups concealed? Q3, Were treatment groups similar at the baseline? Q4, Were participants blind to treatment assignment? Q5, Were those delivering treatment blind to treatment assignment? Q6, Were outcomes assessors blind to treatment assignment? Q7, Were treatment groups treated identically other than the intervention of interest? Q8, Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analyzed? Q9, Were participants analyzed in the groups to which they were randomized? Q10, Were outcomes measured in the same way for treatment groups? Q11, Were outcomes measured in a reliable way? Q12, Was appropriate statistical analysis used? Q13, Was the trial design appropriate, and any deviations from the standard RCT design (individual randomization, parallel groups) accounted for in the conduct and analysis of the trial? Full checklist explanations are available on the JBI website (https://jbi.global/critical-appraisal-tools)

Appendix 11. Early morning sport scheduling is associated with poorer subjective sleep characteristics in British student-athletes (Wilson et al., 2024)

Check for updates

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ORIGINAL ARTICLE

WILEY

Early morning sport scheduling is associated with poorer subjective sleep characteristics in British student-athletes

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Abstract

This study presents the sleep characteristics of British student-athletes and examines the relationships between sport scheduling and time demands on sleep outcomes. Student-athletes ($n = 157$, 51% male) completed the Pittsburgh Sleep Quality Index (PSQI), Epworth Sleepiness Scale (ESS), and the Sleep Hygiene Index (SHI). Self-reported sleep characteristics on weekdays and weekends, weekly frequencies of early morning and late evening sport sessions, and academic-related and sport-related time demands were also collected. Questionnaires revealed a high prevalence of undesired sleep characteristics including poor sleep quality (global PSQI >5 in 49.0%) and low sleep durations on weekdays (25% reporting <7 h). Paired t-tests revealed significant differences in bedtime, waketime, sleep duration, and sleep onset latency between weekdays and weekends (all $p < 0.01$). Hierarchical regression analyses indicated that early morning sport frequency was a significant predictor of PSQI ($\beta = 0.30$) and SHI ($\beta = 0.24$) global scores, weekday waketimes ($\beta = -0.17$), and weekday sleep durations ($\beta = -0.25$; all $p < 0.05$) in models adjusted for participant characteristics. Late evening sport frequency, and academic-related and sport-related time demands, were not significant predictors of any sleep outcome. Adjusting sport scheduling to avoid early start times could provide a means to improve sleep outcomes and may improve sporting performance and academic attainment.

KEYWORDS

scheduling, sleep, social jetlag, student-athlete

1 | INTRODUCTION

Previous research has highlighted suboptimal sleep outcomes among both University student and elite athlete populations,[1,2] prompting increased interest in the sleep characteristics of student-athletes. While various physiological processes underpin sleep regulation, a complex interplay with the social-environmental context influences sleep behaviors and can help elucidate why certain populations, such as student-athletes, may exhibit poorer sleep characteristics.[3] For example, athletes encounter sport-specific risk factors related to training, travel, and competition that can disrupt sleep,[4] while emotional and academic stress contribute towards poor sleep among

University students.[2] Studies on student-athletes have consistently shown a significant proportion to report a nocturnal sleep duration of under 7 h,[5,6] with 61% falling below this threshold when assessed using actigraphy.[7] Approximately half of American student-athletes are classified as poor-quality sleepers when assessed using the Pittsburgh Sleep Quality Index,[5,8] and a high prevalence of excessive daytime sleepiness and poor sleep hygiene behaviors in response to environmental barriers has been observed.[5]

Previous research on student-athlete sleep has predominantly focused on American cohorts. While British student-athletes likely share many characteristics, notable differences in sports, academics, and culture may contribute to distinct sleep outcomes, as indicated by a higher sleep duration previously reported in British counterparts.[9] The typical British student-athlete sporting schedule runs from Monday to Friday with competitions held on Wednesdays, in contrast to the more varied National Collegiate Athletic Association (NCAA) schedule. However, sport training often needs to be scheduled around the academic timetable, resulting in either early morning or late evening sessions. In elite athletes, training timing has been identified as a factor causing social jetlag,[10] which is the inconsistency in sleep/wake timing between work days and free days driven by misalignment of the social and circadian clocks,[11] with social jetlag associated with poorer health outcomes.[12] For instance, Sargent et al.[13] demonstrated that on nights preceding early morning training at 06:00, bedtime was 2.5 h earlier, waketime was 4.0 h earlier, and sleep duration was 2.2 h shorter compared to nights preceding free days in swimmers. The impact of late evening training on sleep in athletes is less clear, although sleep duration has been shown to be shortened following evening competitions.[14] While a small social jetlag effect has been demonstrated between weekdays and weekends in student-athletes,[5,9] this warrants further investigation.

In addition to sport scheduling, another perceived sleep risk factor unique to student-athletes is the challenge of balancing the demanding workload inherent in excelling both in sports and academics.[15] NCAA athletes have reported a combined sport and academic workload exceeding 60 h per week, with only 54–66% of Division I athletes believing they were able to find a balance between academics and extracurricular activities, and felt able to keep up with classes in-season.[16] However, it has been contested that workload is responsible for poor sleep in student-athletes.[17] Currently, it remains unknown whether the sporting and academic time demands in British student-athletes are comparable to those of NCAA counterparts. However, differences in academic structure and sporting culture between countries provide grounds to investigate the impact of time demands on sleep among British student-athletes.

Given the paucity of existing sleep research in British student-athletes, there is a need to gain further insight into this group and how they compare to previous findings. This study aimed to utilize questionnaires as a recommended tool to screen and assess sleep outcomes in an athlete populations,[18] with the following objectives: (1) assess the sleep outcomes of a cohort of British student-athletes to enable comparisons with other athlete and student-athlete populations; (2) examine differences in sleep outcomes between weekday and weekend nights; and (3) investigate the association between sport scheduling and time demands on sleep, and whether these variables serve as significant predictors of sleep outcomes. It was anticipated that sleep outcomes in British student-athletes would align with those observed in student-athletes of other nationalities. Furthermore, it was anticipated that sleep outcomes would exhibit significant differences between weekday and weekend nights and that both sport scheduling and time demands would emerge as significant predictors of sleep outcomes.

2 | MATERIALS AND METHODS

2.1 | Participants

Participants were recruited from a single University and College center located in the South-West United Kingdom. Informed consent was obtained from each participant, and study approval was obtained from the Hartpury University Ethics Committee (ETHICS2021-117). The criteria to be classified as a student-athlete was defined as: (1) enrolled on an academic course for the 2022/23 academic year, and (2) registered with the center's performance sports academy, inferring a minimum performance level of British Universities and Colleges Sport (BUCS) competition. Participants were excluded if they disclosed any previous or current history of a medically diagnosed sleep-related disorder prior to the study.

All academic and sporting activities, including matches, took place on weekdays, with no scheduled activities on weekends. Training and match schedules for sports teams varied. University students typically had training sessions scheduled outside the academic timetable (Monday, Tuesday, Thursday, and Friday from 08:30 to 20:30). The college academic timetable ran from 09:00 to 15:30, with some college student-athletes having training sessions integrated into their academic timetable.

2.2 | Protocol

Participants completed an online survey during Autumn 2022 over a 2-week period. This timeframe was during academic teaching weeks but outside any examination periods, and all sports were in-season. Convenience sampling was used to recruit participants through emails sent directly from the lead researcher to student-athletes on two occasions, and signposting from head sports coaches. The survey was administered through Qualtrics XM online platform (Qualtrics, Provo, UT).

2.3 | Content

Participant characteristics were gathered through questions related to age, sex, level of study, sport, and residential status. Self-assessed chronotype was captured using the reduced Morningness-Eveningness questionnaire (rMEQ).[19] The rMEQ consists of 5 items relating to sleep–wake preferences and alertness to estimate circadian phase, scored from 1–5 (Q1-4) or 0–6 (Q5) with items summed for a global score between 4 and 26. Higher scores indicate an earlier circadian phase. Cut-off scores were used to categorize evening-type (<12), neither-type (12–17), and morning-type (>17) groups, but were kept as a continuous variable for regression analyses.

The Pittsburgh Sleep Quality Index (PSQI) was used to measure subjective sleep quality.[20] The PSQI consists of 19 items relating to habitual sleep over the previous month. These items form seven equally weighted components scored 0–3, and are summed for a global score from 0 to 21. A threshold score of >5 is used to identify poor-quality sleepers.[20] A threshold of ≥8 is also reported and has been used to indicate highly disturbed sleep in athletes.[4] PSQI questions 1–4 relating to typical bedtime, sleep onset latency (SOL), waketime, and total sleep time (TST) were split into separate questions for weekdays and weekends and used separately for further analyses. For PSQI global scoring, a 5:2 ratio of weekday to weekend responses was calculated to reflect the original questionnaire.

The Epworth Sleepiness Scale (ESS) was used to measure subjective daytime sleepiness.[21] The ESS consists of 8 items regarding sleep propensity in different scenarios. These are scored on a range from 0 to 3 and summed for a global score between 0 and 24, with higher scores reflecting higher daytime sleepiness. A threshold score of ≥10 indicates excessive daytime sleepiness.[21]

The Sleep Hygiene Index (SHI) was used to assess the practice of sleep hygiene behaviors.[22] The SHI consists of 13 items on the presence of behaviors that can facilitate or hinder sleep. These are scored on a range from 1–5 and summed for a global score between 13 and 65, with higher scores indicative of poorer sleep hygiene practices.

The scheduling of early morning (AM) and late evening (PM) sport was assessed by asking for the typical weekly frequency of training or competition before 09:00 and after 21:00 respectively, to capture training sessions that were placed prior to the academic timetable and may require an earlier awakening than preferred, or were placed close to typical weekday bedtimes and may interrupt sleep onset.[23] Sporting and academic time demands were assessed by asking for the typical weekly hours spent on academic-related and sport-related activities. Participants were also asked whether they believed balancing sporting, academic, employment, and social activities restricted sleep opportunities below personal preference.

2.4 | Statistical analysis

Raw data from Qualtrics XM was exported to Microsoft Excel (Microsoft, Redmond, WA), and then uploaded to IBM SPSS version 26 (IBM, Chicago, IL) for all statistical analyses. Preliminary data screening was performed using guidelines outlined by Tabachnick and Fidell (2013).[24] Seven participants were removed for reporting a current or previous sleep disorder. Six data points from three cases were considered invalid responses (e.g., out-of-range values) and treated as missing data. As Little's missing completely at random test was non-significant ($\chi^2 = 24.893$, $df = 33$, $p = 0.844$), data was replaced using multiple imputations as to not greatly influence the variation in data.[24] Eight data points from five cases were considered univariate outliers assessed using standardized z-scores ($z > 3.29$, $p < 0.001$). These were manually screened and deemed to be valid responses. To minimize the impact of outliers on correlation and regression analyses, these outliers were assigned to the next most extreme non-outlier score in the distribution. Scores were considered normally distributed through visual inspection of normal Q–Q plots and assessment of skewness and kurtosis (z_{skew} and $z_{kurt} < 3.29$). No multivariate outliers were identified through Mahalanobis distances using a $p < 0.001$ criterion for Mahalanobis D^2. Reliability analysis was performed on validated questionnaires (PSQI, $\alpha = 0.62$; SHI, $\alpha = 0.72$; ESS, $\alpha = 0.71$; rMEQ, $\alpha = 0.58$).

Descriptive data are presented as mean ± SD, with bias-corrected and accelerated 95% confidence intervals (10 000 bootstrapped samples) reported. Differences in sleep outcomes, categorized by participant characteristics, were assessed using independent t-tests (for two factors) or one-way ANOVAs (for three or more factors). Paired t-tests were employed to evaluate differences between self-reported weekday and weekend sleep as derived from the

PSQI. Pearson correlations were conducted between sport scheduling, time demand predictor variables, and sleep outcomes. Multiple regression analyses were employed to investigate the predictive ability of sport scheduling and time demands on sleep outcomes while controlling for fixed predictor variables (participant characteristics showing differences in sleep outcomes). Each sleep outcome was assessed in a separate model using the enter method, with fixed predictors entered at step 1, followed by the inclusion of sport scheduling and time demand predictors at step 2.

3 | RESULTS

3.1 | Sleep characteristics

A total of 157 participants, with a mean age of 18 ± 2 years (range 16–25), were included in the analyses. Participant characteristics and differences in sleep outcomes based on participant characteristics are summarized in Table 1. In addition, age was significantly associated with PSQI ($r=0.171$, $p=0.032$, 95%CI [0.014, 0.319]), ESS ($r=0.189$, $p=0.018$, 95%CI [0.033, 0.355]), weekday waketime ($r=-0.428$, $p=<0.001$, 95%CI [−0.540, −0.315]), and weekday TST ($r=-0.257$, $p=0.001$, 95%CI [−0.381, −0.146]). The proportion of participants reporting poor perceived sleep quality (PSQI > 5) was 49.0% ($n=77$), while 23.6% ($n=37$) had a PSQI score above the higher threshold (PSQI ≥8). Regarding perceived daytime sleepiness, 22.9% ($n=36$) exceeded the clinical threshold (ESS ≥10).

When considering the difference between PSQI-derived sleep outcomes on weekdays and weekends, a statistically significant mean difference was observed for all sleep outcomes. On average, participants went to bedtime 38 min earlier ($t(156)=-8.45$, $p<0.001$, $d=0.67$ (0.50, 0.85)), a waketime 118 min earlier ($t(156)=-16.93$, $p<0.001$, $d=1.35$ (1.13, 1.57)), had a TST 67 min shorter ($t(156)=-11.59$, $p<0.001$, $d=0.93$ (0.74, 1.11)), and had a SOL 3 min longer ($t(156)=3.90$, $p<0.001$, $d=0.31$ (0.15, 0.47)) on weekdays when compared to weekends (Figure 1). A total of 39 participants (24.8%) reported a weekday TST <7 h compared to 13 (8.3%) at weekends.

3.2 | Sport scheduling and time demands

The frequency of AM and PM sport sessions were 2.7 ± 2.0 and 0.7 ± 1.1 per week, respectively. In total, 132 participants (84%) participated in at least one AM or PM sport session, with 63 participants (40%) reporting both AM and PM sport sessions. The weekly time spent on academic-related activities was 17.7 ± 8.8 h, while 13.2 ± 6.5 h were spent on sport-related activities. A total of 52.2% (n = 82) of participants believed that balancing sport-related and academic-related activities in addition to social and employment activities restricted sleep opportunity below their personal preference.

A correlation matrix showing the relationships between predictor variables and sleep outcomes is presented in Table 2. A higher frequency of AM sport sessions was associated with shorter weekday TST ($p<0.001$, 95%CI [−0.415, −0.167]), earlier weekday waketimes ($p<0.001$, 95%CI [−0.474, −0.213]), and higher PSQI ($p<0.001$, 95%CI [0.169, 0.436]), ESS ($p=0.005$, 95%CI [0.059, 0.371]), and SHI ($p=0.023$, 95%CI [0.000, 0.320]) global scores. The frequency of PM sport sessions was not associated with any sleep outcome. Increased academic-related time demands were associated with higher weekend TST ($p=0.025$, 95%CI [0.048, 0.308]), while increased sport-related time demands were associated with earlier weekday bedtimes ($p=0.036$, 95%CI [−0.314, −0.021]) and weekday waketimes ($p=0.039$, 95%CI [−0.321, −0.005]).

For the linear regression analyses, the fixed predictors entered into the models at Step 1 were age, chronotype (rMEQ global score), residential status, and sex. The level of study was omitted due to the high correlation with age ($r=0.76$, $p<0.001$) and the presence of multicollinearity when included in regression models, as assessed by variance inflation factors. Type of sport was excluded based on the absence of significant differences in sleep outcomes observed in earlier ANOVAs.

