



Sleep and Performance in Professional Athletes

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Accepted: 3 November 2022 / Published online: 17 January 2023
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Abstract

Purpose of Review Sleep is an essential human behavior that plays a key role in proper biopsychosocial development as well as short- and long-term biological, physical, psychological, and cognitive health. Sleep plays a key role in athletic performance, influencing an athlete's ability to train, recover, and perform, as well as their overall wellness. Over the recent decade, the awareness of sleep's import has penetrated just about every professional sport domain. The purpose of the review was to identify and synthesize the literature published within the past 5 years (2018–2022) that relates to sleep and performance in professional athletes. Literature related to nonprofessional, high-level athletes (e.g., collegiate; Olympic) was omitted as well as those associated with non-traditional professional sports (e.g., eSports).

Recent Findings Results from 38 articles were incorporated into this review, which covered (1) the sleep's role in the training, physical injury prevention and recovery, competitive performance, and mental health of professional athletes, (2) common sleep problems and disorders in professional athletes, and (3) the impact of unique challenges from training, travel, competition, and other factors on sleep health. Additionally, we provide an orientation to utilized strategies and interventions to assist with sleep health in professional athletes, as well as conclude with a commentary on critical steps forward.

Summary Sleep plays a critically important role in the training, recovery, performance, and overall wellness of professional athletes. Professional athletes are vulnerable to a variety of sleep-related problems and disorders, due to unique factors related to training, travel, and competition, among other factors. Improved, standardized research methodology and partnerships between professional athletes, coaches, teams, and organizations and researchers are necessary to advance the knowledge of sleep and performance in professional athletes, including identifying sport-specific differences and variation across individual characteristics, as well as developing individualizable, dynamic, and appropriate interventions for improving sleep health among professional athletes.

Keywords Sleep · Athletes · Professionals · Performance · Health · Circadian · Travel · Fatigue

This article is part of the Topical Collection on *Sleep and Athletic Performance*

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Introduction

Sleep is an essential human behavior that plays a key role in proper biopsychosocial development as well as short- and long-term biological, physical, psychological, and cognitive health [1]. Sleep health shares an intimate, bidirectional relationship with mental health [2] and plays a notable role in one's social, occupational, and academic functionality [3, 4]. Furthermore, sleep has been shown to impact all aspects of athletic performance, from training to actual performance to recovery [5–7]. This has led to increased empirical attention towards the sleep health of athletes [8], which largely began with the foundational work of Mah and colleagues (2011) that showed the beneficial effects of improved sleep health on the athletic performance of collegiate basketball players [9].

Over the recent decade, the awareness of sleep's import on an athlete's training, recovery, performance, and wellness has penetrated just about every professional sport domain. Professional athletes face unique demands, such as frequent travel resulting in circadian disruption and misalignment, strenuous training regimens, and significant anxiety and stress related to competitive performance, that heighten the risk for poor sleep health. Although still relatively understudied, there has been a notable uptick over the recent years in empirical research related to sleep in professional athletes.

Purpose and Scope

This review is purposed to summarize the recent research published within the 5 past years that centers specifically on sleep and performance in professional athletes. As such, only literature published in 2018 and beyond will be included in this review. We recommend the work of Watson (2017) [10], Gupta and colleagues (2017) [11], Simpson and colleagues (2017) [12], and Nedelec and colleagues (2018) [13] for review of related literature published prior to 2018. Furthermore, given the strict emphasis on professional athletes, this review will not include literature related to nonprofessional, high-level athletes (e.g., collegiate). For specific information on sleep and performance in nonprofessional, high-level athletes, we recommend the work of Knufinke M and colleagues (2017) [14], Kroshus E and colleagues (2019) [15], Wilkes JR and colleagues (2021) [16], and Charest and Grandner (2022) [5]. Additionally, we omitted research related to professional eSports, given our intentional focus on traditional athletics. Very limited literature pertained to sleep in eSports professionals, even though this population of professional athletes may be uniquely vulnerable to poor sleep health due to factors including notable sleep–wake schedule irregularities, frequent and prolonged electronic screen exposure, and elevated caffeine consumption. If interested in sleep within this population of professional athletes, we recommend the work of Bonnar D and colleagues (2019) [17], Bonnar D and colleagues (2022) [18], and Lee S and colleagues (2021) [19].

In total, we identified 38 different articles that met inclusionary criteria for this review, with these serving as the literature utilized to synthesize the recent findings on sleep and performance in professional athletes (Table 1).

Sleep's Role in Athletics at the Professional Level

Sleep health influences all aspects of athletics, including training, injury risk and recovery, and actual performance [5]. Additionally, sleep health shares an intimate relationship

with mental health [2], which also has unique influence on an athlete's ability to train, recover, and perform [5]. The following sections review the recent literature related to the relationships of sleep with training, injury risk and recovery, performance, and mental health within professional athletes.

