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REVIEW

Sleep Health in the Student-Athlete: A Narrative Review of Current Research and Future Directions

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Abstract

Purpose of the Review Student-athletes face unique challenges around sleep related to combining performance sport and education. This review aims to summarise the available evidence on sleep health in student-athletes, examine the upstream factors that influence sleep health and the downstream consequences that arise from suboptimal sleep health, and provide directions for future research.

Recent Findings Evidence indicates that student-athletes exhibit suboptimal sleep health across multiple dimensions, such as short total sleep durations and irregular sleep timing between days. Various upstream influences, including factors related to sports, academics, and individual characteristics, underpin these observations of suboptimal sleep health. These influences have wide-reaching downstream consequences that may affect athletic performance, concussion and injury risk, academic achievement, and wellbeing. While interventions to improve sleep health have been designed and implemented, their effectiveness remains mixed, highlighting the need for targeted designs that address upstream influences that are specific to student-athletes.

Summary Student-athletes present with suboptimal sleep health across multiple dimensions, which should be addressed to facilitate not only performance on the field and in the classroom, but for health and wellbeing. Future research should aim to provide a more comprehensive understanding of sleep health and the contributing factors that distinguish this population from elite athletes and student peers. Key stakeholders including coaches and academic staff should be made aware of the unique challenges around sleep faced by student-athletes to support the implementation of practical and evidence-based sleep health strategies.

Keywords Sleep · Athletes · Performance · Health · Education · Student

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Introduction

Sleep is a fundamental health behaviour that is essential for optimal functioning. Given the dual demands of excelling in both sports and academics, student-athletes have much to gain from maintaining good sleep health, which supports performance in these areas as well as overall health and wellbeing [1]. Despite this, there is mounting evidence to indicate a high prevalence of suboptimal sleep health, as highlighted in previous reviews by Kroshus et al. [2] and Brauer et al. [3]. Since these reviews were published, a substantial amount of sleep research has been published using student-athlete populations. Therefore, this narrative review aims to synthesise research in this population into four primary sections: the current sleep health of student-athletes, the upstream influences that underpin the observed sleep practices, the downstream consequences that suboptimal sleep health can elicit, and intervention studies to improve sleep health (Fig. 1). This will focus on primary literature using student-athletes– defined in this review as participation in university-level education and performance sport (e.g., National Collegiate Athletic Association competition)– while drawing upon relevant student or athlete research for comparison. This is followed by highlighting areas for future research to address current knowledge gaps.

Sleep Health in Student-Athletes

Sleep health has gained increasing attention as a multidimensional concept that views healthy sleep not only as the absence of disorders, but as a positive attribute of health that can be applied to all individuals [4]. Framing sleep in this way is particularly suitable for student-athletes whom as a population can be considered non-clinical, but where improvements in sleep health can yield benefits for overall health, wellbeing, and performance [4]. Buysse proposed a framework termed 'RU-SATED' (regularity, satisfaction, alertness, timing, efficiency, and duration), where each dimension can contribute towards healthy sleep [5]. This section will consider the available evidence for each RU-SATED dimension within student-athlete populations.

Regularity

Sleep regularity refers to the maintenance of consistent sleep onset and offset timings [5], and is important as irregular timings between days can lead to circadian misalignment and adversely affect health and performance [6]. Despite the importance of regular sleep, a systematic review found only 16 studies reported a measure of regularity in athletes as of early 2022 [7]. In student-athletes, a pattern of social jetlag– shifts in sleep timing between workdays and free days [8]– 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 [9, 10]. This assumes that student-athletes only work Monday through Friday and are free on weekends, whereas in practice 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. However, alternative measures of regularity still support irregular sleep patterns in student-athletes. Leduc et al. [10] demonstrated that student-athletes displayed greater intra-individual variability (i.e., changes between days in the same individual) in self-reported sleep parameters compared to non-athlete students. Meanwhile, Wilson et al. [11] found the median Sleep Regularity Index– a measure of regularity that accounts for differences between consecutive days that may be more reflective of circadian disruption - of student-athletes that train in the morning to correspond to the lowest quintile of British adults from the UK Biobank [12]. These findings support irregular sleep timing across the week, likely driven by misalignment between sport and academic scheduling and chronotype as discussed later.