Regression models revealed four sleep outcomes for which the frequency of AM sport sessions was a significant predictor of the model when fixed predictors were included. Specifically, AM sport frequency significantly predicted PSQI ($p<0.001$) and SHI global scores ($p=0.005$), alongside weekday TST ($p=0.003$) and weekday waketime ($p=0.024$). However, the frequency of PM sport sessions and academic-related and sport-related time demands did not emerge as significant predictors in these models. The complete regression models for these four sleep outcomes are detailed in Table 3.

The regression models for ESS global score ($F(3, 153)=2.811$; $p=0.009$, $R^2=0.117$), weekday bedtime ($F(3, 153)=6.911$; $p<0.001$, $R^2=0.245$), weekend bedtime ($F(3, 153)=4.778$; $p<0.001$, $R^2=0.183$), and weekend waketime ($F(3, 153)=3.664$; $p=0.001$, $R^2=0.147$) were statistically significant, but were only predicted by the fixed predictors entered into the models. The models for the remaining sleep outcomes (weekday SOL, weekend SOL, and weekend TST) did not reach statistical significance ($p>0.05$). The full regression analyses for these seven sleep outcomes are available in the Supplemental File Tables S1 and S2.

TABLE 1 Sleep parameters split by participant characteristics.

Variable		PSQI	ESS	SHI	Weekday bedtime	Weekday SOL	Weekday waketime	Weekday TST	Weekend bedtime	Weekend SOL	Weekend waketime	Weekend TST
All (n = 157)		5.7 ± 2.6	6.7 ± 3.7	31.9 ± 6.6	23:01 ± 00:56	22 ± 14	07:00 ± 01:04	7.3 ± 1.1	23:39 ± 01:19	19 ± 12	08:58 ± 01:26	8.4 ± 1.3
Sex	Male (n = 80)	5.2 ± 2.5	6.5 ± 3.3	29.9 ± 6.2	22:59 ± 00:57	21 ± 14	06:49 ± 01:03	7.1 ± 1.1	23:36 ± 01:11	17 ± 12	08:29 ± 01:35	8.2 ± 1.3
	Female (n = 77)	6.2 ± 2.7	6.9 ± 4.0	33.9 ± 6.4	23:03 ± 00:52	23 ± 14	07:11 ± 00:56	7. 3 ± 1.1	23:43 ± 01:16	21 ± 13	09:07 ± 01:16	8.5 ± 1.1
	Effect size	**d = 0.39 (0.07, 0.70)***	d = 0.10 (−0.21, 0.41)	**d = 0.63 (0.31, 0.95)****	d = 0.07 (−0.25, 0.38)	d = 0.14 (−0.18, 0.45)	**d = 0.37 (0.06, 0.69)***	d = 0.24 (−0.07, 0.56)	d = 0.10 (−0.21, 0.42)	**d = 0.38 (0.06, 0.69)***	d = 0.21 (−0.11, 0.52)	d = 0.24 (−0.08, 0.55)
Level of study	College (n = 89)	5.2 ± 2.6	6.0 ± 3.4	31.6 ± 7.0	23:06 ± 00:51	20 ± 13	07:19 ± 00:56	7.5 ± 1.0	23:45 ± 01:16	18 ± 13	09:01 ± 01:25	8.4 ± 1.2
	University (n = 68)	6.3 ± 2.6	7.6 ± 3.8	32.2 ± 6.1	22:55 ± 00:59	24 ± 14	06:35 ± 00:57	7.0 ± 1.1	23:32 ± 01:08	19 ± 12	08:54 ± 01:29	8.4 ± 1.4
	Effect size	**d = 0.40 (0.08, 0.72)****	**d = 0.44 (0.12, 0.75)****	d = 0.09 (−0.23, 0.41)	d = 0.21 (−0.10, 0.53)	d = 0.24 (−0.08, 0.56)	**d = 0.79 (0.46, 1.12)****	**d = 0.53 (0.20, 0.85)****	d = 0.18 (−0.13, 0.50)	d = 0.07 (−0.24, 0.39)	d = 0.08 (−0.24, 0.39)	d = 0.03 (−0.29, 0.34)
Sport	Rugby (n = 86)	5.8 ± 2.7	6.5 ± 3.8	31.8 ± 7.2	23:07 ± 00:59	22 ± 14	07:06 ± 00:56	7.3 ± 1.1	23:37 ± 01:12	19 ± 13	09:03 ± 01:17	8.4 ± 1.2
	Football (n = 42)	5.1 ± 2.3	6.6 ± 3.3	30.4 ± 5.7	22:58 ± 00:43	19 ± 13	06:49 ± 00:54	7.3 ± 1.0	23:39 ± 01:11	16 ± 12	08:48 ± 01:40	8.4 ± 1.4
	Netball (n = 13)	6.2 ± 3.2	9.2 ± 4.1	35.0 ± 6.2	22:48 ± 00:35	19 ± 11	07:14 ± 01:17	7.4 ± 1.1	23:42 ± 01:01	21 ± 13	09:29 ± 01:19	8.7 ± 0.8
	Other (n = 16)	6.1 ± 2.0	6.0 ± 3.0	33.4 ± 5.1	22:50 ± 01:11	29 ± 15	06:45 ± 01:18	7.0 ± 1.1	23:53 ± 01:36	23 ± 14	08:31 ± 01:38	7.7 ± 1.5
	Effect size	η^2 = 0.02 (0.00, 0.07)	η^2 = 0.04 (0.00, 0.11)	η^2 = 0.04 (0.00, 0.10)	η^2 = 0.02 (0.00, 0.06)	η^2 = 0.05 (0.00, 0.11)	η^2 = 0.03 (0.00, 0.08)	η^2 = 0.01 (0.00, 0.03)	η^2 = 0.00 (0.00, 0.02)	η^2 = 0.02 (0.00, 0.07)	η^2 = 0.03 (0.00, 0.08)	η^2 = 0.04 (0.00, 0.09)
Residential status	On-site (n = 48)	5.1 ± 2.3	6.5 ± 3.5	32.6 ± 6.9	23:15 ± 00:54	19 ± 11	07:36 ± 00:50	7.5 ± 0.9	23:46 ± 01:18	17 ± 11	09:10 ± 01:17	8.5 ± 1.1
	Off-site (n = 109)	6.0 ± 2.7	6.8 ± 3.8	31.5 ± 6.5	22:55 ± 00:54	23 ± 15	06:44 ± 00:58	7.2 ± 1.1	23:36 ± 01:11	20 ± 13	08:53 ± 01:30	8.3 ± 1.3
	Effect size	**d = 0.35 (0.01, 0.69)***	d = 0.06 (−0.28, 0.40)	d = 0.16 (−0.18, 0.50)	**d = 0.38 (0.03, 0.72)***	**d = 0.32 (−0.03, 0.65)***	**d = 0.92 (0.56, 1.27)****	d = 0.33 (−0.01, 0.67)	d = 0.13 (−0.20, 0.48)	d = 0.24 (−0.10, 0.58)	d = 0.19 (−0.15, 0.53)	d = 0.10 (−0.24, 0.44)
Chronotype	Morning-type (n = 28)	5.2 ± 2.1	5.6 ± 3.7	29.9 ± 6.7	22:12 ± 01:01	22 ± 17	06:20 ± 01:04	7.6 ± 0.9	22:51 ± 01:05	20 ± 16	08:08 ± 01:10	8.2 ± 1.1
	Intermediate-type (n = 105)	5.7 ± 2.6	7.2 ± 3.6	32.2 ± 6.1	23:07 ± 00:46	21 ± 12	07:04 ± 00:56	7.2 ± 1.0	23:41 ± 01:07	17 ± 10	09:00 ± 01:21	8.4 ± 1.2
	Evening-type (n = 24)	6.2 ± 3.2	5.6 ± 3.7	32.8 ± 8.3	23:22 ± 00:49	26 ± 16	07:31 ± 00:52	7.1 ± 1.4	00:29 ± 01:14	24 ± 16	09:49 ± 01:38	8.3 ± 1.5
	Effect size	η^2 = 0.01 (0.00, 0.06)	**η^2 = 0.04 (0.00, 0.11)***	η^2 = 0.02 (0.00, 0.07)	**η^2 = 0.20 (0.09, 0.30)****	η^2 = 0.02 (0.00, 0.08)	**η^2 = 0.12 (0.04, 0.22)****	η^2 = 0.02 (0.00, 0.07)	**η^2 = 0.15 (0.06, 0.25)****	**η^2 = 0.04 (0.00, 0.11)***	**η^2 = 0.12 (0.03, 0.21)****	η^2 = 0.00 (0.00, 0.03)

Abbreviations: ESS, Epworth Sleepiness Scale; PSQI, Pittsburgh Sleep Quality Index; SHI, Sleep Hygiene Index; SOL, sleep onset latency; TST, total sleep time.

Statistical significance: *$p < 0.05$; **$p < 0.01$.

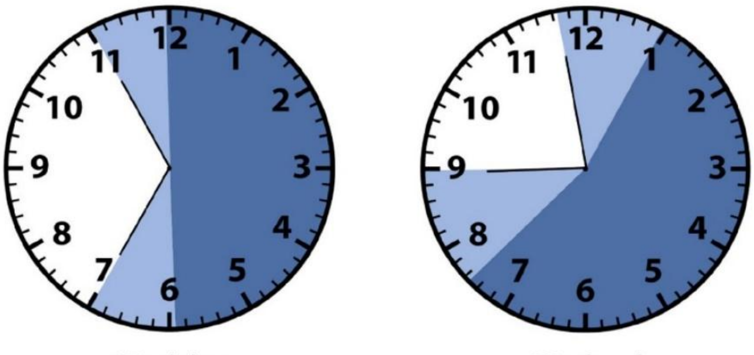

FIGURE 1 Graphical illustration of sleep time on weekday and weekend nights. All shaded segments reflect the self-reported sleep window, with lighter shading reflecting the SD.

TABLE 2 Correlation table showing the relationship between predictor variables and sleep parameters.

Sleep parameter	AM sport	PM sport	Academic time	Sport time
PSQI	**0.30****	0.03	−0.05	−0.02
ESS	**0.23****	0.15	0.09	0.11
SHI	**0.18***	0.12	0.13	0.04
Weekday bedtime	−0.12	−0.04	−0.15	**−0.17***
Weekday SOL	0.07	−0.08	−0.09	0.02
Weekday waketime	**−0.35****	0.00	0.07	**−0.16***
Weekday TST	**−0.29****	−0.03	0.14	−0.02
Weekend bedtime	−0.06	0.02	−0.11	−0.04
Weekend SOL	0.08	−0.11	−0.03	−0.04
Weekend waketime	−0.13	−0.11	0.05	−0.01
Weekend TST	−0.12	−0.03	**0.18***	0.07

Abbreviations: ESS, Epworth Sleepiness Scale; PSQI, Pittsburgh Sleep Quality Index; SHI, Sleep Hygiene Index; SOL, sleep onset latency; TST, total sleep time.

Statistical significance: *$p < 0.05$; **$p < 0.01$.

4 | DISCUSSION

This study aimed to present the sleep characteristics of a cohort of British student-athletes, explore differences in sleep outcomes between weekdays and weekends, and investigate the association and predictive value of sport scheduling and time demands on sleep outcomes. The primary findings are: (1) British student-athletes exhibited a high prevalence of poor sleep characteristics, aligning with previous research in other student-athlete cohorts; (2) significant differences in sleep outcomes were observed between weekday and weekend nights; and (3) early morning training frequency emerged as the sole significant predictor of multiple sleep outcomes when controlling for participant characteristics influencing sleep. Therefore, refraining from scheduling training in the early morning may be a prudent measure to improve sleep outcomes within student-athlete populations.

The poor sleep characteristics identified through questionnaires in this study align with previous research findings. For instance, the 49% exhibiting poor sleep quality (PSQI >5) is comparable to the 42–55% observed in mixed-sport, mixed-gender samples of American student-athletes during the competitive season.[5–8] Although there have been suggestions that the PSQI may overestimate sleep problems in athletes,[25] the widespread use in research enables comparisons across populations and indicates that poor sleep quality in student-athletes exceeds many other non-clinical groups.[26] The prevalence of excessive daytime sleepiness (ESS ≥10, 23%) substantially differs from the 51% observed by Mah et al. (2018) despite comparable PSQI scores.[5] This variation may be explained

TABLE 3 Hierarchical regression models with AM training as a significant predictor of sleep outcome.

	PSQI				SHI				Weekday waketime				Weekday TST			
	B	B_{SE}	β	t	B	B_{SE}	β	t	B	B_{SE}	β	t	B	B_{SE}	β	t
Step 1: Fixed predictors																
(Intercept)	3.68	2.11		1.74	21.83	5.47		**3.99****	648.02	43.02		**15.06****	548.18	53.78		**10.19****
Age	0.34	0.12	0.24	**2.88****	0.29	0.30	0.08	0.94	−8.25	2.40	−0.25	**−3.44****	−10.15	3.00	−0.28	**−3.38****
Chronotype	−0.20	0.06	−0.25	**−3.22****	−0.41	0.16	−0.20	**−2.49***	−5.84	1.28	−0.31	**−4.56****	4.60	1.60	0.23	**2.87****
Residential status	−0.94	0.45	−0.17	**−2.11***	0.21	1.16	0.01	0.18	34.37	9.11	0.26	**3.77****	10.36	11.39	0.07	0.91
Sex	−1.49	0.40	−0.29	**−3.72****	−4.33	1.04	−0.33	**−4.17****	−12.09	8.16	−0.10	−1.48	−4.76	10.20	−0.04	−0.47
Model fit	$F(4,152)=7.304$, $R^2=0.161$**				$F(4,152)=5.617$, $R^2=0.129$**				$F(4,152)=20.388$, $R^2=0.349$**				$F(4,152)=5.315$, $R^2=0.123$**			
Step 2: Added scheduling and time demand predictors																
(Intercept)	6.49	2.21		**2.94****	25.67	5.79		**4.43****	616.88	46.52		**13.26****	491.39	57.27		**8.58****
Age	0.16	0.13	0.11	1.27	−0.06	0.33	−0.02	−0.17	−5.77	2.64	−0.17	**−2.18***	−6.29	3.25	−0.18	−1.93
Chronotype	−0.22	0.06	−0.27	**−3.55****	−0.50	0.16	−0.24	**−3.08****	−5.37	1.32	−0.28	**−4.08****	5.16	1.62	0.25	**3.18****
Residential status	−0.93	0.44	−0.17	**−2.15***	0.04	1.14	0.00	0.03	35.09	9.18	0.27	**3.82****	10.51	11.30	0.07	0.93
Sex	−1.54	0.42	−0.30	**−3.69****	−4.03	1.10	−0.31	**−3.68****	−14.27	8.81	−0.12	−1.62	−4.54	10.84	−0.04	−0.42
AM sport	0.40	0.11	0.30	**3.64****	0.81	0.29	0.24	**2.84****	−5.22	2.29	−0.17	**−2.28***	−8.45	2.82	−0.25	**−2.99****
PM sport	0.12	0.18	0.05	0.65	0.61	0.48	0.10	1.28	1.00	3.84	0.02	0.26	−2.40	4.72	−0.04	−0.51
Academic time	−0.02	0.02	−0.06	−0.74	0.03	0.06	0.05	0.52	−0.20	0.52	−0.03	−0.38	0.24	0.64	0.03	0.37
Sport time	−0.01	0.03	−0.03	−0.32	0.03	0.08	0.03	0.35	−0.17	0.66	−0.02	−0.25	0.01	0.82	0.00	0.01
Model fit	$F(8,148)=5.402$, $R^2=0.241$**				$F(8,148)=4.457$, $R^2=0.194$**				$F(8,148)=10.982$, $R^2=0.372$**				$F(8,148)=4.044$, $R^2=0.179$**			

Abbreviations: B, unstandardized coefficient; B_{SE}, standard error of unstandardized coefficient; β, standardized coefficient; PSQI, Pittsburgh Sleep Quality Index; SHI, Sleep Hygiene Index; TST, total sleep time.
Statistical significance: *$p<0.05$; **$p<0.01$.

by the previous study collecting responses immediately before or after training where perceived tiredness may be heightened, compared to this study where responses were collected online and ESS scores are comparable to previous research in University students that adopted a similar approach.[2] Similarly, the SHI global score reflects previous research indicating poor sleep hygiene practices in student and athlete populations,[22,27] while the high prevalence of short sleep durations also align with past research in student-athletes.[5]

The discrepancy in bedtimes and waketimes between weekdays and weekends indicates social jetlag in this population.[11] This phenomenon is commonly observed in educational settings, where morning lessons on weekdays enforce an earlier waketime not fully compensated by shifting bedtime earlier,[28] and has also been demonstrated in student-athletes.[5] Social jetlag has been associated with adverse effects such as impaired cognitive performance and metabolic disruption,[12] emphasizing the need to minimize fluctuations in sleep timing where possible. While this research highlights differences in sleep outcomes between weekdays and weekends, it remains unclear how sleep may vary between weekdays. The wide range of morning and evening sport frequencies reported in this study suggests there are variations in sport scheduling throughout the week to allow for preparation for competition and recovery from physical demands. Consequently, the timing of the student-athlete day may vary substantially between weekdays. Previous research has indicated that student-athletes display greater sleep/wake irregularity than other populations,[9,29] a factor potentially detrimental to health outcomes and deserving further exploration in empirical research.