Training

Optimal athletic performance requires effective training. Although there is variation across sport type and between athletes within the same sport type, professional athletes generally train year-round, during and outside of competition periods, with the intensity of training adjusting across the calendar year and competition schedule. Sleep plays a central role in an athlete's ability to not only attend and navigate demanding training schedules but also to maximize benefit from training by being able to provide peak effort and endurance.

In our review of the literature, we identified four articles specifically analyzing the role of sleep in the training of professional athletes [20–23]. In a study of professional mixed martial arts athletes across a 6-week training camp, Peacock and colleagues (2018) found that greater sleep quality and regularity associated with fewer missed practice sessions, likely due to reductions in fatigue, illness, and injuries [20]. This finding aligns with the work from Fitzgerald and colleagues (2019), whereby reduced sleep quantity was associated with greater incidence of illness in professional Australian football athletes [21]. Additionally, Peacock and colleagues showed that better sleep characteristics, such as reduced sleep latency, were related to improved physical performance abilities during the 6 weeks of training [20]. Similarly, Teece and colleagues (2021) highlighted the negative effects of short sleep duration on the aerobic capacity of professional rugby athletes during preseason training [22]. Lastly, Serpell and colleagues (2019) showcased significant relationships between sleep duration and efficiency with salivary testosterone and cortisol levels in a sample of professional rugby athletes [24], which is important given the fact that these hormones have a notable impact on an athlete's training ability and outcomes [23].

Taken together, sleep has been shown to have an impact on the ability of professional athletes to attend training sessions as well as enhance outcomes from training due to physical performance during training and physiological factors that influence training. There is a need for future research to better evaluate how enhancing sleep health in professional athletes influences training outcomes as well as assists in managing variations in training load and intensity. Furthermore, there is a need to produce research that showcases the positive effects of good sleep health on prevention of illness, increased training attendance, and enhanced training effectiveness. Research is often shaped to focus on the

Table 1 Focal, relevant literature included in review
Focal, relevant literature included in review

Ref #	Article name	Authorship (publication year)	Sample: sport type(s)	Locations in review	Key takehomes
20	Sleep Data, Physical Performance, and Injuries in Preparation for Professional Mixed Martial Arts	Peacock CA et al. (2018)	8 male mixed martial artists	Sleep's role in athletics at the professional level a.a.a. <i>Training</i> b.b.b. <i>Physical Injury: prevention and recovery</i> c.c.c. <i>Competitive performance</i>	<ul style="list-style-type: none"> Greater sleep schedule variability directly correlated with greater number of injuries Greater severity of sleep initiation difficulties associated with worse maximum rate of oxygen (VO_{2MAX}), vertical jump, and heart rate recovery Lower sleep efficiency associated with worse heart rate recovery
21	The influence of sleep and training load on illness in nationally competitive male Australian Football athletes: A cohort study over one season	Fitzgerald D et al. (2019)	44 male Australian Football League athletes	Sleep's role in athletics at the professional level a. a. <i>Training</i> Common sleep problems in professional athletes Unique challenges for professional athletes that can negatively influence sleep a.a.a. <i>Other factors: physical injury and illness, electronic use, and nutritional habits</i>	<ul style="list-style-type: none"> Lower sleep quantity associated with greater occurrence of illness On average, sufficient sleep duration was present within this sample Athletes experiencing acute or chronic illness generally showed lower sleep duration and reduced sleep quality
22	Sleep and Performance during a Preseason in Elite Rugby Union Athletes	Teece AR et al. (2021)	29 rugby union athletes	Sleep's role in athletics at the professional level a.a.a. <i>Training</i> b.b.b. <i>Mental health</i> Common sleep problems in professional athletes Unique challenges for professional athletes that can negatively influence sleep a.a.a. <i>Training factors</i>	<ul style="list-style-type: none"> Shorter sleep duration associated with worse aerobic capacity Higher sleep efficiency and shorter sleep latency correlated with better overall wellness, including mood Sample PSQI average score suggested clinically significant poor sleep quality Nearly half of the sample experienced insufficient sleep duration Athletes displayed 73-min reduction in nightly sleep duration during preseason training

Table 1 (continued)