Satisfaction

Sleep satisfaction relates to the subjective perception of sleep [5]. This dimension is possibly best captured through qualitative research, and interviews exploring general health in student-athletes would indicate general dissatisfaction and a tendency to neglect sleep [13–15]. In the absence of sleep-focused qualitative research, the most common approach to operationalise sleep satisfaction within the RU-SATED framework is through self-reported sleep diaries and questionnaires [16]. The Pittsburgh Sleep Quality Index (PSQI) has been the most widely used questionnaire in student-athletes [17], where multiple components are summed to generate a global score and identify 'poor' sleepers (PSQI > 5). Multi-sport studies have shown 29–54% of the sampled population to score above this threshold when reported [9, 10, 18–23], while studies using a single sport sample report similar findings [24–27]. Alternative measures include the Athlete Sleep Screening Questionnaire [ASSQ; 28], which was developed as an athlete-specific screening tool. Research indicates that 24–39% of student-athletes exhibit moderate or severe sleep difficulty scores using the ASSQ and may require additional support or clinical evaluation [29–32]. Notably, this proportion is higher than typically reported in elite athletes [e.g., 33]. As demonstrated by Sargent et al. [34], direct lines of questioning can also indicate sleep satisfaction, such as asking participants "how satisfied

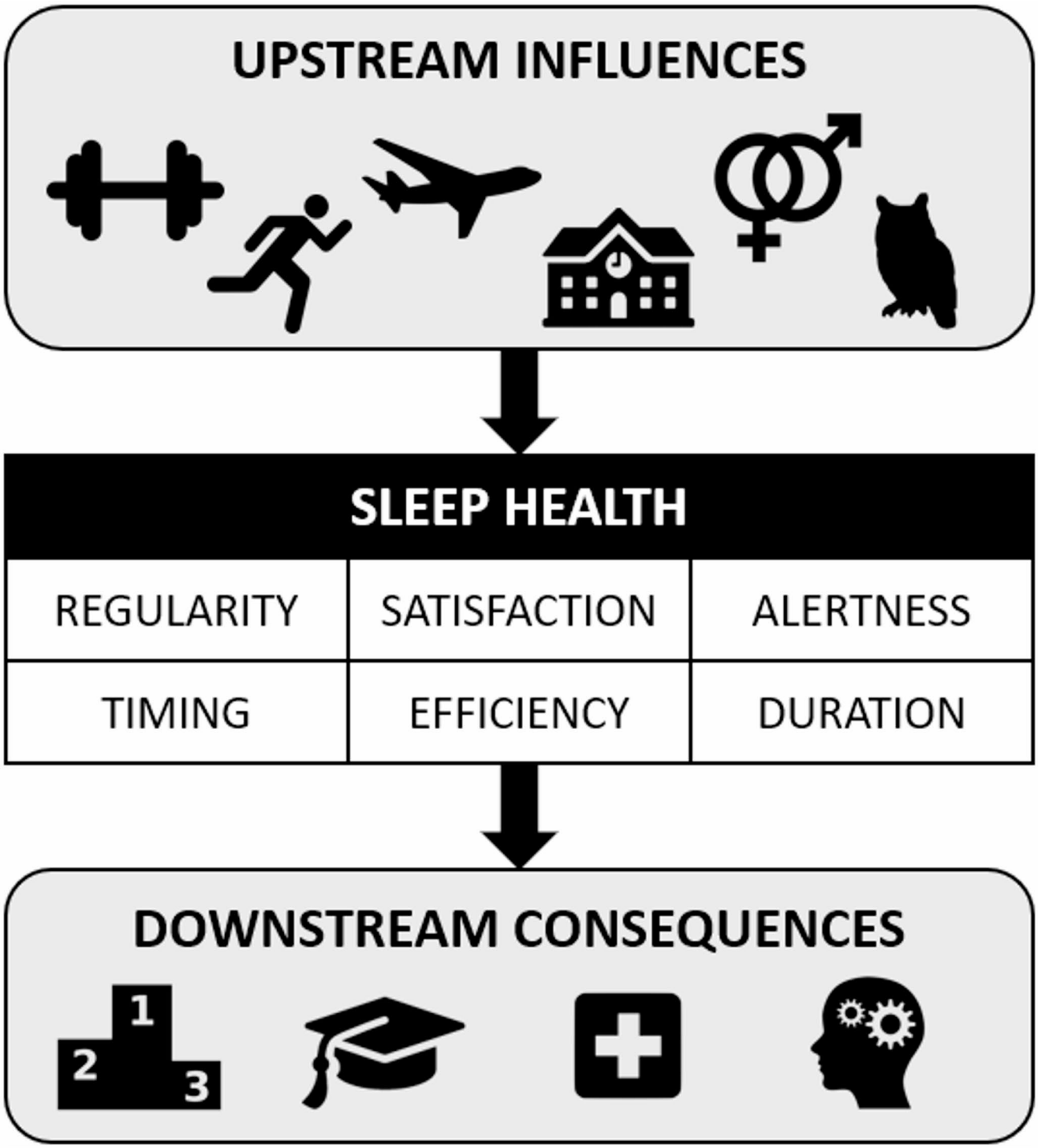

Fig. 1 Various upstream influences– training, competition, travel, academics, sex-related differences, and chronotype– each contribute towards suboptimal sleep health in student-athletes across multiple dimensions. These can result in downstream consequences relating to sport performance, academic attainment, injury, and wellbeing.

are you with the amount of sleep you get", with responses logged on a 1–10 Likert scale. While this approach may provide less detail than a validated questionnaire, simple lines of questioning may be used to direct further individualised lines of investigation for sleep optimisation, with individualised approaches previously advocated for [35, 36].

Alertness