Regression analyses exploring the impact of sport scheduling on sleep outcomes revealed that a higher frequency of morning (AM) sport was predictive of elevated PSQI and SHI global scores, earlier weekday wake times, and shorter weekday sleep durations. This aligns with findings in elite athletes, indicating that scheduling training early in the morning detrimentally affects sleep outcomes, leading to reduced total sleep time the preceding night.[10] The organizational structure of the education provider in this study – common in many British institutions – often mandates scheduling training around the academic timetable. While allowing for a later start in the morning, whether through a delay in the academic timetable or improved integration between sport and academic schedules, presents logistical challenges, it may profoundly impact sleep. For instance, an acute change in training timing from 06:30 to 09:30 improved sleep duration by 46 min in Judo athletes.[30] In contrast, the frequency of evening (PM) sport was not predictive of any sleep outcome. This aligns with evidence suggesting that evening exercise is unlikely to impair subsequent sleep unless performed within an hour of bedtime.[23] However, sleep disruption after evening competition in athletes, often attributed to increased arousal, is common.[14] It remains unclear whether high-intensity evening sport may elicit a similar effect.

This study found that neither academic-related nor sport-related time demands predicted any sleep outcome. These results are consistent with a previously published research abstract, which indicated that scheduled sporting and academic commitments are not associated with sleep duration in American student-athletes.[17] This finding contrasts with the common perception that the balance between academic and sport demands restricts sleep opportunity in student-athletes. This perception was echoed in our study, where over half of the participants reported that the workload associated with being a student-athlete restricted their sleep below their personal preference. Interestingly, student-athletes in our study reported a combined academic and sporting workload of 30.9 h per week, sharply contrasting with NCAA findings reporting a median of 68 h per week spent on academic and athletic requirements across all three divisions.[16] While sport-related time demands did not predict sleep outcomes in this study, it is important to note that, although physical activity is generally beneficial for sleep outcomes,[31] the physiological arousal from high training loads can act as a sport-specific sleep risk factor in performance athletes.[1] Therefore, it appears that the placement of these student-athlete demands poses a greater threat to sleep than the overall time devoted to student-athlete commitments.

These results suggest that morning sport scheduling may play a crucial role in contributing to poor sleep characteristics in British student-athletes, and efforts should be made to avoid scheduling sports activities during this time. In the United Kingdom, the academic structure typically involves lessons spread throughout the day rather than in consolidated blocks, a format that students often find challenging to adapt to.[32] Aligning academic and sport schedules into a shorter, more consistent period could offer a solution to both streamline the student-athlete day and improve sleep outcomes by eliminating early morning training sessions. In situations where structural changes are impractical due to logistical challenges (e.g., timetabling restrictions or lighting conditions), it becomes essential to equip student-athletes with resources to enhance sleep within the existing framework. Walsh et al.[1] recommend that all athletes receive sleep education due to its limited current implementation, with previous sleep education interventions showing promise in both athlete and student populations.[33,34] Meanwhile, student-athletes displaying poor sleep characteristics should undergo screening to identify whether they require referral to a sleep specialist. If not, efforts should focus on identifying individual-level factors and behaviors driving poor sleep and addressing them.[1]

4.1 | Limitations

The cross-sectional design employed means that findings can only be applied to the time of data collection. Sleep characteristics are temporally sensitive and fluctuate in response to various factors that can influence sleep; for example, higher PSQI scores have been observed in student-athletes during months with increased academic and sporting stressors,[35] while the prevalence of PSQI scores >5 was higher pre-exam than post-exam or during the semester in students.[36] While the sleep questionnaires employed are widely used and generic in their application, they have yet to be validated in student-athlete populations. Validated athlete-specific sleep questionnaires exist, such as the Athlete Sleep Screening Questionnaire.[26] However, they may not be suitable for student-athletes as academic-specific risk factors are not considered that may also contribute to poor sleep in this population. Finally, this study pooled all weekdays together for self-reported sleep timing and duration. While all sporting and academic activities were placed on weekdays in this sample, the timing and placement of these are likely to fluctuate day-to-day, and as such sleep may shift accordingly between weeknights. Therefore, there is a need for longitudinal study designs in future research to investigate social jetlag and sleep regularity throughout the week. Additionally, employing alternative sleep measurement methodologies, such as actigraphy, will offer a deeper understanding of sleep in student-athlete populations.[18]

5 | CONCLUSION

In summary, British student-athletes exhibit a high prevalence of poor sleep characteristics based on self-reported measures, aligning with previous findings in student-athletes from various nationalities. The sport and academic schedules occurring on weekdays, contributed to a pattern of social jetlag characterized by a phase advance in sleep timing and reduced sleep duration on weekdays compared to weekends. Logistic regression analyses revealed that the frequency of early morning training sessions (before 09:00) significantly predicted several sleep outcomes, even when controlling for participant characteristics. However, the frequency of late evening training sessions (after 21:00), as well as both academic-related and sport-related time demands, did not emerge as predictive factors for sleep outcomes.

6 | PERSPECTIVE

The key finding of this study was that an increased frequency of morning training sessions was predictive of poorer sleep outcomes. Therefore, it is important that sports coaches and administrators are aware of the impact of early morning sport on sleep, and the potentially harmful downstream effects of poor sleep on performance on the sports field and academic attainment in the classroom,[37,38] in addition to general health and wellbeing. Where sporting activity in the morning before academic lessons cannot be avoided, it is important to design alternative interventions that are specific to the student-athlete population and help improve sleep outcomes within a challenging structure.

ACKNOWLEDGEMENTS

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CONFLICT OF INTEREST STATEMENT

The authors report no competing interests to declare.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author, SMBW, upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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Appendix 12. The napping behaviours of British student-athletes (Wilson et al., 2023)

D2.S1.3 - 5 in 5 Free Communications - Multi: Sport and Performance and Physiology and Nutrition

D2.S1.3(1) The napping behaviours of British student-athletes

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Hartpury University, Gloucester, United Kingdom

Student-athletes are a population that display a high prevalence of poor sleep characteristics in response to sport- and academic-related sleep risk factors, and poor sleep may be harmful to sporting and academic performance (Kroshus et al., 2019, British Journal of Sports Medicine, 53(12), 731-736). Napping provides a means to supplement restricted nocturnal sleep. Therefore, the aim of this investigation was to examine the self-reported sleep characteristics and napping behaviours of British student-athletes. With institutional ethics approval, 157 participants (age range 16-25, 51.0% male) completed the Pittsburgh Sleep Quality Index (PSQI), Epworth Sleepiness Scale (ESS), and the Sleep Hygiene Index (SHI). Participants that reported napping also completed a modified version of a 6-item napping questionnaire (Lovato et al., 2014, PLoS ONE, 9(11):e113666). Associations between sleep questionnaires and napping were investigated using Pearson correlations. The results demonstrated that 100 participants (63.7%) reported napping ≥1 weekly and were classified as nappers. Amongst nappers, mean (±SD) weekly nap frequency was 2.5 ± 1.3 times. Most participants reported napping once (26%) or twice (31%) weekly (three: 24%; four: 14%; five or more times: 5%). Moderate significant associations with SHI ($r(98) = .423$, $P < 0.001$) and ESS ($r(98) = .417$, $P < 0.001$) global scores and nap frequency were observed, indicating poorer sleep hygiene behaviours and increased daytime sleepiness as nap frequency increased. Mean (±SD) nap onset time was 14:43 ± 02:09, with 45% of naps commencing between 14:00 and 16:00. Participants reported naps were more commonly initiated spontaneously (39%) rather than planned (13%), with 48% of responses reporting a mixture of both. Similarly, naps were ended spontaneously (42%) more often than using an alarm (28%), with 28% reporting a mixture. Only 28% of participants reported short nap durations of <30 minutes, whereas longer durations of 30-45 minutes (22%), 45-60 minutes (31%), and >60 minutes (19%) were more common. The most reported reason for napping was feeling sleepy during the day (58%), followed by the nap refreshing them (26%), having spare time (5%), avoiding feeling sleepy later (5%), with 6% providing other reasons. These results indicate that napping is a common practice amongst British student-athletes, but some napping behaviours do not align with sleep hygiene recommendations (Irish et al., 2015, Sleep Medicine Reviews, 22, 23-36). These are likely to be driven by poor behavioural practices and inappropriate scheduling of training and lessons, which should seek to be addressed through targeted sleep interventions.

Appendix 13. Application for ethical approval (ETHICS2021-117)

This appendix has been removed as it contains personal information.

Appendix 14. Participant information sheet and consent form (ETHICS2021-117)

HARTPURY

Participant Information Sheet

Assessing the Sleep Characteristics of Hartpury Student-Athletes

Invitation to Allow Use of Data Collected

My name is Sandy Wilson and I am a current PhD candidate at Hartpury University, and I would like to invite you to participate in this research study. Before making a decision regarding participation, it is important to understand the purpose of the research and what it will involve from you. Please read the following information carefully before deciding whether or not you wish to take part. Please do contact me (Alexander.Wilson@hartpury.ac.uk) if you have any questions, or if anything is unclear. Thank you for your time in considering participation.

Purpose of the Study

This study has three primary research aims: (a) Assess the subjective sleep characteristics of Hartpury student-athletes; (b) Establish whether sleep characteristics differ between under 18 and over 18 student-athletes; and (c) Initial exploration of the factors and behaviours underpinning observed sleep characteristics.

A significant number of student-athletes display poor sleep characteristics. Athletes and students face unique demands related to sport and study respectively that can negatively impact sleep quality, and student-athletes face a dual threat in attempting to balance these demands, alongside a mismatch between age related biological sleep preferences and societal structure. Research has demonstrated that certain elements integral to academic attainment, components of sport performance, and wellbeing can be impaired as a result of poor sleep quality. Therefore, it is imperative to improve sleep quality amongst student-athletes and enable behaviours that facilitate optimal sleep practices. This study is the first in a series of work that provide a rationale for the creation of a sleep education intervention for student-athletes.

Do you have to take part?

It is your decision whether or not to participate in this study. If you do participate, you will be asked to sign a consent form (on the next page). If you complete the survey but later wish to withdraw, you are free to do this without giving a reason up until the commencement of data analysis on 07/11/2022.

You will be provided a unique random ID at the start of the survey that will be required for withdrawal.

If you take part, what will you have to do?
You will be asked to complete a survey of approximately 15 minutes using Qualtrics survey software. This will comprise of four standardised questionnaires commonly used in sleep research (Pittsburgh Sleep Quality Index, Epworth Sleepiness Scale, Sleep Hygiene Index, and Reduced Morningness-Eveningness Questionnaire), alongside additional questions relevant to the research aims such as time demands, the scheduling of training and University teaching, and previous experience of sleep education. Questions will be a mix of multiple choice, slider, and text entry formats.

Possible risks of participation
There are no anticipated risks to participation

Possible benefits of participation
You will be contributing to the understanding of sleep characteristics in student-athletes, which will provide a rationale for the creation of a sleep education intervention for this population. Results will be disseminated through an infographic that summarises main findings, and will be available on Moodle.

What if something goes wrong?
If you are unhappy at any stage of the study please contact study supervisor and director of studies, Dr. John Parker, to raise your concerns (John.Parker@hartpury.ac.uk). You are also free to withdraw from the study up to the designated point of withdrawal without giving a reason by contacting me (Alexander.Wilson@hartpury.ac.uk).

Confidentiality
All information which is collected about you during the course of the research will be kept securely with the lead researcher. A unique randomised ID will be provided for you at the start of the survey, so no personal identifiers are used and you cannot be recognised from submitted data.

What will happen to the results?
The results will be used in my thesis for the fulfilment of my doctoral degree. A paper and electronic copy of the thesis will be kept at Hartpury. In addition to the sharing of results with participants mentioned above, findings will be presented to the wider academic community through presentations at research conferences and publication in an academic journal.

What to do next?

If you wish to participate in this study, please tick the box below. The next page will send you to the Participant Consent Form; once completed you will be able to access the survey.

Thank you for taking the time to read this information sheet.

Participant Consent Form

Assessing the Sleep Characteristics of British Student-Athletes

Please enter your personal details below

Participant name: ________

Address: ________

Contact number: ________

Hartpury email address: ________

I in the capacity as the individual listed, hereby grant consent for participation in this research, and give my permission for Sandy Wilson and fellow research supervisors to use the data obtained from this to be used and analysed over the course of the research study. I understand that data collected will be anonymous and that I cannot be identified from that point.

Please sign below

____

Appendix 15. Research data management plan (ETHICS2021-117)

This appendix has been removed as it contains personal information

Appendix 16. Risk assessment (ETHICS2021-117)

HARTPURY RISK ASSESSMENT

ACTIVITY / PROCESS ASSESSED: ………Research Study…………… DATE: …02/08/2022…………

DEPARTMENT: ……Sport…………………… ASSESSORS: ………Alexander Wilson………………………………..