Focal, relevant literature included in review

Ref #	Article name	Authorship (publication year)	Sample: sport type(s)	Locations in review	Key takehomes
24	Sleep and Salivary Testosterone and Cortisol During a Short Preseason Camp: A Study in Professional Rugby Union	Serpell BG et al. (2019)	Male, rugby union athletes	Sleep's role in athletics at the professional level a.a.a. <i>Training</i> b.b.b. <i>Physical injury: prevention and recovery</i> Unique challenges for professional athletes that can negatively influence sleep a.a.a. <i>Training factors</i>	<ul style="list-style-type: none"> ●●● Sleep duration and sleep efficiency directly correlated with salivary testosterone and cortisol levels ●●● Measured sleep parameters did not correlate with general daily muscle soreness ●●● A short, 4-day preseason camp did not produce changes in sleep duration or latency
28	The Effects of Sleep Extension on Sleep, Performance, Immunity and Physical Stress in Rugby Players	Swinbourne R et al. (2018)	19 male professional rugby athletes	Sleep's role in athletics at the professional level a.a.a. <i>Physical injury: prevention and recovery</i> b.b.b. <i>Competitive performance</i> Common sleep problems in professional athletes	<ul style="list-style-type: none"> ●●● Sleep extension intervention resulted in a significant decrease in mean cortisol levels ●●● Increasing sleep duration and quality associated with improved reaction time ●●● Sample PSQI average score was just slightly below the established threshold for poor sleep quality
36	A 12-month prospective cohort study of symptoms of common mental disorders among professional rugby players	Gouttebauge V et al. (2018)	595 male professional rugby athletes	Sleep's role in athletics at the professional level a.a.a.a.a. <i>Mental health</i>	<ul style="list-style-type: none"> ●●● High incidence rates of mental health problems, including anxiety/depression (28%), adverse alcohol use (22%), eating disorders (12%), sleep disturbances (11%), and general psychological distress (11%), were captured in this sample ●●● Additionally, 19% of sample reported have 2 + problems currently
37	Impact of the SARS-CoV-2 Coronavirus Pandemic on Physical Activity, Mental Health and Quality of Life in Professional Athletes—A Systematic Review	Jurecka A, Skucińska P, and Gądek A. (2021)	Male and female from variety of professional sports	Sleep's role in athletics at the professional level a.a.a. <i>Mental health</i>	<ul style="list-style-type: none"> ●●● Highlighted an intimate relationship between sleep and mental health, whereby both sleep and mental health simultaneously degraded in response to the distress associated with the SARS-CoV-2 coronavirus pandemic

Table 1 (continued)

Focal, relevant literature included in review

Ref #	Article name	Authorship (publication year)	Sample: sport type(s)	Locations in review	Key takehomes
38	Sleep as a Major Determinant for Mental Health Outcomes in Elite Australian Football League (AFL) Athletes	Facer-Childs ER et al. (2022)	68 male Australian Football League athletes	Sleep's role in athletics at the professional level <i>b. Mental health</i> Common sleep problems in professional athletes	<ul style="list-style-type: none"> ••• Showcased significant role that sleep health has on mental health, whereby 31 to 51% of the variance in depression, anxiety, and stress symptoms was explained by a combination of multiple sleep monitoring measures ••• 38.6% of the sample provided PSQI scores suggestive of clinically significant poor sleep quality ••• Worse sleep quality, captured by the PSQI, was associated with slower reaction times as well as worse perceptual ability
40	Sleep Quality's Effect on Vigilance and Perceptual Ability in Adolescent and Adult Athletes	Stavrou VT et al. (2021)	86 male soccer athletes	Sleep's role in athletics at the professional level <i>a.a. Competitive performance</i>	<ul style="list-style-type: none"> ••• Athletes with good sleep quality prior to Ramadan experienced less deleterious effects on performance while fasting during Ramadan than those with poor sleep quality prior to Ramadan
41	Sleep Quality and Performance in Professional Athletes Fasting during the Month of Ramadan	Lipert A et al. (2021)	32 male, middle-distance runners	Sleep's role in athletics at the professional level <i>c. Competitive performance</i> Common sleep problems in professional athletes	<ul style="list-style-type: none"> ••• Sample PSQI average score at baseline suggested clinically significant poor sleep quality ••• Top 3 finishers in the race obtained significantly more sleep duration across the 5-day race than the bottom 3 finishers ••• On average, a sample of cyclists were experiencing insufficient sleep duration
42	Consecutive Days of Racing Does Not Affect Sleep in Professional Road Cyclists	Sargent C et al. (2022)	14 male road cyclists	Sleep's role in athletics at the professional level <i>d. Competitive performance</i> Common sleep problems in professional athletes	<ul style="list-style-type: none"> ••• Sleep restriction, as a consequence of late-night tweeting, associated with worse next-day game performance, evidenced most strongly by significant decreases in shooting accuracy ••• Athletes may be uniquely susceptible to late-night tweeting (and other forms of social media use) due to timing of games/practices, which has consequences for sleep ability, quality, and duration
43	Association between late-night tweeting and next-day game performance among professional basketball players	Jones JJ et al. (2019)	112 male National Basketball Association athletes	Sleep's role in athletics at the professional level <i>e. Competitive performance</i> Unique challenges for professional athletes that can negatively influence sleep <i>a.a. Other factors: physical injury and illness, electronic use, and nutritional habits</i>	

Table 1 (continued)