Alertness is the ability to maintain attention during wakefulness [5]. This dimension is commonly assessed using the Epworth Sleepiness Scale [ESS; 37], which, although primarily a measure of subjective daytime sleepiness, is often used as a proxy indicator of alertness within the RU-SATED framework [16]. Findings indicate that 22–51% of student-athletes score above the threshold (ESS ≥ 10) to indicate excessive daytime sleepiness [9, 18, 25, 38–40]. The variations in daytime sleepiness between studies may be explained by the differences in the timing of questionnaire completion, with perceived alertness being temporally sensitive. For instance, in the study with the highest prevalence, questionnaires were administered immediately before or after training when perceived alertness may be heightened [9]. To mitigate against this factor, future studies should report of the timing of questionnaire completion and the placement around training or competition. Additionally, it remains unclear whether excessive daytime sleepiness in student-athletes impairs alertness to a degree that affects performance in sporting or academic contexts, or whether these effects differ between the two settings.

Timing

Timing relates to the placement of sleep within the 24-hour day [5]. The recommendation within RU-SATED is for an individual to be asleep or trying to sleep between 02:00–04:00. While cross-sectional studies suggest that most student-athletes would typically be asleep at this time [e.g., 10], the irregular sleep patterns outlined earlier (see Sect. 2.1) likely increase the occurrence of individual nights that would fall outside of this range. Thus, longitudinal studies presenting sleep outcomes on a nightly basis are required to enable a clearer picture on sleep timing.

Furthermore, sleep timing needs to be considered in relation to chronotype. The age-related changes in chronotype would suggest that student-athlete cohorts, consisting primarily of young adults, would have a higher proportion of evening-type chronotypes where a later sleep timing may be more appropriate [41]. This is supported by research showing a slightly higher proportion of evening-type than morning-type chronotypes amongst student-athletes [21, 42–46]. With student-athlete sport training often occurring in the morning, there is rationale for a greater proportion of morning-type chronotypes due to the better alignment with morning start times [47]. Litwic-Kaminska and Kotysko [21] found a shift towards morning-types compared to non-athlete peers, although no significant difference was observed by Morita and Sasai-Sakuma [40]. Therefore, optimal sleep timing would be best considered on an individual basis in student-athletes.