HAZARD	AT RISK	CONTROLS	RISK RATING	OTHER PRECAUTIONS
Psychological risk – some questions relate to sleep health that may be uncomfortable to answer	Participants (Students)	Participants able to exit the survey at any time with no requirement for explanation	2	All surveys will also be anonymous at the point of data collection such that participants cannot be identified
			Review Date:	

Hazard and severity (1 = minor, 2 = serious, 3 = very serious / fatal)
Risk (likelihood: 1 = very unlikely, 2 = unlikely, 3 = likely / very likely)
Hazard x Risk = Hazard severity (1,2,3, = low, 4 = medium, 6+ = high)

Appendix 17. Statistically significant hierarchical regression models (*p* <.05) with no significant scheduling or time demand predictor (*p* >.05)

	ESS				Weekday bedtime				Weekend bedtime				Weekend waketime			
	B	B_{SE}	β	*t*	B	B_{SE}	β	*t*	B	B_{SE}	β	*t*	B	B_{SE}	β	*t*
Step 1: Fixed predictors																
(Intercept)	.03	3.18		.01	45.63	42.14		1.08	120.02	59.07		**2.03***	686.62	71.43		**9.61****
Age	.49	.18	.24	**2.75****	.62	2.35	.02	.26	.01	3.29	.00	.00	-.43	3.98	-.01	-.11
Chronotype	-.11	.09	-.10	-1.21	-8.03	1.26	-.47	**-6.39****	-9.25	1.76	-.40	**-5.26****	-9.04	2.13	-.33	**-4.25****
Residential Status	.14	.67	.02	.21	14.90	8.92	.13	1.67	1.27	12.51	.01	.10	5.97	15.13	.03	.39
Sex	-.73	.60	-.10	-1.21	-4.50	8.00	-.04	-.56	-11.00	11.21	-.08	-.98	-19.96	13.55	-.12	-1.47
Model fit	*F(4,152) = 2.131, R^2 = .053*				*F(4,152) = 12.165, R^2 = .242***				*F(4,152) = 7.597, R^2 = .167***				*F(4,152) = 5.546, R^2 = .127***			
Step 2: Added scheduling and time demand predictors																
(Intercept)	.54	3.38		.16	61.93	45.76		1.35	141.16	64.37		**2.19***	677.66	77.73		**8.72****
Age	.38	.19	.18	1.96	.59	2.60	.02	.23	-.76	3.65	-.02	-.21	-.32	4.41	-.01	-.07
Chronotype	-.18	.10	-.15	-1.83	-7.55	1.29	-.44	**-5.83****	-9.30	1.82	-.41	**-5.11****	-9.26	2.20	-.34	**-4.21****
Residential Status	-.03	.67	.00	-.05	17.31	9.03	.15	1.92	4.08	12.70	.03	.32	6.65	15.34	.04	.43
Sex	-.41	.64	-.06	-.64	-10.58	8.66	-.10	-1.22	-18.09	12.19	-.12	-1.48	-18.53	14.72	-.11	-1.26
AM sport	.32	.17	.17	1.92	-.48	2.26	-.02	-.21	.64	3.18	.02	.20	-2.12	3.83	-.05	-.55
PM sport	.50	.28	.15	1.80	-.34	3.77	-.01	-.09	2.32	5.31	.03	.44	-9.22	6.41	-.11	-1.44
Academic time	.05	.04	.12	1.29	-.97	.51	-.15	-1.88	-1.08	.72	-.13	-1.50	.24	.87	.02	.27
Sport time	.01	.05	.02	.26	-.15	.65	-.02	-.22	.88	.92	.08	.96	1.32	1.11	.10	1.19
Model fit	*F(8,148) = 2.444, R^2 = .117**				*F(8,148) = 6.615, R^2 = .263***				*F(8,148) = 4.168, R^2 = .184***				*F(8,148) = 3.212, R^2 = .148***			

Statistical significance: *p < .05; **p < .01

Abbreviations: ESS, Epworth Sleepiness Scale; B, unstandardised coefficient; B_{SE}, standard error of unstandardised coefficient; β, standardised coefficient.

Appendix 18. Statistically non-significant hierarchical regression models (p >.05)

	Weekday SOL				Weekend SOL				Weekend TST			
	B	B_{SE}	β	*t*	B	B_{SE}	β	*t*	B	B_{SE}	β	*t*
Step 1: Fixed predictors												
(Intercept)	13.77	11.84		1.16	16.199	10.686		1.516	512.56	66.34		**7.73****
Age	1.05	.66	.14	1.59	.627	.596	.091	1.053	-.82	3.70	-.02	-.22
Chronotype	-.51	.35	-.12	-1.45	-.299	.318	-.077	-.940	.80	1.98	.03	.41
Residential Status	-4.09	2.51	-.14	-1.63	-3.707	2.263	-.137	-1.638	3.20	14.05	.02	.23
Sex	-3.61	2.25	-.13	-1.61	-5.880	2.028	-.236	**-2.900****	-16.32	12.59	-.11	-1.30
Model fit	*F(4,152) = 2.163, R^2 = .054*				*F(4,152) = 2.741, R^2 = .067**				*F(4,152) = .603, R^2 = .016*			
Step 2: Added scheduling and time demand predictors												
(Intercept)	18.98	12.95		1.47	22.508	11.658		1.931	459.22	71.65		**6.41****
Age	.83	.74	.11	1.13	.341	.661	.049	.516	1.53	4.07	.04	.38
Chronotype	-.49	.37	-.11	-1.33	-.249	.330	-.064	-.756	.52	2.03	.02	.25
Residential Status	-3.58	2.56	-.12	-1.40	-3.373	2.300	-.125	-1.466	1.21	14.14	.01	.09
Sex	-4.59	2.45	-.17	-1.87	-6.450	2.207	-.259	**-2.922****	-10.11	13.57	-.07	-.75
AM sport	.18	.64	.03	.28	.417	.575	.065	.725	-5.23	3.53	-.14	-1.48
PM sport	-.83	1.07	-.06	-.78	-1.096	.962	-.094	-1.140	-3.02	5.91	-.04	-.51
Academic time	-.16	.15	-.11	-1.14	-.115	.131	-.081	-.882	1.13	.80	.13	1.40
Sport time	.12	.18	.06	.67	-.005	.166	-.002	-.028	.72	1.02	.06	.71
Model fit	*F(8,148) = 1.324, R^2 = .067*				*F(8,148) = 1.710, R^2 = .085*				*F(8,148) = 1.034, R^2 = .053*			

Statistical significance: *p < .05; **p < .01

Abbreviations: SOL, sleep onset latency; TST, total sleep time; B, unstandardised coefficient; B_{SE}, standard of unstandardised coefficient;

β, standardised coefficient.

Appendix 19. Irregular sleep/wake patterns in student-athletes exposed to early morning training (Wilson et al., 2025)

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Irregular sleep/wake patterns in student-athletes exposed to early morning training

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ABSTRACT

This study aimed to examine the sleep parameters and sleep/wake regularity of a cohort of student-athletes who start training between 06:30 and 07:00. Twenty-one male Rugby Union players, aged 21 ± 2 years and competing at a national level, were assessed using actigraphy over two weeks, and the Athlete Sleep Screening Questionnaire (ASSQ). Sleep/wake regularity was calculated using the Sleep Regularity Index (SRI). Wilcoxon signed-rank tests showed that nocturnal sleep preceding morning training had a significantly shorter sleep duration (1.8 hr, $r = .67$), and advanced sleep onset (0.9 hr, $r = .50$) and sleep offset times (3.2 hr, $r = .85$) compared to nocturnal sleep preceding free days. The variability of training demands resulted in an inconsistent sleep pattern between consecutive days, resulting in a median SRI score of 67.0 (interquartile range: 17.0). Pearson correlations revealed that lower SRI was significantly associated with a higher daily sleep duration including naps ($r = -.62$), delayed sleep onset ($r = -.50$) and sleep offset ($r = -.60$), and a later chronotype assessed using the ASSQ ($r = .52$). These findings indicate that early morning training is a factor contributing to irregular sleep/wake patterns in student-athletes, and where feasible should be scheduled at an alternative time.

KEYWORDS

Athletes; chronotype; sleep; sleep regularity; students

Introduction

Sleep has garnered growing attention within student-athlete populations, with the National Collegiate Athletic Association (NCAA) establishing a task force to review current evidence and shape future practices to support healthy sleep habits (Kroshus et al., 2019). Previous research has indicated that student-athletes exhibit a high prevalence of undesired sleep characteristics, including poor perceived sleep quality (Leduc et al., 2020; Mah et al., 2018; Stephenson et al., 2022), sleep durations under the public health recommendations of seven to nine hours per night for young adults (Carter et al., 2020; Driller et al., 2017; Hirshkowitz et al., 2015; Mah et al., 2018), and poor sleep hygiene behaviours (Driller et al., 2017). In addition, about one-quarter of sleep screened student-athletes present with moderate to severe sleep disturbances (Rabin et al., 2020; Rebello et al., 2022). The reasons underpinning these findings are diverse, with both sport-related risk factors, such as travel to and from competition (Walsh et al., 2021), and academic-related risk factors, such as emotional and academic stress (Lund et al., 2010). Accordingly, student-athletes should be considered a unique population within sleep research.

The scheduling of training, particularly when placed early in the morning, constitutes a significant sleep risk factor in athletes (Walsh et al., 2021). In elite athletes, an advance in morning training timing significantly reduces total sleep time the prior night (Sargent et al., 2014), with this finding supported by subsequent research on student-athletes (Benjamin et al., 2019; Merfeld et al., 2022). The scheduling of training early in the morning is common amongst student-athletes and stems from the logistical necessity of fitting training around academic teaching hours. However, this timing conflicts with the changes in chronotype that occur during young adulthood, marked by a peak phase delay at this age (Roenneberg et al., 2004). Consequently, adapting to early morning starts may pose particular challenges for student-athletes. Furthermore, it has been shown that athletes are more likely to participate in sports that align with their chronotype, and the misalignment in chronotype and training timing in student-athletes could result in challenges adapting to this schedule and hinder progression to higher performance levels in the future (Lastella et al., 2016).

Walsh et al. (2021) have noted that the timing of training and competition can disrupt consistent sleep patterns in performance athletes. Maintaining a consistent sleep/wake pattern is an important component of healthy sleep to support the circadian process of sleep regulation, with a recent consensus statement indicating that regular sleep timing is important for various health and performance outcomes (Sletten et al., 2023). Additionally, irregular sleep/wake patterns have been associated with poorer academic attainment (Phillips et al., 2017). Previous sleep research in athletes has often presented sleep parameters as an average value over the monitoring period without reporting any measure of within-person variability between days (Halson et al., 2022). A recent systematic review identified only 16 studies reporting within-person variability in sleep for athletes (Kemp et al., 2023). The most common metric used in these studies is intra-individual variability, where sleep parameters on each night are compared to an individual's average sleep pattern (Fischer et al., 2021), and it is evident that athletes exhibit high intra-individual

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variability in sleep parameters (Kemp et al., 2023; Nedelec et al., 2018). A study on British student-athletes revealed greater intra-individual variability in sleep parameters compared to non-athlete students (Leduc et al., 2020), while elite junior athletes exhibited greater intra-individual variability in time in bed and sleep duration measures compared to elite and sub-elite senior athletes (Caia et al., 2017). Therefore, student-athletes may be more susceptible to greater sleep variability than other athlete groups.

One potential limitation in applying intra-individual variability to student-athlete groups is that it functions as an 'overall' metric, establishing variability in comparison to an individual mean across a monitoring period. To gauge day-to-day variability, a 'consecutive' measure is required that may be more reflective of circadian disruption (Fischer et al., 2021). This is especially pertinent for a student-athlete population, where significant variations in daily schedules may influence sleep parameters between consecutive days. The Sleep Regularity Index (SRI) is a novel consecutive metric that calculates the probability of an individual being in the same sleep/wake state at time points 24 hours apart (Phillips et al., 2017). Another advantage of assessing sleep across a 24-hour window is the ability to capture daytime napping, which is a common practice amongst student-athletes with up to 80% reporting napping at least once per week (Mah et al., 2018; Stephenson et al., 2022), and often employed by athletes to supplement lost nocturnal sleep (Walsh et al., 2021).

The SRI has previously been used to evaluate sleep regularity in University students (Phillips et al., 2017; Windred, Stone, et al., 2021) and elite athletes (Alves Facundo et al., 2022; Halson et al., 2022; Teece et al., 2024). Understanding the sleep/wake patterns of student-athletes has important implications for sport stakeholders, and can help make informed decisions on the timing of training sessions to facilitate healthy sleep practices, including regular sleep/wake timing. However, despite a rationale to anticipate irregular sleep/wake patterns in student-athletes, it has not been examined using a consecutive measure of sleep regularity in empirical research. Therefore, this study aimed to; (1) present the sleep parameters (including daytime napping) and SRI of a cohort of student-athletes, (2) examine differences in sleep parameters when categorised by day of the week and the presence or absence of morning training, and (3) examine the relationship between SRI and sleep parameters, including napping.

Methods

Participants

Twenty-eight male student-athletes were recruited from a single Rugby Union team competing in the British Universities and Colleges Sport Super Rugby league, the highest level of university competition in the United Kingdom, and gave informed consent to participate in the study. Student-athletes were excluded from participation if they had any previous history of a sleep-related disorder, current medication that may interfere with sleep, or any concussion since the start of the competitive season. These were self-reported and checked against medical records kept by team staff. Participants were required to provide valid actigraphy data for ≥5 days of overlapping epochs of actigraphy to enable an accurate assessment of sleep regularity for inclusion (Fischer et al., 2021). Six participants were excluded for insufficient valid actigraphy data, one of which was related to a device fault. One further participant was excluded for a suspected irregular sleep wake rhythms disorder (SRI = 3.9 with multiple sleep bouts and fragmented nocturnal sleep), with the participant signposted towards their General Practitioner.

Twenty-one participants were included in statistical analyses with a mean (±SD) age of 21 ± 2 years, height of 1.80 ± 0.17 m, and mass of 97.9 ± 24.5 kg. The majority of the sample identified as White ($n = 18$), while three participants identified as Black, Black British, Caribbean, or African. The level of study varied across undergraduate 1st year ($n = 7$), 2nd year ($n = 6$), 3rd year ($n = 5$) and postgraduate ($n = 3$), with all participants residing off-campus. The sample included both forwards ($n = 11$) and backs ($n = 10$) playing positions.

This study expanded upon a pilot study with 10 participants that are not included in this dataset. A conference proceeding summarising the pilot has been previously published (S. Wilson et al., 2023). The study received approval from Hartpury University Ethics Committee (ETHICS2023-01).Participants were offered individual feedback and entered into a prize draw for three £25 gift vouchers upon study completion.

Procedure

Data collection was conducted between 9 October 2023, and 23 October 2023, during the competitive sporting season and academic teaching weeks. The training and match schedule during the data collection period is detailed in Table 1. Recovery sessions on Thursday were optional, and Saturday conditioning sessions were completed at a self-selected time

Table 1. Training and match schedule of participants split by day.

Day of week	Session type	Timing
Monday	Field and gym training	Week 1 and Week 2: 06:30–10:30 and 12:00–12:30
Tuesday	Field training	Week 1: 06:45–08:30 Week 2: 06:30–08:30
Wednesday	Match (including preparation and travel)	Week 1: 14:00–22:00 (away, kick-off 18:00) Week 2: 17:15–21:00 (home, kick-off 18:30)
Thursday	Recovery – Medical and Yoga	Self-scheduled
Friday	Field and gym training	Week 1: 06:30–10:30 Week 2: 07:00–10:30
Saturday	Conditioning	Self-scheduled
Sunday	Rest day	–

with an approximate duration of 1.5 hr. All other sessions were mandatory. The academic timetable commenced no earlier than 09:30 with no lessons scheduled on the Wednesday before matches.

Participants were instructed to maintain their usual sleep habits throughout the study. On each morning, participants completed a short questionnaire including a shortened version of the core Consensus Sleep Diary (Carney et al., 2012), and self-reported training attendance and daytime napping. This was administered in both paper and online formats based on participant preference.