Focal, relevant literature included in review

Ref #	Article name	Authorship (publication year)	Sample: sport type(s)	Locations in review	Key takehomes
44	Greater circadian disadvantage during evening games for the National Basketball Association (NBA), National Hockey League (NHL) and National Football League (NFL) teams traveling westward	Roy J and Forest G (2018)	National Basketball Association, National Hockey League, and National Football League (teams)	Sleep's role in athletics at the professional level a.a.Travel and time zone change: negative influence on sleep that affects performance	<ul style="list-style-type: none"> ●●●Traveling westward for an away game in the evening associates with a significant competitive disadvantage ●●●Competitive disadvantage increases linearly as a function of the number of time zones traveled ●●●NBA teams generally have a 3.69% lower winning percentage when traveling westward, relative to eastward travel ●●●Yet, sequence of games (e.g., Away-Home, Home-Away, and Away-Away) and distance traveled for the game were identified as factors that moderate the effect of westward travel
45	Impacts of travel distance and travel direction on back-to-back games in the National Basketball Association	Charest J et al. (2021)	National Basketball Association (teams)	Sleep's role in athletics at the professional level a.a.Travel and time zone change: negative influence on sleep that affects performance	<ul style="list-style-type: none"> ●●●Free throw shooting abilities were significantly worse when jet-lagged (defined as travel across at least 3 time zones), relative to non-jetlagged games ●●●Yet, this relationship only emerged when traveling westward
46	Impact of jet lag on free throw shooting in the National Basketball Association	Glinski J and Chandu D. (2022)	National Basketball Association (athletes and teams)	Sleep's role in athletics at the professional level a.a.Travel and time zone change: negative influence on sleep that affects performance	<ul style="list-style-type: none"> ●●●Time zone change in the eastward, but not westward direction, was associated with reduced NBA winning percentage, as well as overall point, rebound, and field goal percentage differential ●●●Eastward travel across time zones associated with worse performance results than westward travel across time zones in soccer athletes ●●●Showcased lower winning percentages, shooting accuracy, effort, and defensive performance when traveling across time zones, regardless of travel direction
47	Eastward Jet Lag is Associated with Impaired Performance and Game Outcome in the National Basketball Association	Leota J et al. (2022)	National Basketball Association (teams)	Sleep's role in athletics at the professional level a.a.Travel and time zone change: negative influence on sleep that affects performance	<ul style="list-style-type: none"> ●●●Time zone change in the eastward, but not westward direction, was associated with reduced NBA winning percentage, as well as overall point, rebound, and field goal percentage differential ●●●Eastward travel across time zones associated with worse performance results than westward travel across time zones in soccer athletes ●●●Showcased lower winning percentages, shooting accuracy, effort, and defensive performance when traveling across time zones, regardless of travel direction
48	Direction of travel of time zones crossed and results achieved by soccer players. The road from the 2018 FIFA World Cup to UEFA EURO 2020	Zacharko M et al. (2020)	32 soccer teams participating in international competitions	Sleep's role in athletics at the professional level a.a.Travel and time zone change: negative influence on sleep that affects performance	<ul style="list-style-type: none"> ●●●Time zone change in the eastward, but not westward direction, was associated with reduced NBA winning percentage, as well as overall point, rebound, and field goal percentage differential ●●●Eastward travel across time zones associated with worse performance results than westward travel across time zones in soccer athletes ●●●Showcased lower winning percentages, shooting accuracy, effort, and defensive performance when traveling across time zones, regardless of travel direction
49	Utilizing the National Basketball Association's COVID-19 restart "bubble" to uncover the impact of travel and circadian disruption on athletic performance	McHill AW and Chinoy ED. (2020)	National Basketball Association (teams)	Sleep's role in athletics at the professional level a.a.Travel and time zone change: negative influence on sleep that affects performance	<ul style="list-style-type: none"> ●●●Time zone change in the eastward, but not westward direction, was associated with reduced NBA winning percentage, as well as overall point, rebound, and field goal percentage differential ●●●Eastward travel across time zones associated with worse performance results than westward travel across time zones in soccer athletes ●●●Showcased lower winning percentages, shooting accuracy, effort, and defensive performance when traveling across time zones, regardless of travel direction

Table 1 (continued)