Efficiency

Efficiency in the context of sleep health refers to the ability to fall asleep and maintain sleep throughout the sleep episode [5]. This dimension can be assessed using various measures including sleep efficiency (SE; the proportion of the sleep episode spent asleep), sleep onset latency (SOL; the time between intending to fall asleep and actual sleep initiation), the number of awakenings during sleep, and wake after sleep onset (the cumulative duration of awakenings). Comparing results across studies is challenging due to differing definitions of variables and the reduced accuracy of actigraphy in detecting wakefulness versus sleep [48]. However, reported SOLs of 20–40 min [18, 49], and SEs of 81–92% [18, 50–52], are broadly consistent with findings in elite athletes and suggest potential difficulties with both falling asleep (SOL > 30 min) and maintaining sleep (SE < 85%) compared to other non-clinical populations [53]. Subjective measures of efficiency report comparable findings with lower SEs and longer SOLs than may be optimal [e.g., 10].

Duration

Duration relates to the amount of sleep achieved, typically within a 24-hour period [5]. Wrist-worn accelerometery, using both research-grade and commercial devices, is commonly used to estimate sleep duration amongst athletic cohorts, via the detection of movement counts distinguishing the state of sleep from that of wakefulness [54]. Previous studies generally report average total sleep times of less than seven hours [18, 39, 49–51, 55], which falls below recommended durations of seven to nine hours for young adults [56], yet given the additional recovery demands of athletes, it seems logical that the upper estimates of sleep duration should be targeted. In contrast, Driller et al. [52] observed a higher total sleep time of 7.6 h per night in student-athletes, though this was still less than non-athlete student group in the study (7.9 h). 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., 9, 18].

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 [9, 23, 32]. Longer napping episodes appear to be commonplace in student-athletes; for instance, Mah et al. [9] found 25% of respondents to report a typical nap duration exceeding one hour. Lever et al. [57] found that napping significantly reduced subsequent nocturnal sleep duration

Table 1 Summary of evidence for dimensions of sleep health in student-athletes

Dimension	Current evidence
Regularity	• Social jetlag creates 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 consecutive days
Satisfaction	• Low satisfaction using subjective questionnaires (e.g., 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 in young adulthood
Efficiency	• Evidence of low actigraphy-derived sleep efficiency (< 85%) and sleep onset latency (> 30 min) comparable to elite athletes
Duration	• Shorter self-reported and actigraphy-derived sleep durations than public health recommendations (7–9 h) in a high proportion of student-athletes

in student-athletes. As nocturnal sleep episodes and longer napping episodes are likely to influence the sleep regulation bidirectionally and are present in a large proportion of student-athletes, the authors advocate for considering sleep as a 24-hour behaviour and capturing napping episodes alongside nocturnal sleep.

RU-Sated

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 for each RU-SATED dimension is presented in Table 1.

Upstream Influences

When applying a social-ecological approach to sleep health, there will be various factors that act as determinants of the suboptimal sleep health discussed in the previous section (see Fig. 1). These are termed 'upstream' influences, and can act at different levels, such as directly upon the individual or at broader social and societal levels [58]. This section will focus on key upstream influences for which where is an established evidence base in student-athletes, although there are other plausible upstream influences common to many student-athletes that could affect sleep health (e.g., part-time employment demands).

Training

The timing of training can have a pronounced effect upon sleep in student-athletes. Sleep durations tend to be shorter on nights preceding days with morning training sessions when compared to days nights preceding evening training sessions or rest days, likely due to the misalignment between training timing and preferred wake times [24, 59]. The frequency of such sessions may also be important, as a higher frequency of morning sessions (4–7 per week) has been associated with poor sleepers assessed using the PSQI, whereas a lower frequency of morning sessions (0–3 per week), or any frequency of evening sessions, was not significantly associated with PSQI scores [22]. This is supported by Wilson et al. [60], where early morning training frequency was a significant predictor of poorer sleep quality, poorer sleep hygiene practices, earlier wake times, and shorter total sleep times. In contrast, evening training frequency was not predictive of changes in any measured sleep outcome.