Measures

Before data collection, participants completed the Athlete Sleep Screening Questionnaire (ASSQ) (Samuels et al., 2016). The ASSQ is a validated sleep screening tool for athlete populations (Bender et al., 2018; Samuels et al., 2016). Six Likert scale questions are summed to provide a sleep difficulty score (ASSQ-SDS), and can be used to categorise athletes into none (0–4), mild (5–7), moderate (8–10) and severe (11–17) sleep problem groups. Chronotype is estimated through four Likert scale questions that are summed (ASSQ-Chronotype), and range from 0 (greatest eveningness) to 14 (greatest morningness). ASSQ-Chronotype does not cluster participants into chronotype groups, but can be used to identify extreme evening-types (ASSQ-Chronotype ≤4). The ASSQ includes additional modifier questions related to sleep-disordered breathing, travel-related disturbance, napping, caffeine consumption and electronics use which were not used for analyses.

Actigraphy-derived sleep parameters were collected using GENEActiv monitors (Activinsights, Cambridge, United Kingdom). These record movement through a tri-axial accelerometer with a range of ± 8 *g*, light wavelength (range: 400–1100 nm), light intensity (range: 0–3000 lux), and temperature (range: 0–60 °C). Monitors sampled at 40 Hz to allow sufficient storage capacity over the data collection period. Participants were asked to wear monitors on the non-dominant at all times except for contact training and to use the event marker button to denote sleep onset and offset. Data was extracted and saved in raw format files (.bin) using GENEActiv PC software v3.3.

The GGIR v3.0 R-package was used to process raw accelerometer data in RStudio (Migueles et al., 2019). Initial signal processing included automatic calibration using local *g* as a reference, detection of abnormal values, non-wear detection, and the quantification of dynamic wrist acceleration using the Euclidean Norm Minus One metric in 5-second epochs (Van Hees et al., 2013, 2015). The Sleep Period Time (SPT) was determined using a pre-defined analysis pathway incorporating event markers, raw accelerometer and light data, and/or sleep diary entries. The full analysis pathway is presented in the Supplementary File (Figure S1). This process differentiated sustained inactivity bouts (SIBs) classified as sleep from sedentary periods outside the SPT window. SIB identification utilised the Van Hees et al. (2015) algorithm, which classifies periods where wrist rotation (z-axis) does not change by > 5° for a minimum of 5 minutes. The algorithm has been validated using GENEActiv monitors with an overall accuracy of 83% (sensitivity: 91%, specificity: 45%) compared to polysomnography (Van Hees et al., 2015). Subsequent research has indicated comparable outcomes to other research-grade actigraphy monitors (Plekhanova et al., 2020). The same analysis strategy was applied to detect daytime napping, with the SPT for a given nap set using sleep diary entries.

The actigraphy-derived sleep parameters examined for each sleep episode (including naps) were: *sleep onset* (hh:mm), the first instance of sleep in the SPT; *sleep offset* (hh:mm), the final instance of sleep in the SPT; and *Total Sleep Time* (TST; hr), the total amount of sleep within the SPT. In addition, the following parameters were extracted for nocturnal sleep episodes: *sleep period* (hr), the time between sleep onset and sleep offset; *Wake After Sleep Onset* (WASO, hr), the time awake between sleep onset and sleep offset; *sleep efficiency* (SE, %), the proportion of the sleep period spent asleep (i.e. TST/sleep period); and *Sleep Onset Latency* (SOL, hr), the period of time between reported bedtime and sleep onset. The *cumulative sleep duration* across each 24-hour from 12:00 to 12:00 was calculated by adding the TST of all sleep episodes including naps.

Data processing

The Sleep Regularity Index (SRI) was used as a measure of the regularity of sleep/wake patterns (Phillips et al., 2017). The SRI calculates the probability of being in the same sleep/wake state at any given time point 24-hours apart and averaged across the study duration. SRI is scaled to a theoretical range between −100–100, but in practice typically ranges from 0 (random) – 100 (perfect regularity) using the formula:

$$SRI = -100 + \frac{200}{M(N-1)} \sum_{j=1}^{M} \sum_{i=1}^{N} \delta\left(s_{i,j}, s_{i+1,j}\right)$$

where M = number of daily epochs; N = number of days; $s_{i,j} = 0$ for sleep and 1 for wake; and $\delta\left(s_{i,j}, s_{i+1,j}\right) = 1$ when $s_{i,j} = s_{i+1,j}$ and 0 when $s_{i,j} \neq s_{i+1,j}$. SRI was calculated using the sleepreg R-package (Windred, Stone, et al., 2021). A binary sleep-wake format was used, with diurnal shifts in the sleep/wake cycle assessed using the actigraphy-derived sleep onset and offset times.

Participants were split by napping status for further analyses to establish the relationship with SRI scores. Twelve participants napped at least once in the study duration and were considered 'nappers', with the remaining nine considered 'non-nappers'

Statistical analysis

The distribution of sleep onset, sleep offset, WASO, SE and SOL were considered non-normal (Shapiro-Wilk, $p < .05$). SRI scores were also treated as non-normal due to negative skew, confirmed through visual inspection of Q-Q plots and in alignment with previous research (Windred, Jones, et al., 2021). Descriptive analyses of sleep parameters are presented as median (IQR). Differences between nights preceding morning training and free mornings were assessed using Wilcoxon signed-rank tests. Differences in sleep parameters across days of the week were evaluated with Friedman tests, and significant results underwent post-hoc analysis using Wilcoxon signed-rank tests for each day-pair, with Bonferroni correction applied for multiple tests to determine p-value significance. A Mann-Whitney U test was performed to compare SRI between napper and non-napper groups. Pearson bivariate correlations assessed the relationship between SRI and other sleep parameters, with bias-corrected and accelerated 95% confidence intervals (1000 samples) reported. Data analysis was performed using R (v4.1.3) and SPSS (v29.0.0) statistical software.

Results

Athlete sleep screening questionnaire

The mean ASSQ-SDS was 6 ± 2, with players categorised into none ($n = 5$), mild ($n = 13$) and moderate ($n = 3$) sleep problem groups. No participants presented with severe sleep problems. The mean ASSQ-Chronotype score was 7 ± 2, with one student-athlete classed as having an extreme evening chronotype (ASSQ-Chronotype ≤4).

Sleep parameters

Table 2 presents actigraphy-derived nocturnal sleep parameters across all nights. At the person-level, 14/21 (66.7%) displayed a mean TST of <7 hours per night. For the napping subgroup ($n = 12$), The median nap TST was 1.91 hr (1.28 hr) with a nap onset of 13:28 (02:33) and a nap offset of 15:11 (03:30). The median cumulative sleep duration was 6.90 hr (2.44 hr), with 9/21 (42.9%) participants displaying a mean cumulative sleep duration of <7 hours across the study.

A statistically significant difference in cumulative sleep duration was observed based on the day of the week (Friedman, $\chi^2(6) = 51.531$, $p < .001$; Figure 1(a)). The post-hoc analysis identified significant differences in eight day-pairs. Furthermore, both sleep onset ($\chi^2(6) = 32.857$, $p < .001$) and sleep offset ($\chi^2(6) = 62.571$, $p < .001$) times significantly varied depending on the day of the week, with significant post-hoc differences observed between 7 and 12 day-pairs for onset and offset respectively (Figure 1(b)). Additional significant differences were found between eight day-pairs for the sleep period ($\chi^2(6) = 29.036$, $p < .001$), nine day-pairs for TST ($\chi^2(6) = 29.036$, $p < .001$), and four day-pairs for WASO ($\chi^2(6) = 18.429$, $p = .005$). No significant day-pair differences were identified for SE following post-hoc analysis ($\chi2(6) = 13.250$, $p = .039$) and SOL ($\chi2(6) = 1.433$, $p = .963$). Complete results for post-hoc analysis assessing day-pair differences are presented in Table 3.

Among the seven examined nocturnal sleep parameters, 37/41 (90.2%) day-pairs with a significant difference occurred between a night preceding morning training (Monday, Thursday, and Sunday) and a night preceding free mornings (Tuesday, Wednesday, Friday, and Saturday). When results are grouped accordingly, nights preceding morning training exhibited a shorter sleep period (2.13 hr), shorter TST (1.80 hr), shorter WASO (0.26 hr), earlier sleep onset (00:53), and earlier sleep offset (03:12) compared to nights preceding free mornings (Wilcoxon, all $p < .001$; Table 2). No significant differences were observed between groups for SE (1.5% increase preceding morning training, $p = .053$). In total, 93/109 (85.3%) of nights preceding morning training had a TST <7 hr, compared to 41/121 (33.8%) of nights preceding free mornings.

Sleep regularity

The student-athletes exhibited a median (IQR) SRI of 67.0 (17.0), with scores ranging between 38.1 and 79.8. Participants who napped had a significantly lower median SRI of 57.9 (15.9) compared to a median of 73.6 (9.1) in non-nappers (Mann-Whitney, $z = -2.88$, $p = .004$; Figure 2(a)).

Pearson bivariate correlations revealed an inverse correlation between SRI and cumulative sleep duration ($r = -.62$, $p = .003$, 95%CI [−.79, −.44]; Figure 2(b)). However, when considering only nocturnal sleep, TST was not associated with SRI ($r = -.01$, $p = .949$, 95%CI [−.64, .54]). Lower SRI scores were also significantly inversely associated with a delayed sleep onset ($r = -.50$, $p = .022$, 95%CI [−.75, −.03]) and sleep offset ($r = -.60$, $p = .004$, 95%CI [−.82, −.37]), but not significantly associated with sleep period ($r = .10$, $p = .662$, 95%CI [−.52, .59]), SE ($r = -.34$, $p = .134$, 95%CI [−.71, .12]), WASO ($r = .33$, $p = .147$, 95%CI [−.13, .65]), or SOL ($r = -.17$, $p = .453$, 95%CI [−.59, .38]). With respect to the ASSQ, SRI was positively associated with ASSQ-Chronotype score ($r = .52$, $p = .016$, 95%CI [.02, .81]), indicating lower SRI scores in student-athletes with more evening-type chronotypes. ASSQ-SDS was not associated with SRI ($r = -.31$, $p = .172$, 95%CI [−.57, .02])).

Discussion

The purpose of this study was to examine sleep/wake regularity in student-athletes that are exposed to early morning training.

Table 2. Nocturnal sleep parameters for all nights, and split by nights preceding morning training and preceding free mornings.

Variable	All nights ($n = 230$)	Nights preceding morning training ($n = 109$)	Nights preceding free mornings ($n = 121$)	Morning training vs. free mornings effect size (r)
Sleep period (hr)	7.48 (2.59)	6.73 (1.37)	8.86 (2.06)	.69 (large)*
TST (hr)	6.67 (2.19)	5.86 (1.32)	7.66 (1.85)	.67 (large)*
WASO (hr)	0.85 (0.65)	0.72 (0.42)	0.98 (0.72)	.49 (medium)*
SE (%)	88.7 (6.7)	89.6 (6.1)	88.1 (7.1)	.19 (small)
Sleep onset (hh:mm)	23:37 (01:40)	23:07 (01:21)	00:00 (01:50)	.50 (large)*
Sleep offset (hh:mm)	07:08 (03:17)	05:45 (00:30)	08:57 (01:32)	.85 (large)*
SOL (hr)	0.08 (0.10)	0.08 (0.09)	0.08 (0.10)	.08 (negligible)

Data presented as median (interquartile range). Abbreviations: TST = total sleep time; WASO = wake after sleep onset; SE = sleep efficiency; SOL = sleep onset latency.
*Denotes significant difference between groups ($p < .05$). Effect sizes (r) interpreted using guidelines by Cohen (1988).

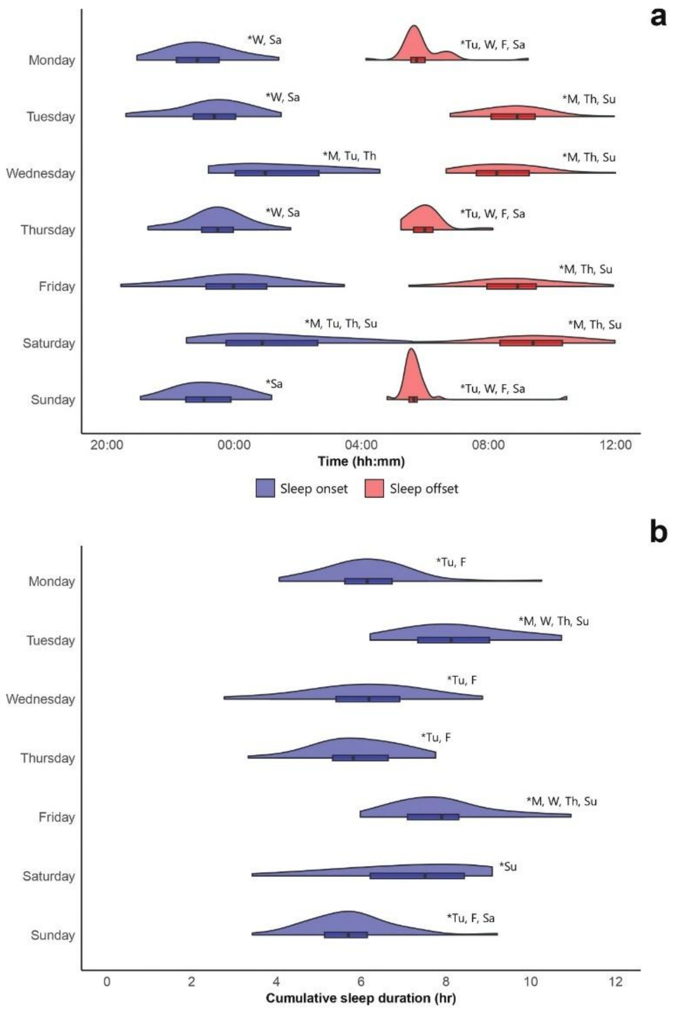

Figure 1. Violin plots demonstrating the distribution of **(A)** nocturnal sleep onset and offset times, split by day of the week, and **(B)** cumulative sleep duration including napping *denotes statistically significant difference in post-hoc Wilcoxon rank-sum test with Bonferroni adjustment applied to the *p*-value for multiple tests ($p < .00238$). Abbreviations: *M* = Monday; Tu = Tuesday; W = Wednesday; Th = Thursday; F = Friday; Sa = Saturday; Su = Sunday.

When assessed using the SRI, student-athletes displayed irregular sleep/wake patterns in response to changing daily training demands, with nights preceding morning training exhibiting advanced sleep onset and offset times, and shorter sleep durations. Additionally, SRI was significantly lower in student-athletes that napped compared to non-nappers, and a lower SRI was significantly associated with greater eveningness in chronotype assessed using the ASSQ, increased cumulative sleep duration, and delayed sleep onset and offset times.

The sleep parameters highlight a clear disparity between nights preceding morning training and free mornings. This observation aligns with previous findings in NCAA student-athletes that showed a significant reduction in TST on nights preceding morning training (Merfeld et al., 2022). While student-athletes attempted to compensate for the early start enforced by training by advancing sleep onset by 0.88 hours on nights preceding morning training, this adjustment did not fully compensate for the advance in sleep offset, which exceeded 3 hours. To fully compensate for morning training, a student-athlete wishing to wake 05:30 in advance of training at 06:30 and achieve a sleep period of 8 hours would need to fall asleep by 21:30. However, this may not be feasible due to both homeostatic (insufficient sleep pressure) and circadian (high alertness) processes at this time (Borbély et al., 2016), in addition to any academic, social, or work demands in the late evening. With respect to sleep durations, both the median TST of 6.67 hours and cumulative sleep duration of 6.90 hours fall below public health recommendations for young adults (Hirshkowitz et al., 2015), indicating that many student-athletes may not be meeting their optimal sleep needs. The notable differences in sleep parameters between days reflect the unique scheduling of the student-athlete day, which

Table 3. Post-hoc analysis of Wilcoxon signed-rank tests to assess between-day differences in actigraphy-derived sleep outcomes.