Focal, relevant literature included in review

Ref #	Article name	Authorship (publication year)	Sample: sport type(s)	Locations in review	Key takehomes
50	The Negative Influence of Air Travel on Health and Performance in the National Basketball Association: A Narrative Review	Huyghe T et al. (2018)	Narrative review focused on National Basketball Association (teams)	Sleep's role in athletics at the professional level <i>f. Travel and time zone change: negative influence on sleep that affects performance</i> Unique challenges for professional athletes that can negatively influence sleep a.a.a. <i>Travel factors</i> b.b.b. <i>Competition factors</i>	<ul style="list-style-type: none"> ●●●Frequent travel is mentally and physically fatiguing, with these consequences having the potential to degrade sleep health that in turn negatively influences performance ●●●Congested competition schedules in the NBA require frequent travel, often with time zone change, that can have widespread consequences, including degraded sleep health
53	Inter-relationship between sleep quality, insomnia and sleep disorders in professional soccer players	Khalladi K et al. (2019)	111 male soccer athletes from Premier League in Qatar	Common sleep problems in professional athletes	<ul style="list-style-type: none"> ●●●68.5% of the sample provided PSQI scores suggestive of clinically significant poor sleep quality ●●●35.1% of the sample were experiencing insufficient sleep duration ●●●27% of the sample reported subthreshold (or worse) insomnia symptoms ($ISI \geq 11$)
54	Complete sleep evaluation of top professional cross-country mountain bikers' athletes	Garbellotto L et al. (2022)	8 male and female cross-country mountain bikers	Common sleep problems in professional athletes	<ul style="list-style-type: none"> ●●●On average, sufficient sleep duration was present within this sample
55	The Sleep Behaviors of Elite Australian Rules Footballers Before and After Games During an Entire Season	Sargent C et al. (2022)	37 male Australian rules footballers	Common sleep problems in professional athletes Unique challenges for professional athletes that can negatively influence sleep a.a.a. <i>Competition factors</i>	<ul style="list-style-type: none"> ●●●Average sleep duration within the sample was insufficient across the entire season ●●●On nights after competition, bedtime was delayed and risetime was advanced, resulting in ~2.5 h of reduced sleep duration on competition nights

Table 1 (continued)

Focal, relevant literature included in review

Ref #	Article name	Authorship (publication year)	Sample: sport type(s)	Locations in review	Key takehomes
56	An Individualized Intervention Increases Sleep Duration in Professional Athletes	Sargent C et al. (2021)	19 cricketers	Common sleep problems in professional athletes Unique challenges for professional athletes that can negatively influence sleep <i>g. Training factors</i> Strategies and interventions to assist with sleep in professional athletes	<ul style="list-style-type: none"> ●●● On average, habitual sleep duration was insufficient, with this being a notable reduction from the sample reporting a nightly sleep need of 8 + h ●●● Training demands, such as early morning mandatory training and/or meetings, inhibited athletes from achieving their prescribed sleep duration targets during an individualized sleep intervention ●●● An individualized sleep intervention showcased significantly better sleep health characteristics (e.g., bedtime timing, time in bed, and total sleep time), post intervention, relative to control group
57	The Impact of Chronotype on the Sleep and Training Responses of Elite Female Australian Footballer	Lastella M et al. (2021)	36 female Australian footballers from Australian Football League Women	Common sleep problems in professional athletes	<ul style="list-style-type: none"> ●●● Insufficient sleep duration was present among athletes reporting eveningness preference, but not those who identified as a morning or intermediate circadian preference
58	Psychological correlates of insomnia in professional soccer players: An exploratory study	Ballesio A et al. (2022)	210 male soccer athletes	Common sleep problems in professional athletes Unique challenges for professional athletes that can negatively influence sleep <i>a.a. Training factors</i> <i>b.b. Other factors: physical injury and illness, electronic use, and nutritional habits</i>	<ul style="list-style-type: none"> ●●● 36.6% of the sample reported at least subclinical symptoms of insomnia (ISI > 7) ●●● Surprisingly, no association was observed between late night training and insomnia symptom severity, which is antithetical to the belief that late night training induces pre-sleep arousal ●●● Consumption of stimulants (caffeine, nicotine, and chocolate) associated with heightened insomnia-related characteristics

Table 1 (continued)

Focal, relevant literature included in review

Ref #	Article name	Authorship (publication year)	Sample: sport type(s)	Locations in review	Key takehomes
59	Effect of Training/Competition Load and Scheduling on Sleep Characteristics in Professional Rugby League Athletes	Conlan G et al. (2021)	26 male National Rugby League athletes	Common sleep problems in professional athletes Unique challenges for professional athletes that can negatively influence sleep a.a.a. <i>Training factors</i>	<ul style="list-style-type: none"> •••Sample displayed clinically significant wake after sleep onset (> 30 min) and sleep efficiency (< 85%) on average, with this uninfluenced by whether assessed during low load training, high load training, or match weeks
60	Professional Athletes Have Poorer Sleep Quality and Sleep Hygiene Compared With an Age-Matched Cohort	Cameron AFM, Perera N, and Fulcher M. (2021)	184 male and female rugby, netball, and soccer athletes	Common sleep problems in professional athletes Unique challenges for professional athletes that can negatively influence sleep a.a.a. <i>Competition factors</i>	<ul style="list-style-type: none"> •••Professional athletes showed worse sleep behaviors, such as schedule irregularity and maladaptive sleeping environments, and reported more general sleep disturbances relative to an age-matched non-athlete cohort •••68.5% of the sample reported having difficulties sleeping after competition
61	Obstructive sleep apnea in professional rugby athletes: An exploratory study	Caia J et al. (2020)	22 male rugby league athletes	Common sleep problems in professional athletes Unique challenges for professional athletes that can negatively influence sleep a.a.a. <i>Training factors</i>	<ul style="list-style-type: none"> •••As a sample, average apnea-hypopnea index (AHI) was in the none/minimal range. Yet, 31.8% (AHI = 5–14) and 13.6% (AHI = 15–29) of the sample displayed mild and moderate sleep-disordered breathing, respectively •••Sleep duration was significantly reduced on training days, relative to non-training days
62	Perceived Training Load, Muscle Soreness, Stress, Fatigue, and Sleep Quality in Professional Basketball: A Full Season Study	Clemente FM et al. (2019)	15 European basketball athletes	Common sleep problems in professional athletes Unique challenges for professional athletes that can negatively influence sleep a.a.a. <i>Competition factors</i>	<ul style="list-style-type: none"> •••Sleep quality was generally good across the entire season in this sample of basketball players •••Congested competition weeks associated with lower sleep quality ratings, relative to regular weeks •••Sufficient sleep duration was observed, on average, in this sample. This sample also demonstrated sleep latency and efficiency within healthy limits •••Sleep hygiene education quickly improved sleep behaviors in this sample, yet the durability of effects was limited
63	The influence of sleep hygiene education on sleep in professional rugby league athletes	Caia J et al. (2018)	24 rugby league athletes	Common sleep problems in professional athletes Strategies and interventions to assist with sleep in professional athletes	<ul style="list-style-type: none"> •••Sleep hygiene education quickly improved sleep behaviors in this sample, yet the durability of effects was limited