Training load has been identified as a sleep risk factor for athletes due to heightened physiological arousal [61]. Assessment of this relationship is complicated in student-athletes due to the concurrent fluctuations in academic demands that, as discussed later, can influence sleep. Some studies have indicated that increased training load or changes in the training phase can result in unfavourable changes to sleep [50], while others report no clear differences [55, 62, 63]. In the absence of a consensus within the literature, an individualised approach appears warranted in assessing training load as a risk factor for sleep that considers each individual's circumstances and their unique physical and psychological responses to training demands.

Competition

While competition is an established upstream influence in elite athletes [61], there is a notable lack of research on sleep in the acute period around competition among student-athletes. Studies assessing in-season phases of training with actigraphy often report average results across the collection period without distinguishing between competition and non-competition nights [e.g., 50]. A meta-analysis in elite athletes suggests that while sleep is largely unaffected the night before a competition (although athletes in individual sports may be more likely to experience sleep disruption), it is frequently disrupted the night after [64]. Post-competition sleep disruption can be attributed to various factors including increased physiological arousal, travel, and caffeine consumption [64], all of which are pertinent for student-athletes. A culture of alcohol use in some student-athlete sports may result in a higher prevalence of excessive

consumption post-competition [65], and when combined with the aforementioned factors cause substantial sleep disruption, although this has not been empirically examined.

Travel

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 [66]. 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. [9] found that student-athletes reported better sleep during travel compared to on-campus, possibly due to a more favourable sleep environment than habitually experienced in student accommodation (e.g., lower noise pollution). 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 [67]. The impact of travel on student-athlete sleep is likely to be influenced by geographical location; for instance, while NCAA conferences may span large distances across multiple time zones, smaller countries may cover shorter distances with no changes in time zone.

Academics

Similar to the impact of training timing, earlier lesson start times have been shown to reduce sleep durations in university students [68]. However, how this applies to student-athletes remains unclear, as their wake times are often dictated by sport-related demands that begin earlier than academic classes [11]. Student-athletes face significant time pressures when balancing academic and sporting workloads, with the NCAA reporting a combined workload exceeding 60 h per week, and many struggling to balance academics with extracurricular activities [69]. A greater combined workload between sport and study has been linked to poorer self-reported sleep [70], although it has been argued that workload does not necessarily reduce sleep opportunity in student-athlete populations if good sleep practices are applied and prioritised [71].

Sleep outcomes also fluctuate across the academic semester. Bolin [72] found that sleep duration and variability remained stable early in the semester but worsened progressively as the term advanced. Hamlin et al. [73] 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 [74]. The year of study may also influence sleep, though it remains unclear which years are most affected by sleep-related challenges [31]. First-year students may experience greater sleep disruption due to the adjustment to significant life changes [9, 31], while final-year students may face disrupted sleep due to exam-related stressors [75]. Therefore, particular attention to sleep may be required at these academic stages.

Sex-Related Differences

Females commonly experience more sleep-related difficulties than males, as indicated by higher ASSQ sleep difficulty scores [29, 31], and a higher prevalence of travel-related sleep disturbances and daytime dysfunction [29]. Differences between males and females are perhaps expected, given the physiological and psychological differences between sexes. For example, Cain et al. [76] found women display shorter circadian rhythms in terms of melatonin and temperature, two important modulators of sleep, and slept at a later biological time and therefore required higher sleep efficiency to fulfil sleep needs. However, the impact of sex on perceived sleep in student-athletes remains inconclusive [18, 19, 25, 77]. Similarly, mixed findings have been reported for daytime sleepiness [18, 25]. Actigraphy-assessed sleep parameters typically show fewer sex differences. Goldman et al. [39] reported reduced wake after sleep onset in females, though no significant differences were found in other sleep outcomes, including sleep regularity. Meanwhile, Carter et al. [18] found that females had higher sleep efficiencies, shorter sleep onset latencies, and less wake after sleep onset compared to males, however this was limited by the data collection occurring over a short time frame of three days. Carter et al. [18] also found females to more accurately self-assess their total sleep time, although this contrasts with findings in other young female athletes where the mean disagreement between self-report and actigraphy measured sleep duration exceeded 30 min [78].