Day-pair	Sleep period	TST	WASO	SE	Sleep onset	Sleep offset	SOL	Cumulative sleep duration
Mon-Tue	−4.924*	−4.895*	−4.155*	−1.617	−1.777	−5.373*	−.966	−4.895*
Mon-Wed	−.678	−.330	−2.381	−2.902	−3.632*	−4.015*	−.141	−.330
Mon-Thu	−1.410	−1.205	−.966	−.470	−2.317	−1.325	−1.244	−1.205
Mon-Fri	−4.390*	−4.311*	−2.704	−.901	−2.948	−5.110*	−.761	−4.422*
Mon-Sat	−2.787	−2.138	−1.970	−1.129	−4.373*	−4.493*	−.757	−2.883
Mon-Sun	−1.523	−1.911	−.598	−1.065	−1.359	−1.599	−1.178	−1.507
Tue-Wed	−3.424*	−3.493*	−.817	−.852	−3.354*	−.678	−.465	−3.493*
Tue-Thu	−5.086*	−5.018*	−4.351*	−2.146	−.607	−5.086*	−.422	−5.018*
Tue-Fri	−1.245	−.638	−1.416	−1.330	−2.228	−.721	−.154	−1.179
Tue-Sat	−2.595	−2.571	−1.441	−.553	−4.036*	−1.802	−.795	−2.475
Tue-Sun	−5.143*	−4.595*	−3.063*	−.377	−.280	−4.918*	−.286	−5.143*
Wed-Thu	−1.894	−.539	−3.007	−3.007	−3.945*	−4.015*	−.310	−.539
Wed-Fri	−2.972	−2.510	−.391	−1.569	−2.450	−1.025	−.653	−3.215*
Wed-Sat	−1.929	−2.275	−3.92	−.941	−.156	−2.624	−.227	−2.381
Wed-Sun	−1.721	−.392	−1.964	−1.547	−3.010	−3.294*	−.259	−1.199
Thu-Fri	−4.796*	−4.292*	−3.377*	−1.655	−1.188	−4.967*	−.392	−4.710*
Thu-Sat	−2.739	−3.162*	−2.866	1.816	−3.556*	−4.397*	−.127	−2.811
Thu-Sun	−.231	−.874	−1.940	−2.111	−1.184	−2.915	−.075	−.812
Fri-Sat	−1.730	−1.874	−.312	−.793	−2.402	−1.257	−.162	−1.874
Fri-Sun	−4.783*	−4.717*	−1.765	−.648	−2.065	−4.444*	−.661	−4.717*
Sat-Sun	−3.147*	−3.123*	−1.689	−.317	−3.111*	−4.015*	−.200	−3.123*

Data presented as Wilcoxon signed-rank Z-score. Abbreviations: TST = total sleep time; WASO = wake after sleep onset; SE = sleep efficiency; Mon = Monday; Tue = Tuesday; Wed = Wednesday; Thu = Thursday; Fri = Friday; Sat = Saturday; Sun = Sunday.
*Denotes significant difference between day-pair at Bonferroni-corrected significance level ($p < .00238$).

involves sport training and competition distributed throughout the week, along with academic and social demands (Brauer et al., 2019). This contrasts with a more typical working schedule where demands are consistent over multiple consecutive days, creating a sleep pattern resembling social jetlag on a daily basis in student-athletes. These increased levels of variability can prevent the establishment of consistent sleep/wake patterns, impacting healthy circadian regulation (Wittmann et al., 2006).

The SRI scores observed indicate that the student-athletes in this study exhibit some of the most irregular sleep/wake patterns among healthy populations. All participants had SRI scores below the median of 81.0 observed in the British population using data from the UK Biobank (Windred, Jones, et al.,

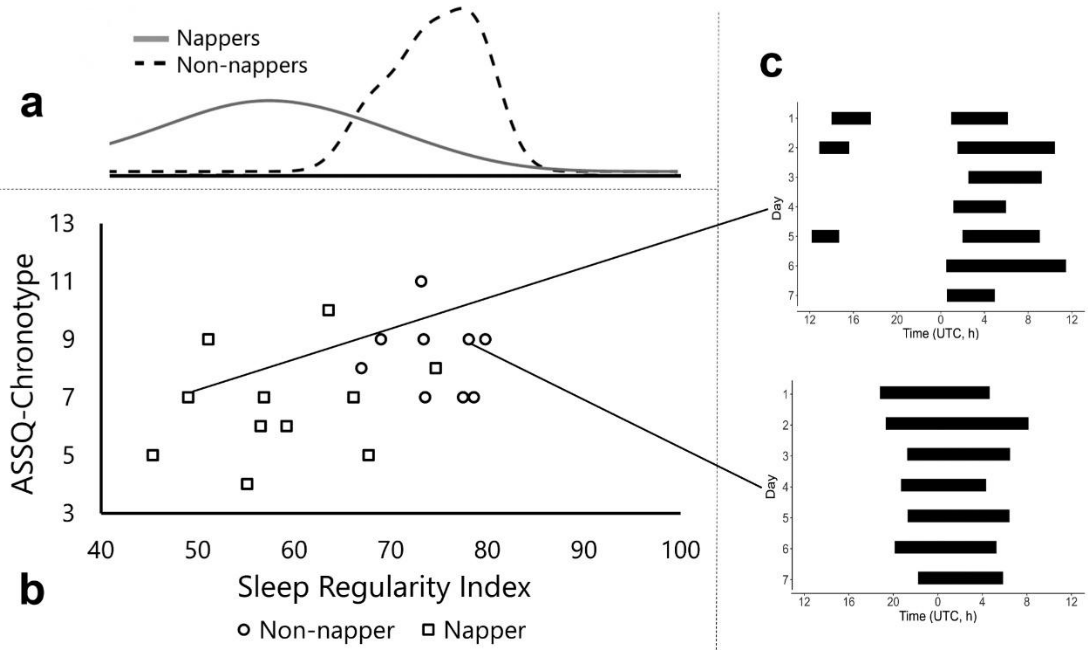

Figure 2. (a) Smoothed kernel density estimation of SRI student-athletes in the study classified as nappers and non-nappers; (b) Scatter plot highlighting the positive relationship between SRI and ASSQ-Chronotype, with data points split by napping status; (c) Example raster plots of two participants displaying differing SRI scores and napping status.

2021), whilst 9/21 participants (42.9%) presented an SRI that would place them in the lowest 10th percentile (SRI <65.1). Previous studies on university students in Australia (mean SRI = 79.9) (Windred, Stone, et al., 2021) and the United States (mean SRI = 73) (Phillips et al., 2017) also demonstrated greater sleep/wake regularity. The low SRI observed also aligns with previous findings by Leduc et al. (2020), demonstrating greater sleep variability in British student-athletes compared to non-athlete peers (Leduc et al., 2020), suggesting that the combination of performance sport and academic study can lead to sleep/wake irregularity. The SRI in this study was notably lower than observed by Halson et al. (2022) in a cohort of elite athletes (median SRI = 85.1) and by Teece et al. (2024) in professional rugby union players (median SRI = 76.4), although only nocturnal sleep episodes were considered in these studies However, Alves Facundo et al. (2022) demonstrated lower SRI scores in national (mean SRI = 68.7) and regional (mean SRI = 73.8) level athletes compared to international athletes (mean SRI = 80.1)). The difference between groups may be attributed to the additional demands on sub-elite athletes, including work and/or education commitments, as is often the case for student-athletes (Brauer et al., 2019). Additionally, lower SRI values were found in team sports compared to individual sports and in male athletes compared to females (Alves Facundo et al., 2022), providing further rationale for the irregular sleep/wake patterns present within this study.

When considering the relationship between SRI and sleep parameters, we observed an inverse relationship between SRI and sleep onset, sleep offset, and cumulative sleep duration, while participants classified as nappers had a lower SRI than non-nappers. However, no relationship was found between TST and SRI. This finding partially contrasts with previous research by Phillips et al. (2017), which showed greater daytime sleep and delayed sleep timing in irregular sleepers but found no relationship between cumulative sleep duration and SRI . Therefore, it appears that naps were used to add to nocturnal sleep, rather than compensate for lower nocturnal sleep than non-napping peers. However, this practice comes with the consequence of lower sleep regularity due to the variable placement and duration of naps during the day. It is unclear whether the potential benefit of increasing cumulative sleep duration through napping – in a population where sleep durations often fall below public health recommendations (Hirshkowitz et al., 2015) – outweigh any negative effects of the subsequent reduction in sleep regularity and requires attention in future research. In addition, while shorter naps of 10–20 minutes are recommended for adults with regular sleep/wake schedules (Milner & Cote, 2009), the longer naps observed in our study may result from restricted nocturnal sleep opportunity, as demonstrated by the advanced sleep offset times and shortened TST on nights preceding morning training.

SRI was also significantly associated with ASSQ-Chronotype, revealing that a later chronotype was associated with greater sleep/wake irregularity. While student-athletes may generally display a greater tendency towards early chronotypes than non-athlete students (Litwic-Kaminska & Kotysko, 2020), age-related changes in chronotype mean that a substantial number of student-athletes will still present with later chronotypes (Roenneberg et al., 2004). Although the ASSQ-Chronotype does not enable grouping of participants, the results do not indicate any skew towards morning-types, in contrast to other elite athlete groups that train in the morning in response to adaptation to early morning starts or being drawn towards sports that match their own chronotype (Lastella et al., 2016; Rae et al., 2015). The impact of aligning the timing of sport training and competition to circadian preferences is currently unclear. However, current evidence suggests some favourable outcomes, such as reduced perceived exertion and improved performance on standardised physical tests (Lastella et al., 2021; Roveda et al., 2020).

It is evident from our results that the observed sleep/wake irregularity in student-athletes has important implications and necessitates additional consideration. At a population level, greater variation in sleep timing has been associated with various health concerns, including physical, mental, and metabolic health (Sletten et al., 2023), in addition to all-cause mortality (Omichi et al., 2022). Furthermore, research by Phillips et al. (2017) found a relationship between lower SRI scores and academic performance , possibly linked to experimental findings showing greater morning sleepiness and heightened negative mood states in the evenings when sleep variability is high (Sun et al., 2023). However, it is currently unclear how SRI is related to components of sports performance. Our findings underscore the importance of future research exploring sleep in student-athletes to consider sleep across the 24-hour day and utilise measures of sleep variability (Kemp et al., 2023; Nedelec et al., 2018).

There is a need to explore changes that can be made at the individual, social, and societal levels to support regular sleep in student-athletes (Grandner, 2019). For instance, a previous sleep workshop intervention that allowed student-athletes to self-select a sleep behaviour to change showed that maintenance of a more consistent sleep/wake cycle was the most common selection (Kaier et al., 2016). Future studies should utilise behaviour change theory to identify barriers to achieving consistent sleep (Wilson et al., 2024). However, achieving a meaningful change may be challenging with the continued scheduling of training in the morning, and therefore a more effective social-level change could be to adjust training timings to align with age-related changes in chronotype. Delayed start times in school settings have proven effective in improving sleep and classroom performance (Watson et al., 2017), prompting the need to explore similar changes among student-athletes.

There are limitations to the present study that should be considered. Firstly, academic scheduling was not considered as lessons on all days except Thursday were preceded by sports training. However, earlier class start times have been associated with unfavourable changes to sleep/wake behaviours and poorer academic attainment (Yeo et al., 2023), and as such could have influenced sleep on a Wednesday night. Secondly, all student-athletes resided off-campus during the study. Travelling to the training venue likely enforced an earlier sleep offset time than may have been present if residing on-site, and a comparison between accommodation locations warrants future research. Thirdly, the timing and location of Wednesday matches differed between the two weeks. This did not result in any significant change in sleep parameters between subsequent nights, although greater discrepancies in competition timing are present throughout the season and can influence sleep parameters in athletes (Sargent & Roach, 2016). Lastly, the study results may not be fully representative of the entire student-athlete population. For instance, student-athletes who train in the evening after lessons may align better with age-related changes in chronotype (Roenneberg et al., 2004), whilst between-sex chronobiological differences mean that morning training is less disruptive to sleep in female groups (Power et al., 2023). Therefore, future research should examine sleep/wake regularity in female student-athlete groups, and the influence of academic scheduling in student-athlete groups that do not have training sessions prior to lessons.

Conclusion

The current study has been the first to assess sleep/wake regularity using the SRI in a student-athlete population and revealed that student-athletes exposed to early morning training exhibited irregular sleep/wake patterns and undesirable sleep parameters on nights preceding training. These findings carry implications for both sports and academic performance, as well as for physical and mental health. Stakeholders in sports should carefully consider the timing of training and matches for student-athletes and take into account the impact these structural factors have on sleep. Further research is warranted to explore the potential implications of irregular sleep/wake timing on circadian health and to investigate novel interventions targeted specifically at improving sleep regularity in student-athletes.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Appendix 20. Irregular sleep/wake patterns in student-athletes (Wilson et al., 2023)

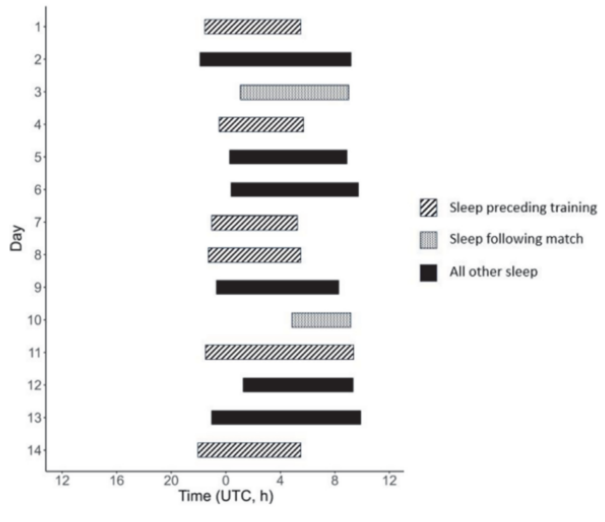
O11 IRREGULAR SLEEP/WAKE PATTERNS IN STUDENT-ATHLETES

Sandy Wilson*, Stephen Draper, Martin Jones, John Parker. *Hartpury University, Hartpury, UK*

10.1136/bmjresp-2023-BSSconf.11

Introduction Student-athletes are exposed to a range of academic-related and sport-related risk factors that can threaten healthy sleep practices.[1 2] Emerging evidence has shown that student-athletes display a high prevalence of short sleep durations and poor perceived sleep quality.[3] However, empirical research has primarily reported sleep outcomes over a set monitoring period rather than assessing day-to-day variability in sleep patterns. Therefore, this study aimed to use the Sleep Regularity Index (SRI) to assess sleep variability in student-athletes and examine the impact of training and competition on sleep outcomes.[4]

Methods Rugby Union student-athletes (n = 10, all male) from a single University were recruited with no diagnosed sleep disorder and with a sleep difficulty score <12 on the Athlete Sleep Screening Questionnaire.[5] Actigraphy monitors (GENEActiv, Activinsights, Cambridge, UK) were worn for 14 consecutive nights. Data were collected during normal teaching weeks and in-season with both morning training and evening matches. Sleep/wake and SRI were assessed using open-source GGIR and sleepreg packages on R software.[6]



Raster plot of sleep onset and offset for a participant with irregular sleep (SRI: 65.4)

Results Preliminary results showed that participants had an average sleep duration of 6.85 ± 0.46hr. Nights preceding morning training were of shorter duration with earlier sleep onset and offset, while nights following evening matches were of shorter duration with later sleep onset and offset (table 1). The SRI across participants was 72.0 ± 5.4, with a range of 65.4 – 80.0 (figure 1).