Table 1 (continued)

Focal, relevant literature included in review

Ref #	Article name	Authorship (publication year)	Sample: sport type(s)	Locations in review	Key takehomes
64	Sleep Regularity and Predictors of Sleep Efficiency and Sleep Duration in Elite Team Sport Athletes	Halson SL et al. (2022)	203 male and female netball, Australian rules football, rugby league, and soccer athletes	Common sleep problems in professional athletes	<ul style="list-style-type: none"> ●●●Athletes with sleep schedule irregularity had significantly lower sleep efficiency, relative to those with regular sleep schedules ●●●Although sleep duration was lower on training days relative to non-training days, sleep duration and sleep efficiency were still within healthy limits on typical training days ●●●Long-haul air travel, with minimal time zone change, significantly disrupted sleep–wake behaviors and degraded sleep health
74	Travel fatigue and sleep/wake behaviors of professional soccer players during international competition	Lastella M, Roach GD, and Sargent C. (2019)	7 male soccer athletes	Unique challenges for professional athletes that can negatively influence sleep a.a.a. <i>Training factors</i> b.b.b. <i>Travel factors</i> c.c.c. <i>Competition factors</i>	<ul style="list-style-type: none"> ●●●Bedtime was latest on nights following competition, while risetime was earliest on mornings following competition, relative to other conditions (training, rest, and pre-competition), with this resulting in significantly reduced sleep duration that also coincided with significantly reduced sleep efficiency
75	Around the world in 16 days: the effect of long-distance transmeridian travel on the sleep habits and behaviors of a professional Super Rugby team	Smithies TD et al. (2021)	37 male super rugby athletes	Unique challenges for professional athletes that can negatively influence sleep a.a.a. <i>Travel factors</i> b.b.b. <i>Competition factors</i>	<ul style="list-style-type: none"> ●●●Long-distance transmeridian travel (LDTT), defined as travel across more than 3 time zones, produced significant irregularities in the timing of sleep onset and offset, as well as significant variation in sleep duration ●●●Athletes displayed significantly shorter sleep duration (~70 min) on night's following competition, with this partly explained by earlier risetimes for early travel

Table 1 (continued)