When taken together, the existing evidence indicates that differences in sleep may exist between sexes in student-athletes, with females more likely to report poorer sleep outcomes than males. The perception of poor sleep in females may be explained by longer sleep latencies than males, combined with reports of poorer sleep quality [79]. Furthermore, difficulties in initiating sleep may be concurrent with increased psychological stress [80]. However, the differences in study designs and participant characteristics make disentangling any differences in sleep between male and female student-athletes challenging, and further research in this remit is advised.

Chronotype

Student-athletes with an evening-type chronotype may be more susceptible to sleep disruptions, as reflected by their inclusion as a risk factor in the ASSQ [28]. Evening-type student-athletes are more likely to report poor sleep quality [49] and greater sleep difficulty [31] than those with a morning-type or intermediate-type chronotype. As discussed previously, this finding is likely explained by the misalignment between the preferred sleep patterns of evening-type chronotypes, and sport and/or academic activities being placed in the morning. 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 [45]. Such misalignment can affect sport performance, with evening-type collegiate swimmers performing a time trial significantly slower and with elevated levels of α-amylase (a biomarker for exercise-induced stress) when performing in the morning compared to the evening [43].

Downstream Consequences

In addition to the upstream factors discussed above, sleep health viewed from a social-ecological perspective will have widespread downstream consequences on health and well-being, reflecting the fundamental importance of sleep [58]. This section will discuss some of the key consequences for student-athletes, although there are likely to be many others 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

Few studies have examined the impact of sleep on performance in student-athletes without intervention and present mixed findings. Carazo-Vargas and Moncada-Jiménez [81] found that sleep efficiency was not related general or sport-specific physical performance, in contrast to research showing individual improvements in peak power output to be associated with multiple dimensions of sleep health including regularity, efficiency, and duration [82]. Han et al. [83] reported that sleep duration did not affect tennis performance, although greater variability in sleep durations was linked to poorer service accuracy. Meanwhile, 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 [84–86]. 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 [87]. Given the prevalence of sub-optimal sleep health amongst student-athletes, this would appear to be a key area for further research development, with a view towards both performance enhancement and mitigation of performance degradation.

Academic Attainment

Research indicates that several dimensions of sleep health, including regularity, efficiency, and duration, are associated with academic attainment [88]. Data from the US National College Health Assessment suggest that sleep-related factors, such as insufficient sleep and daytime tiredness, are linked to lower academic performance in NCAA student-athletes [89]. However, these relationships may be influenced by extraneous variables, and the reliance on self-reported measures introduces additional uncertainty when interpreting this association.

Injury

Participation in sports elevates the risk of concussion and injury, and sleep may play a role in both. Studies have shown that student-athletes with insufficient sleep durations are nearly twice as likely to sustain a concussion [90]. Additionally, insomnia symptoms and daytime sleepiness are independently associated with concussion risk [91]. Post-concussion, shorter sleep duration may be linked to increased symptom severity and impaired cognitive performance [92, 93]. Sleep characteristics can also influence baseline concussion assessment scores [44, 94, 95], underscoring the importance of conducting such assessments when student-athletes have had sufficient sleep. Research on the relationship between sleep and injury or illness risk in student-athletes is unclear, with studies indicating that acute sleep characteristics might influence injury risk [96, 97]. However, long-term associations between sleep and injury remain inconclusive, with some studies reporting significant relationships [73, 98–102], and others reporting null findings [103, 104]. 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 [105].