Discussion The findings support previous research indicating that training and competition can impair sleep in athlete populations. Sleep regularity was substantially lower than observed in elite athletes.[7] Furthermore, despite only considering nocturnal sleep, the observed SRI was lower than previous research that also included daytime napping, that is typically more erratic in placement and duration.[4 8] The impact of training and match scheduling on sleep should be considered, and alterations may reduce sleep irregularity in student-athletes.

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Abstract O11 Table 1 Results of independent t-tests of differences between sleep outcomes on nights preceding training days and following match days compared to all other nights

	Sleep preceding training				Sleep following match			
	Training	No training	*t*	ES (g ± 95% CI)	Match	No match	*t*	ES (g ± 95% CI)
Sleep duration (hr)	6.41 ± 1.24	7.15 ± 1.49	3.02*	0.53 ± 0.35	5.85 ± 1.26	6.97 ± 1.41	3.01*	0.80 ± 0.53
Sleep onset (hh:mm)	23:06 ± 00:49	00:27 ± 01:38	5.66*	1.00 ± 0.37	02:16 ± 01:25	23:31 ± 01:10	-8.54*	2.27 ± 0.59
Sleep offset (hh:mm)	06:28 ± 01:22	08:41 ± 01:11	9.87*	1.74 ± 0.41	08:51 ± 00:46	07:34 ± 01:43	-2.99*	0.79 ± 0.53

Sleep outcomes presented as mean ± SD, ES presented as Hedges' *g* ± 95%CI. *p <.01

Appendix 21. Application for ethical approval (ETHICS2023-01)

This appendix has been removed as it contains personal information

Appendix 22. Participant information sheet and consent form (ETHICS2023-01)

HARTPURY

Participant Information Sheet

Assessment of sleep/wake patterns in student-athletes in relation to academic and sporting scheduling

Invitation to Allow Use of Data Collected

My name is Sandy Wilson and I am a current PhD candidate at Hartpury University, and I would like to invite you to participate in this research study. Before making a decision regarding participation, it is important to understand the purpose of the research and what it will involve from you. Please read the following information carefully before deciding whether or not you wish to take part. Please do contact me (Alexander.Wilson@hartpury.ac.uk) if you have any questions, or if anything is unclear. Thank you for your time in considering participation.

Purpose of the Study

This study has three primary research aims: (a) Examine the regularity of sleep/wake placement across a 2-week window in Hartpury Rugby Union student-athletes using actigraphy; (b) Examine the impact of sporting and academic scheduling on observed sleep/wake characteristics in the preceding and following days; and (c) Understand the perceived facilitators and barriers to sleep behaviours, and map these against the COM-B model of behaviour change.

A significant number of student-athletes display poor sleep characteristics, which was demonstrated in a previous research study at Hartpury. Athletes and students face unique demands related to sport and study respectively that can negatively impact sleep quality, and student-athletes face a dual threat in attempting to balance these demands, alongside a mismatch between age related biological sleep preferences and societal structure. Research has demonstrated that certain elements integral to academic attainment, components of sport performance, and wellbeing can be impaired as a result of poor sleep quality. Therefore, it is imperative to improve sleep quality amongst student-athletes and enable behaviours that facilitate optimal sleep practices. This study is part of a series of work that provide a rationale for the creation of a sleep intervention for student-athletes.

Do you have to take part?

It is your decision whether or not to participate in this study. If you do participate, you will be asked to sign a consent form (on the next page). If you complete the study but later wish to withdraw, you are free to do this without giving a reason up until the commencement of data analysis on 28/11/2023.

If you take part, what will you have to do?
At the start of the study you will be asked to attend an initial meeting during an S&C session. This will include an explanation of how to use GENEActiv monitors and complete the daily survey, time to complete a short online survey (approx. 10 minutes) that includes demographic questions and baseline sleep screening.

You will be asked to wear the GENEActiv monitor for 14 consecutive days at all times with the exception of prolonged exposure to water (e.g., swimming), and is allowed to be removed during sport training. In addition, you will be required to complete a short online questionnaire each morning. This includes a sleep diary, which is used during the analysis of GENEActiv sleep data, and questions relating to training and academic schedules.

After GENEActiv data has been collected, you may be asked to participate in a 1-to-1 semi-structured interview that will ask you to reflect on your sleep during the objective data collection period to understand the perceived facilitators and barriers to sleep behaviours. This can be arranged at your convenience, and can be done in-person or on Microsoft Teams.

Following data collection, information relating to your individual timetable in relation to academic lessons and training will be collected from central University software and sports coaches to corroborate with daily questionnaire data.

Possible risks of participation
Subjective and objective sleep measures will be collected (initial screening questionnaire, Consensus Sleep Diary, or GENEActiv data) that may indicate the presence of a sleep disorder. Participation in this study will not increase the risk or severity of any pre-existing sleep disorder. If the lead researcher feels that your data is indicative of a sleep disorder, you will be contacted and signposted towards a medical professional (e.g., General Practitioner). Wearing the GENEActiv monitor may present some discomfort, redness, or rash on the wrist. If the discomfort is more than minimal the watch can be removed until this has resolved.

Possible benefits of participation
You will be contributing to the understanding of sleep characteristics in student-athletes, which will provide a rationale for the creation of a sleep education intervention for this population. Individual results can be shared through a written summary if requested, and group results will be shared

amongst athletes and coaches at the end of the study through an optional meeting and accompanying visual report (e.g., infographic).

Upon successful completion of data collection, defined as 12/14 days of valid data from the actigraphy monitor (excluding any device recording errors), and completion of the interview if requested, you will be entered into a prize draw for 3 x £25 Lifestyle 'Eat' vouchers (https://www.lifestylegiftcards.co.uk/). No more than 30 participants will be recruited, with the minimum odds of receiving a prize being 1 in 10. You may withdraw from the prize draw if requested.

What if something goes wrong?
If you are unhappy at any stage of the study please contact study supervisor and director of studies, Dr. John Parker, to raise your concerns (John.Parker@hartpury.ac.uk). You are also free to withdraw from the study up to the designated point of withdrawal without giving a reason by contacting me (Alexander.Wilson@hartpury.ac.uk).

Confidentiality
All information which is collected about you during the course of the research will be kept securely with the lead researcher. Once data has been collected, your data will be anonymised using the GENEActiv monitor ID number, such that no personal identifiers are used and you cannot be recognised from submitted data. A file linking your name to the ID will be stored on a password-protected file stored on the secure Hartpury OneDrive so that results can be linked back to yourself if you wish to receive individual results; this will be deleted after 3 months.

What will happen to the results?
The results will be used in my thesis for the fulfilment of my doctoral degree. A paper and electronic copy of the thesis will be kept at Hartpury. In addition to the sharing of results with participants mentioned above, findings will be presented to the wider academic community through presentations at research conferences and publication in an academic journal.

What to do next?
If you wish to participate in this study, please tick the box below. The next page will send you to the Participant Consent Form; once completed you will be able to access the survey.

Thank you for taking the time to read this information sheet.

Participant Consent Form

<u>Assessment of sleep/wake patterns in student-athletes in relation to academic and sporting scheduling</u>

Please enter your personal details below

Participant name: ________

Address: ________

Contact number: ________

Hartpury email address: ________

I in the capacity as the individual listed, hereby grant consent for participation in this research, and give my permission for Sandy Wilson and fellow research supervisors to use the data obtained from this to be used and analysed over the course of the research study. I understand that data collected will be anonymous and that I cannot be identified from that point.

Please sign below

____

Appendix 23. Research data management plan (ETHICS2023-01).

This appendix has been removed as it contains personal information

Appendix 24. Risk assessment (ETHICS2023-01)

HARTPURY RISK ASSESSMENT

ACTIVITY / PROCESS ASSESSED: ....Research Study.................. DATE: ....08/08/2023...........

DEPARTMENT: ....Sport.............. ASSESSORS: ....Alexander Wilson...................

HAZARD	**AT RISK**	**CONTROLS**	**RISK RATING**	**OTHER PRECAUTIONS**
Psychological risk – some questions relate to sleep health that may be uncomfortable to answer	Participants (Students)	Participants able to exit the study at any time with no requirement for explanation	2	All data will be anonymised using GENEActiv ID number such that no identifiable information is used at the point of data analysis
Risk of potential sleep disorder being uncovered during data analysis (initial screening questionnaire, Consensus Sleep Diary, or GENEActiv data)	Participants (Students)	Participation in this study will not increase the risk or severity of any pre-existing sleep disorder. If data is indicative of a sleep disorder, participant will be contacted and signposted towards a medical professional (e.g., General Practitioner).	4	Participants will be explicitly told of the risk of uncovering a sleep disorder during intake meeting
Discomfort from GENEActiv PU resin strap (this is common in actigraphy research)	Participants (Students)	If discomfort occurs, the participant can take off the watch for a period during the day. If this continues into the night the monitor can be removed and that night will be removed from analysis. If significant rash or redness occurs the participant can pause wearing the watch until resolved, or withdraw from the study	3	Participants will be explicitly told of the risk of discomfort from watches during intake meeting

Risk of cognitive bias in relation to prize draw	Participants (Students)	Participants informed of the criteria required to be entered into the prize draw, and the minimum odds of receiving a prize	2	Caution to emphasise that participation is voluntary and participants can withdraw during the study with no penalty
Risk of eye strain – during data analysis	Researcher	Regular scheduled breaks, limit continuous work period per day, wear prescription glasses	1	N/A
Discomfort from sitting (upper limb, back) – during data analysis	Researcher	Regular scheduled breaks, limit continuous work period per day	1	N/A
Stress – during data analysis	Researcher	Regular scheduled breaks, discontinue work for the day if required	1	N/A
			Review Date: 27/09/2023	

Hazard and severity (1 = minor, 2 = serious, 3 = very serious / fatal)
Risk (likelihood: 1 = very unlikely, 2 = unlikely, 3 = likely / very likely)
Hazard x Risk = Hazard severity (1,2,3, = low, 4 = medium, 6+ = high)

Appendix 25. Post-hoc analysis of Wilcoxon signed-rank tests to assess between-day differences in actigraphy-derived sleep outcomes

Day-pair	Sleep period	TST	WASO	SE	Sleep onset	Sleep offset	SOL	Cumulative sleep duration
Mon-Tue	-4.924*	-4.895*	-4.155*	-1.617	-1.777	-5.373*	-.966	-4.895*
Mon-Wed	-.678	-.330	-2.381	-2.902	-3.632*	-4.015*	-.141	-.330
Mon-Thu	-1.410	-1.205	-.966	-.470	-2.317	-1.325	-1.244	-1.205
Mon-Fri	-4.390*	-4.311*	-2.704	-.901	-2.948	-5.110*	-.761	-4.422*
Mon-Sat	-2.787	-2.138	-1.970	-1.129	-4.373*	-4.493*	-.757	-2.883
Mon-Sun	-1.523	-1.911	-.598	-1.065	-1.359	-1.599	-1.178	-1.507
Tue-Wed	-3.424*	-3.493*	-.817	-.852	-3.354*	-.678	-.465	-3.493*
Tue-Thu	-5.086*	-5.018*	-4.351*	-2.146	-.607	-5.086*	-.422	-5.018*
Tue-Fri	-1.245	-.638	-1.416	-1.330	-2.228	-.721	-.154	-1.179
Tue-Sat	-2.595	-2.571	-1.441	-.553	-4.036*	-1.802	-.795	-2.475
Tue-Sun	-5.143*	-4.595*	-3.063*	-.377	-.280	-4.918*	-.286	-5.143*
Wed-Thu	-1.894	-.539	-3.007	-3.007	-3.945*	-4.015*	-.310	-.539
Wed-Fri	-2.972	-2.510	-.391	-1.569	-2.450	-1.025	-.653	-3.215*
Wed-Sat	-1.929	-2.275	-3.92	-.941	-.156	-2.624	-.227	-2.381
Wed-Sun	-1.721	-.392	-1.964	-1.547	-3.010	-3.294*	-.259	-1.199
Thu-Fri	-4.796*	-4.292*	-3.377*	-1.655	-1.188	-4.967*	-.392	-4.710*
Thu-Sat	-2.739	-3.162*	-2.866	1.816	-3.556*	-4.397*	-.127	-2.811
Thu-Sun	-.231	-.874	-1.940	-2.111	-1.184	-2.915	-.075	-.812
Fri-Sat	-1.730	-1.874	-.312	-.793	-2.402	-1.257	-.162	-1.874
Fri-Sun	-4.783*	-4.717*	-1.765	-.648	-2.065	-4.444*	-.661	-4.717*
Sat-Sun	-3.147*	-3.123*	-1.689	-.317	-3.111*	-4.015*	-.200	-3.123*

Data presented as Wilcoxon signed-rank Z-score. Abbreviations: TST = total sleep time; WASO = wake after sleep onset; SE = sleep efficiency; Mon = Monday; Tue = Tuesday; Wed = Wednesday; Thu = Thursday; Fri = Friday; Sat = Saturday; Sun = Sunday

* Denotes significant difference between day-pair at Bonferroni-corrected significance level (p <.00238).

Appendix 26. Interview guide

Section A

*** Note all facilitators and barriers mentioned during this section***

1. To start, can you discuss me about your general sleep as a student-athlete?

Prompt: What things related to being a student-athlete do you think are (a) beneficial/(b) challenges to your sleep?

Prompt: What additional benefits or challenges do you face that (a)student peers/(b) elite athletes may not?

Prompt: Are you generally satisfied or dissatisfied with your sleep? Why is this?

- Provide athlete with sleep study results. Provide overview and mention that the results will be discussed in more detail after the interview.

2. Looking at the sleep summary, can you reflect on some of the days when you managed (a) more sleep/(b) less sleep. *Adjust if there are specific days of interest noted during analysis*

Prompt: Can you comment on your sleep beyond the details provided in the sleep diary? (e.g., napping)

Section B

3. Next, we are going to discuss some of the things mentioned as being beneficial to sleep earlier.

    1. You mentioned "Facilitator A", can you tell me more about this
    2. Can you give me an example of this?
    3. Tell me more about this example

Repeat for each facilitator listed

4. Now, we are going to discuss some of the things mentioned as being challenges to sleep earlier.

    1. You mentioned "Barrier A", can you tell me more about this
    2. Can you give me an example of this?
    3. Tell me more about this example
    4. Reflecting on "Barrier A", do you have any suggestions as to how this challenge could be addressed?

Repeat for each barrier listed

Appendix 27. P1398 Evaluation of a targeted behavioural sleep intervention for student-athletes (Wilson et al., 2024).

P1398
Poster Session–Public Health–Day 3 (Poster)

Evaluation of a targeted behavioural sleep intervention for student-athletes

Sandy Wilson[*,1], Stephen Draper[1], Martin Jones[1], John Parker[1]
[1]*Hartpury University, Department of Sport*

Introduction: Student-athletes exhibit undesirable sleep characteristics that can negatively affect both academic attainment and athletic performance. Therefore, this pilot study aimed to assess the effectiveness of a targeted intervention designed to modify sleep behaviour in student-athletes.

Method: The intervention design was based on the COM-B model of behaviour change. Previous research utilising the COM-B model in this cohort identified barriers related to psychological capability, physical opportunity, and motivation, which could be addressed to improve sleep behaviour. The intervention focused on enhancing psychological capability and motivation through a 40-min in-person interactive workshop highlighting the consequences of poor sleep and addressing common perceived barriers to sleep. Personalised visual feedback on current sleep practices was also provided. These intervention components incorporated nine distinct behaviour change techniques from the Behaviour Change Technique Taxonomy. Wrist-worn actigraphy (GENEActiv, Activinsights) was used to evaluate sleep timing, duration, and consistency using the Sleep Regularity Index (SRI). Descriptive analysis and paired Wilcoxon signed-rank tests were used to compare outcomes between baseline and a follow-up assessment conducted five weeks post-intervention.