Focal, relevant literature included in review

Ref #	Article name	Authorship (publication year)	Sample: sport type(s)	Locations in review	Key takehomes
76	The impact of matches and travel on rugby	Lo M et al. (2022)	4 super rugby teams	Unique challenges for professional athletes that can negatively influence sleep a.a.a. <i>Travel factors</i> b.b.b. <i>Competition factors</i>	<ul style="list-style-type: none"> ●●● Generally, teams experienced significant reduction in sleep duration when traveling overseas, likely due to a combination of travel fatigue, jet lag, and disruption of normal sleep behaviors ●●● Sleep duration was significantly reduced on competition nights, partly explained by competition-related psychological stressors ●●● Athletes displayed significantly delayed bedtime, shorter sleep duration, longer sleep latency, and worse sleep efficiency on competition nights ●●● Caffeine supplementation prior to and during competition resulted in increased post competition salivary caffeine concentration, which associated with a delayed bedtime, longer sleep latency, and reduced sleep efficiency
77	Does Caffeine Consumption Influence Postcompetition Sleep in Professional Rugby League Athletes	Caia J et al. (2022)	15 rugby league athletes	Unique challenges for professional athletes that can negatively influence sleep a.a.a. <i>Competition factors</i> b.b.b. <i>Other factors: physical injury and illness, electronic use, and nutritional habits</i>	<ul style="list-style-type: none"> ●●● Meal timing was delayed on competition days, which seemingly contributed to later bedtimes and increased wake after sleep onset ●●● Meal timing and composition influenced sleep behaviors, ability, and quality. Delay in meal timing generally associated with delayed bedtime. Additionally, increased daily protein intake associated with lower sleep efficiency and increased wake after sleep onset. Evening caloric intake associated with longer sleep latency, with evening sugar intake having a uniquely detrimental effect on sleep duration, sleep efficiency, and wake after sleep onset
78	Nutrient intake, meal timing and sleep in elite male Australian football players	Falkenberg E et al. (2021)	36 male Australian Football League athletes	Unique challenges for professional athletes that can negatively influence sleep a.a.a. <i>Competition factors</i> b.b.b. <i>Other factors: physical injury and illness, electronic use, and nutritional habits</i>	<ul style="list-style-type: none"> ●●● Meal timing was delayed on competition days, which seemingly contributed to later bedtimes and increased wake after sleep onset ●●● Meal timing and composition influenced sleep behaviors, ability, and quality. Delay in meal timing generally associated with delayed bedtime. Additionally, increased daily protein intake associated with lower sleep efficiency and increased wake after sleep onset. Evening caloric intake associated with longer sleep latency, with evening sugar intake having a uniquely detrimental effect on sleep duration, sleep efficiency, and wake after sleep onset

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Focal, relevant literature included in review					
Ref #	Article name	Authorship (publication year)	Sample: sport type(s)	Locations in review	Key takehomes
79	Managing Load to Optimize Well-Being and Recovery During Short-Term Match Congestion in Elite Basketball	Doeven SH et al. (2021)	16 basketball athletes from Dutch Basketball Association	Unique challenges for professional athletes that can negatively influence sleep a.a.a. <i>Competition factors</i>	<ul style="list-style-type: none"> ●●● Increased match congestion (1 game versus 2 + games in a week) did not result in significant changes in sleep quality ●●● 86% of the sample reported using naps prior to a competitive match, with the sizeable majority of these athletes reporting that they believed napping to benefit their performance
82	Nap to perform? Match-day napping on perceived match performance in professional rugby union athletes	Teece AR et al. (2022)	30 rugby union athletes	Strategies and interventions to assist with sleep in professional athletes	

Table 1 presents the focal, relevant literature included in this review’s synthesis. In-text reference number [Ref #], article title, authorship and publication year, sample information including sport type(s) (sample: sport type(s)), locations in the review, and key takehomes are provided for all included literature. A number of athletes included in the sample are provided, when available. Similarly, the genders within the sample are provided, when explicitly available in the original article

consequences, yet athletes, coaches, teams, and organizations may be more motivated for change if positive outcomes related to training are emphasized.

Physical Injury: Prevention and Recovery

Physical injury is an inherent risk of participation in athletic training and competition. Injuries can interfere with training regimes, degrade competitive performance, and exist as a source of psychological distress. As such, modifiable factors that can enhance prevention and recovery of physical injury in professional athletes are of high import. Sleep has been shown to play a mediating role in an athlete’s risk for developing injury as well as their ability to recover from injury effectively and efficiently [5, 6]. Although this mediating relationship extends to all forms of physical injury associated with athletics, the relationship has been most extensively explored in the context of concussion. Poor sleep health not only exists as a primary risk factor for sport-related concussion but also has been shown to negatively influence concussion severity, recovery timeline, and overall treatment outcomes [25–27].

Somewhat surprisingly, our review identified a scarcity ($N=3$) of recent studies in professional athletes evaluating the relationships of sleep health with physical injury prevention and recovery [20, 24, 28•]. Peacock and colleagues (2019) showed a significant trend between increasing sleep schedule variability and number of injuries in a sample of mixed martial arts professionals [20]. In contrast, Serpell and colleagues (2019) did not find any significant correlations between assessed sleep parameters and general daily muscle soreness—a measure of physical strain and potential proxy into developing injury—across 6 weeks of training in professional rugby athletes [24]. However, this study did demonstrate adverse effects of poor sleep health characteristics on hormones that play central roles in musculoskeletal growth and repair, including testosterone and cortisol [23, 29]. This finding aligns with the work of Swinbourne and colleagues (2018) that evidenced a decrease in mean cortisol levels following a sleep extension intervention in professional rugby players [28•].

Overall, sleep exists as a key factor in the prevention and recovery of physical injury, but there is limited empirical literature directly analyzing the relationships between sleep health and physical injury prevention and recovery in professional athletes. Longitudinal research design, across the full season and/or calendar year, that continuously monitors professional athletes’ sleep, injury status, and relevant physiology, is necessary to further enhance the understanding of the role that sleep health plays in the prevention and recovery of physical injury. Additionally, research should explore differences across sport types, given the differential risk for various injuries as well as variation in physical

demand, competition season length, travel demands, and training and competition schedules.