Wellbeing

The relationship between sleep and wellbeing is an emerging area of interest in student-athletes, as highlighted by the NCAA's recent consensus document on mental health best practices [106]. Cross-sectional studies have shown significant associations between various dimensions of

sleep health and mental health outcomes such as anxiety and depression [19, 22, 77, 107–110], perceived stress [107, 111–113], social support [107], psychological distress [114, 115], and suicide ideation [116]. Additionally, wellbeing-related factors like mindfulness have been shown to improve sleep hygiene [117], while self-compassion is linked to reduced sleep difficulties in student-athletes [118]. Given that poor sleep has also been associated with negative changes in mood [77, 100], implementation of sleep hygiene strategies for student-athletes that integrate such wellbeing related factors would seem imperative.

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 each associated with increased instances of physical and verbal assaults [119]. 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 [120]. 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 [121].

Intervention Studies

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.

Sleep Extension and Restriction Studies

Mah and colleagues conducted a series of sleep extension studies on student-athletes across different sports, including swimming [122], tennis [123], American football [124], and basketball [125]. These studies demonstrated that increasing sleep duration can positively impact various aspects of athletic performance. For instance, an increase of 1.8 h in total sleep time over several weeks led to improvements in shooting accuracy, sprint times, reaction times, reduced daytime sleepiness, and improved mood [125]. Similarly, a self-reported increase in sleep duration of 1.7 h per week improved serve accuracy and reduced daytime sleepiness in varsity tennis players [126]. Leduc et al. [127] found that a single night of sleep extension, instead of waking early for an active recovery session, had a positive effect on cognitive function. However, maintaining extended sleep durations may be unsustainable outside of experimental conditions.

Conversely, sleep restriction studies have examined how sleep loss impairs performance. Blumert et al. [128] 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 [129]. However, they observed substantial negative changes in mood and reduced post-exercise serum cortisol concentrations. Taheri and Arabameri [130] 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 [131]. Taken together, extending sleep would appear to benefit performance in student-athletes. As cognitive performance appear more sensitive to sleep loss than physical output, and most research is based on short, controlled tasks, there is a need for more ecologically valid studies exploring the impact of sleep across different sports and longer-duration activities.

Education Interventions

Education is often seen as a cornerstone of health behaviour change. For instance, an educational leaflet designed for Japanese student-athletes improved their perceived sleep quality [132]. However, sleep education alone may not be sufficient to achieve long-term behavioural changes [133]. 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 [134]. Similarly, a pilot intervention combining education, sleep tracking, and social support led to improvements in sleep, performance, and health [135–137]. Interestingly, there appears to be an appetite to receive sleep education to maximise sport performance in student-athletes, but only a small proportion report having previously received information of healthy sleep practices [138, 139].

Other Intervention Types

A few studies have explored the use of health-based practices to improve sleep in student-athletes. An eight-week mindfulness-based stress reduction intervention improved both subjective and objective sleep quality in collegiate rowers, along with their physical performance [140]. Other relaxation techniques, such as autogenic training [141] and progressive muscle relaxation [142], also led to beneficial changes in sleep outcomes post-intervention. Additionally, alternative approaches such as self-monitoring using mobile phone applications [143] and transcranial direct current

stimulation [144] have been investigated, though evidence supporting these remain inconclusive.

Future Research Directions

The growing academic interest in sleep among student-athletes, as evidenced by the increasing volume of literature over the past decade, is promising. While student-athletes are often more accessible to researchers at academic institutions, this review has highlighted that, despite sharing several sleep-related characteristics with elite athletes, student-athletes should be recognised as a distinct sub-population due to their unique differences.