Results: Fifteen male Rugby Union student-athletes (mean age: 19 ± 1 years) competing at a regional level completed the intervention. Baseline actigraphy data revealed short nocturnal total sleep times (6.5 ± 0.9 h) and low sleep consistency (SRI: 70 ± 9). No significant changes in actigraphy-derived sleep parameters were found for sleep onset time (0.2 h earlier, $p = 0.23$), sleep offset time (0.1 h earlier, $p = 0.87$), daily total sleep time including naps (0.2 h longer, $p = 0.14$), or SRI score (1.0-unit increase, $p = 0.82$) at follow-up compared to baseline.

Conclusion: This study corroborates previous findings indicating that student-athletes have short sleep durations and inconsistent sleep patterns. While the intervention did not significantly change sleep parameters, it may protect against worsening sleep outcomes related to increasing academic-related demands throughout a semester. Accordingly, further exploration in a larger sample with a control group is warranted. However, addressing barriers related to physical opportunity that would require structural-level changes, such as modifications to training schedules, may prove to be a more effective approach to improving sleep behaviour in student-athletes.

Conflict of Interest: No.

Appendix 28. Intervention function definitions and assessment against APEASE criteria

Intervention function	Definition	APEASE criteria?
Education	Increasing knowledge or understanding	Yes
Persuasion	Using communication to induce positive or negative feelings or stimulate action	No
Incentivisation	Creating an expectation of reward	No
Coercion	Creating an expectation of punishment or cost	No
Training	Imparting skills	No
Restriction	Using rules to reduce the opportunity to engage in the target behaviour (or to increase the target behaviour by reducing the opportunity to engage in competing behaviours)	No
Environmental restructuring	Changing the physical or social context	Yes
Modelling	Providing an example for people to aspire to or imitate	No
Enablement	Increasing means/reducing barriers to increase capability (beyond education and training) or opportunity (beyond environmental restructuring)	Yes

Appendix 29. Matrix of links between COM-B components and intervention functions. Blue = viable link to be assessed using APEASE criteria, Grey = COM-B component not indicated to target within intervention

COM-B components	Intervention functions								
	Education	Persuasion	Incentivisation	Coercion	Training	Restriction	Environmental restructuring	Modelling	Enablement
Physical capability									
Psychological capability									
Physical opportunity									
Social opportunity									
Automatic motivation									
Reflective motivation									

Appendix 30. Policy categories definitions and assessment against APEASE criteria

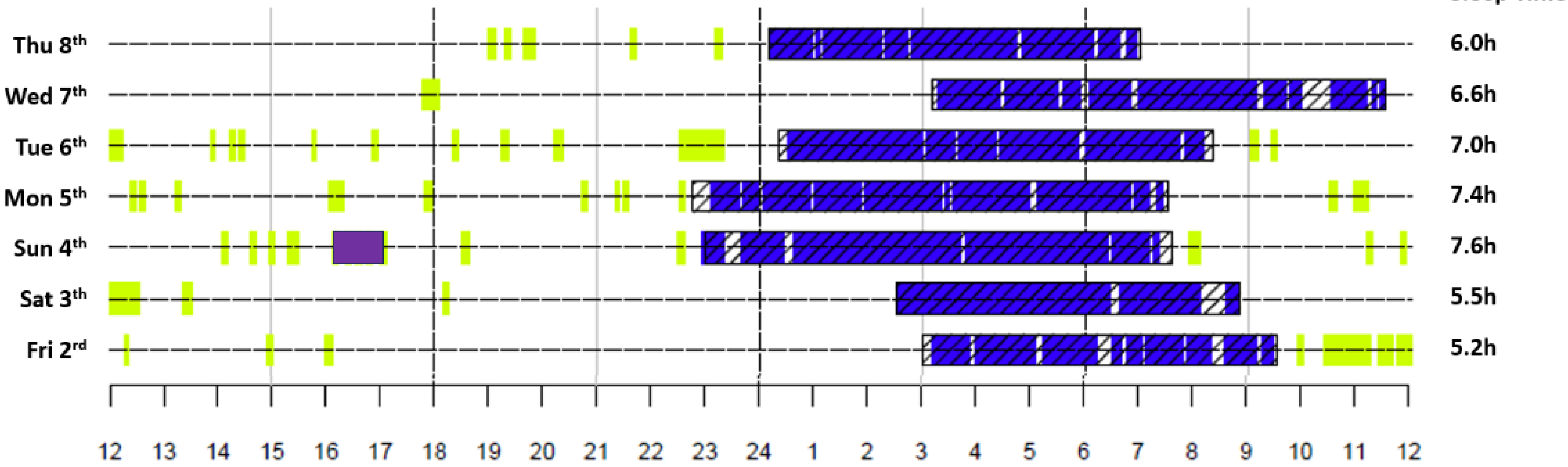
Policy category	Definition	APEASE criteria?
Communication/marketing	Using print, electronic, telephonic or broadcast media	No
Guidelines	Creating documents that recommend or mandate practice. This includes all changes to service provision	No
Fiscal measures	Using the tax system, to reduce or increase the financial cost	No
Regulation	Establishing rules or principles of behaviour or practice	No
Legislation	Making or changing of laws	No
Environmental/social planning	Designing and/or controlling the physical or social environment	Yes
Service provision	Delivering a service	Yes

Appendix 31. Matrix of links between policy categories and intervention functions. Blue = viable link to be assessed using APEASE criteria, Grey = Intervention function not indicated to target within intervention

Policy categories	Intervention functions								
	Education	Persuasion	Incentivisation	Coercion	Training	Restriction	Environmental restructuring	Modelling	Enablement
Communication/marketing									
Guidelines									
Fiscal measures									
Regulation									
Legislation									
Environmental/social planning									
Service provision									

Appendix 32. Example of visual feedback and personalised recommendations

Name: --- Student ID: ---



The image above shows the placement and timing of your sleep (blue) and naps (purple). Each row runs 24 hours from midday to midday the following day. Your average nocturnal sleep duration was **6.5hr**. The recommended sleep duration for a young adult is between 7-9hr for most individuals, so if you find yourself feeling sleepy during the day then sleeping longer could be beneficial.

Your sleep consistency score, which measures the regularity of sleep timing, was **66**. A typical range for a young adult is between 70-80. Try to keep more similar sleep and wake timings between consecutive days where possible.

Sleep consistency score

Appendix 33. Application for ethical approval (ETHICS2023-83)

This appendix has been removed as it contains personal information

Appendix 34. Participant information sheet and consent form (ETHICS2023-83)

HARTPURY

Participant Information Sheet

Creation of a sleep intervention for Hartpury rugby student-athletes

Invitation to Allow Use of Data Collected

My name is Sandy Wilson and I am a current PhD candidate at Hartpury University, and I would like to invite you to participate in this research study. Before making a decision regarding participation, it is important to understand the purpose of the research and what it will involve from you. Please read the following information carefully before deciding whether or not you wish to take part. Please do contact me (Alexander.Wilson@hartpury.ac.uk) if you have any questions, or if anything is unclear. Thank you for your time in considering participation.

Purpose of the Study

This study has three primary research aims: (a) examine the impact of a change in scheduling (training start time) on sleep, health, and academic outcomes; (b) Examine the impact of a targeted behavioural intervention in both the presence/absence of a scheduling change on sleep, health, and academic outcomes; and (c) Provide evidence to the University to inform future scheduling of the academic timetable and Sport Academy training times

A significant number of student-athletes display poor sleep characteristics, which was demonstrated in a previous research study at Hartpury. Athletes and students face unique demands related to sport and study respectively that can impact sleep quality, and student-athletes face a dual threat in attempting to balance these demands, alongside a mismatch between age-related biological sleep preferences and societal structure. This study will examine the implementation of two interventions designed specifically for Hartpury student-athletes, with a scheduling change where training time will alter, and a behavioural intervention.

Do you have to take part?

It is your decision whether or not to participate in this study. If you do participate, you will be asked to sign a consent form (on the next page). If you complete the study but later wish to withdraw, you are free to do this without giving a reason up until the commencement of data analysis on 06/04/2024.

If you take part, what will you have to do?

At the start of the study you will be asked to attend an initial meeting before or after training. This will include an explanation the study and how participants will be allocated to intervention conditions, how to use GENEActiv monitors and complete the sleep diary, and time to read this Participant Information Sheet and sign the Participant Consent Form should you wish to participate

All participants will be asked to wear the GENEActiv monitor for 7 consecutive days on two occasions over the study duration. This should be worn at all times with the exception of prolonged exposure to water (e.g., swimming), and is allowed to be removed during sport training. During each 7-day period, you will be required to complete a short online questionnaire that acts as a sleep diary and is used during the analysis of GENEActiv sleep data.

All participants will be asked to complete an online questionnaire on two occasions at the start and end of the study, comprising the Athlete Sleep Screening Questionnaire to assess sleep practices (Samuels et al., 2016), the Athlete Sleep Behaviour Questionnaire to assess sleep-related behaviours (Driller et al., 2018); the Positive and Negative Affect Schedule (PANAS) as an assessment of affect/mood (Watson et al., 1988), and the Warwick-Edinburgh Mental Well-being Scale (WEMWBS) as a measure of wellbeing (Tennant et al., 2007). In addition, you will be asked to rate your perception of sporting and academic performance over the previous week on a scale of 1-10. This should take no longer than 15-minutes to complete.

Participants allocated to the behavioural intervention will be required to attend an interactive sleep workshop of no longer than 45-minutes. In addition, feedback on your sleep will be provided through an online document sent through Teams on the first occasion of wearing the GENEActiv monitor, with targeted recommendations provided. Participants not allocated to the behavioural intervention will be allowed to attend the sleep workshop and provided feedback upon request after the completion of the study.

The scheduling intervention will take place across the semester, with an offset in training timing between the Fresher 1's and Fresher 2's teams after the first two weeks of the study. This will be applied to all members of both squads regardless of participation in the study, and has been agreed with Rugby Academy coaching staff.

During the study, your academic attendance will be collated using myHartpury. This information is already available to University staff, and will not change how this information is already used by your academic tutor and other University staff or impact any team selection.

Possible risks of participation
Subjective and objective sleep measures will be collected (questionnaire, sleep diary, and/or GENEActiv data) that may indicate the presence of a sleep disorder. Participation in this study will not increase the risk or severity of any pre-existing sleep disorder. If the lead researcher feels that your data is indicative of a sleep disorder, you will be contacted and signposted towards a medical professional (e.g., General Practitioner).

There may be components of the questionnaires relating to sleep, mood and well-being that may be uncomfortable to answer. If there are any concerns or psychological distress while completing these questionnaires then please stop and contact the lead researcher.

Wearing the GENEActiv monitor may present some discomfort, redness, or rash on the wrist. If the discomfort is more than minimal the watch can be removed until this has resolved.

Possible benefits of participation
You will be contributing to the understanding of sleep in student-athlete populations, with the results of this research study being fed back to the University and Sports Academy to inform future directions on what can be implemented to support sleep practices in Hartpury student-athletes. Individual results can be shared through a written summary if requested, and group results will be shared amongst athletes and coaches at the end of the study through an optional meeting and accompanying visual report (e.g., infographic).

Upon successful completion of data collection, , you will be entered into a prize draw for 1 x £50 and 5 x £25 Lifestyle 'Eat' vouchers (https://www.lifestylegiftcards.co.uk/). No more than 60 participants will be recruited, with the minimum odds of receiving a prize being 1 in 10. You may withdraw from the prize draw if requested.

What if something goes wrong?
If you are unhappy at any stage of the study please contact study supervisor and director of studies, Dr. John Parker, to raise your concerns (John.Parker@hartpury.ac.uk). You are also free to withdraw from the study up to the designated point of withdrawal without giving a reason by contacting me (Alexander.Wilson@hartpury.ac.uk).

Confidentiality
All information which is collected about you during the course of the research will be kept securely with the lead researcher. Once data has been collected, your data will be anonymised using the GENEActiv monitor ID number, such

that no personal identifiers are used and you cannot be recognised from submitted data. A file linking your name to the ID will be stored on a password-protected file stored on the secure Hartpury OneDrive so that results can be linked back to yourself if you wish to receive individual results; this will be deleted after 3 months.

What will happen to the results?
The results will be used in my thesis for the fulfilment of my doctoral degree. A paper and electronic copy of the thesis will be kept at Hartpury. In addition to the sharing of results with participants mentioned above, findings will be presented to the wider academic community through presentations at research conferences and publication in an academic journal.

What to do next?
If you wish to participate in this study, please tick the box below. The next page will send you to the Participant Consent Form; once completed you will be able to access the survey.

Thank you for taking the time to read this information sheet.

Participant Consent Form

Please enter your personal details below

Participant name: ________________________

Hartpury email address: __________________________

I in the capacity as the individual listed, hereby grant consent for participation in this research, and give my permission for Sandy Wilson and fellow research supervisors to use the data obtained from this to be used and analysed over the course of the research study. I understand that data collected will be anonymous and that I cannot be identified from that point.

Please sign below

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Appendix 35. Research data management plan (ETHICS2023-83)

This appendix has been removed as it contains personal information

Appendix 36. Risk assessment (ETHICS2023-83)

HARTPURY RISK ASSESSMENT

ACTIVITY / PROCESS ASSESSED: ....Research Study.................. DATE: ....04/12/2023............

DEPARTMENT: ....Sport............... ASSESSORS: ....Alexander Wilson...................

HAZARD	AT RISK	CONTROLS	RISK RATING	OTHER PRECAUTIONS
Psychological risk – questionnaires related to health (sleep, mood, wellbeing) that may be uncomfortable to answer	Participants (Students)	Participants able to exit the study at any time with no requirement for explanation	2	Signposting to student services if any psychological concerns are raised
Risk of potential sleep disorder being uncovered during data analysis (initial screening questionnaire, Consensus Sleep Diary, or GENEActiv data)	Participants (Students)	Participation in this study will not increase the risk or severity of any pre-existing sleep disorder. If data is indicative of a sleep disorder, participant will be contacted and signposted towards a medical professional (e.g., General Practitioner).	4	Participants will be explicitly told of the risk of uncovering a sleep disorder during intake meeting
Discomfort from GENEActiv PU resin strap (this is common in actigraphy research)	Participants (Students)	If discomfort occurs, the participant can take off the watch for a period during the day. If this continues into the night the monitor can be removed and that night will be removed from analysis. If significant rash or redness occurs the participant can pause wearing the watch until resolved, or withdraw from the study	3	Participants will be explicitly told of the risk of discomfort from watches during intake meeting

Risk of cognitive bias in relation to prize draw	Participants (Students)	Participants informed of the criteria required to be entered into the prize draw, and the minimum odds of receiving a prize	2	Caution to emphasise that participation is voluntary and participants can withdraw during the study with no penalty
Risk of eye strain – during data analysis	Researcher	Regular scheduled breaks, limit continuous work period per day, wear prescription glasses	1	N/A
Discomfort from sitting (upper limb, back) – during data analysis	Researcher	Regular scheduled breaks, limit continuous work period per day	1	N/A
Stress – during data analysis	Researcher	Regular scheduled breaks, discontinue work for the day if required	1	N/A
			Review Date: 27/09/2023	

Hazard and severity (1 = minor, 2 = serious, 3 = very serious / fatal)
Risk (likelihood: 1 = very unlikely, 2 = unlikely, 3 = likely / very likely)
Hazard x Risk = Hazard severity (1,2,3, = low, 4 = medium, 6+ = high)