This review summarised evidence for multiple dimensions of sleep health (see Table 1), identifying areas where future research could enhance understanding. Sleep regularity has emerged as a particularly important dimension for health and wellbeing [6]. Student-athletes, who are often prone to irregular sleep/wake patterns, could benefit from longitudinal studies employing actigraphy to assess regularity using appropriate metrics tailored to study design [145]. Additionally, irregular sleep/wake patterns influence daily sleep timing; thus, future studies should report daily measures alongside average sleep parameters. The paucity of research on sleep satisfaction using qualitative methodologies also limits our understanding of its impact on intervention approaches. For example, if student-athletes perceive their sleep as satisfactory, education-based or behavioural interventions may have limited effectiveness. Qualitative research could also elucidate perceived upstream influences on sleep practices, providing valuable intervention targets.

Various factors that act as upstream influences on sleep health were discussed, including sex-based differences. Given the evidenced differences between male and female sleep parameters, and the distinct lack of representation of female athletes in the literature base [146], future research should be directed towards the investigation of female student-athletes, to provide bespoke and accurate advice for sleep improvement. Furthermore, those investigating mixed-sex cohorts should be encouraged to run sub-analyses on sex, to ensure accurate conclusions can be drawn.

One upstream influence that has emerged as an important consideration but has yet to be examined in student-athletes, is light exposure. The circadian cycle governs the fluctuation in sleep propensity over of a period of approximately 24-hours, and is influenced by external environmental cues, with light being the most influential [147]. In professional male athletes, a higher exposure to light in the first two hours of the day was associated with higher actigraphy-derived total sleep time and subjective sleep quality, while higher light exposure in the two hours before bedtime were associated with higher ASSQ global scores [148], highlighting the importance of the timing of light exposure for circadian functioning. Adolescents with irregular sleep patterns also tend to have irregular light exposure, potentially disrupting circadian rhythms [149]. With student-athletes displaying low sleep regularity, this is of particular importance, and the relationship between sleep and light exposure warrants attention.

Research on student-athletes has often prioritised their athletic identity, overlooking the impact of academic demands. These dual demands likely interact in complex ways; for instance, the timing of academic lessons may prevent napping after early-morning training or necessitate earlier wake times than preferred on non-training days. Longitudinal studies examining the timing of both academic and athletic activities, and their impact on sleep/wake patterns, could provide a stronger rationale for structural changes to improve sleep. Such changes might enhance both academic attainment and athletic performance. Interventions aligning the timing of sport and academics with young adults' phase-delayed chronotype should also be explored. Evidence from school settings suggests such interventions can improve sleep outcomes [150], and while these require significant buy-in from multiple stakeholders, may prove a more effective and sustained approach to improvement in sleep outcomes.

In the absence of structural changes, alternative interventions to enhance sleep outcomes are necessary. Sleep hygiene interventions have proven a popular approach in athletes [151]. Such interventions are often effective at initially improving sleep outcomes, although where a long-term follow-up has been conducted, these changes have not been maintained [e.g., 152]. Furthermore, the variations in intervention design and unclear specification of the intervention content make it difficult to understand which components are effective or ineffective at driving sleep-related behaviour change. Subsequently, such interventions should standardised terminology when describing intervention content, such as using a behaviour change technique taxonomy, and integrate behaviour change theory during development to ensure the design intervention is tailored towards the student-athlete population being targeted [153].

Conclusions

The evidence presented indicates that student-athletes present a high prevalence of suboptimal sleep health across multiple dimensions, driven by various upstream influences and resulting in important downstream consequences. Sleep health is particularly pertinent for student-athletes who aspire to perform at a high level in both sporting and

academic domains, yet there is evidence to indicate that poor sleep health can prevent optimal performance in both. Ironically, it is the upstream influences related to their status as a student-athlete that contribute substantially to the sub-optimal sleep health observed. Accordingly, it is important to consider student-athletes as a distinct population from elite athletes, as some of the upstream influences underpinning sleep health are fundamentally different. With sleep in student-athletes now an emerging area of research, there are various avenues of empirical exploration that can advance understanding in this population. A more comprehensive understanding of sleep health and the upstream influences that distinguish this population from elite athletes and non-athlete student peers would aid the design of targeted interventions and implementation of policy measures that support sleep health and enable student-athletes to thrive in both sport and study.

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Declarations

Competing Interests The authors declare no competing interests.

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