Mental Health

The ability to athletically perform at a peak level is contingent upon the mental health status of the athlete [30]. Athletes represent a vulnerable population to mental health problems and disorders due to a multitude of factors including worry over performance outcomes, psychological distress from sources of external pressure (e.g., teammates, coaches, and media outlets), mental fatigue and burnout from constant training and frequent travel, degraded self-esteem from the culture of sport, and unique personality traits that may be advantageous to sport but are also associated with mental health problems and disorders [30, 31]. Indeed, it has been estimated that upwards of 1/3rd of elite athletes (professional or Olympic) experience a mental health problem, such as anxiety or depression [32]. Thus, identifying protective factors as well as characteristics that heighten the risk for developing or exacerbating mental health problems within professional athletes is of utmost importance for not only their performance but overall well-being.

Sleep health and mental health share an intimate, bidirectional relationship [33, 34]. Sleep problems can be a symptom of an existing mental health problem or disorder [34]. Additionally, mental health problems can arise due to an underlying sleep problem or disorder. Sleep and mental health problems often present concurrently, with this often resulting in more severe mental health symptomatology [35]. Given this, the sleep health status of a professional athlete serves as a risk factor for and protective factor against developing mental health problems.

Despite the important relationship between sleep health and mental health, as well as the impact of mental health on athletic performance and overall athlete well-being, we were only able to identify four pieces of literature that were relevant to the relationships between sleep and mental health [22, 36•, 37, 38•]. Gouttebauge and colleagues (2018) evidenced high rates of mental health problems in a sample of professional rugby players [36•]. Specifically, they determined the 12-month incidence of anxiety/depression, adverse alcohol use, eating disorders, sleep disturbances, and general psychological distress to be 28%, 22%, 12%, 11%, and 11%, respectively. Importantly, 19% of the sample reported having two or more symptoms concurrently. Although the data was not available, it seems plausible to speculate that many reporting symptoms of anxiety/depression, eating disorders, or adverse alcohol use were also reporting sleep disturbances, given the intimate relationship between sleep and mental health. Facer-Childs and colleagues (2022) highlighted the significant role that sleep health plays on mental health, whereby a combination of

multiple sleep monitoring measures explained 31 to 51% of the variance in depression, anxiety, and stress symptoms, within a sample of professional Australian Football League athletes [38•]. Jurecka and colleagues (2021) further evidenced this intimate relationship between sleep and mental health in professional athletes [37]. These researchers performed a systematic review related to the impact of the coronavirus pandemic on the mental state and quality of life of professional athletes [37]. A general theme emerged whereby sleep ability and quality as well as mental health simultaneously degraded during this stressful and atypical period for professional athletes. The authors conclude that the mental state of the professional athletes affected their sleep quality, yet it is also plausible to view this relationship from the opposite stance whereby the sleep quality of the professional athlete affected their mental state. Ultimately, this is an inherent challenge of the relationship between sleep and mental health, whereby directionality can be extremely difficult to determine. Lastly, Teece and colleagues (2021) evidenced correlations (albeit small) of higher sleep efficiency and lower sleep latency with positive changes in wellness, including mood, in professional rugby players across preseason.

Yet, clearly there is a deficiency of research assessing the relationships sleep and mental health in professional athletes. Since the bidirectional relationship between these health domains recognizes that enhancing sleep health has the potential to also improve mental health, and vice-versa, it is critically important for future research to better clarify these dynamics in professional athletes, across different sports and individual characteristics, to advance the understanding of the role that sleep health has on the mental health of professional athletes within specific sport contexts.

Competitive Performance

Poor sleep health is likely to lead to worse competitive performance through indirect pathways, such as insufficient and ineffective training, increased frequency of physical injury and illness, and degraded mental health. Yet, acute bouts (e.g., single or multiple nights) of poor sleep can also have a significant, negative influence on performance during athletic competition because of its immediate impact on cognitive, psychological, and physical functioning [5]. The degrading effect of acute poor sleep on cognitive, psychological, and physical functioning is likely to translate into a competitive performance disadvantage through increased reaction time, emotional dysregulation, and lethargy, as well as reduced accuracy, strength, sprint speed, oxygen capacity, endurance, motivational drive, and resiliency, among other factors [39]. In contrast, good sleep prior to competition is likely to enhance performance ability and outcomes. As such, professional athletes should not only prioritize sleep

health across the calendar year for performance and overall wellness, but particularly in the days preceding competition to enhance performance.

Through our literature search, we identified six articles that showcased the effects of sleep on competitive performance abilities and outcomes [20, 28•, 40, 41, 42•, 43]. Swinbourne and colleagues (2018) analyzed the effects of sleep extension on sleep and performance characteristics in a sample of professional rugby players [28•]. Increases in total sleep time and sleep quality were accompanied by a reduction in mean reaction time, which suggests that improving sleep health led to enhanced vigilance. Stavrou and colleagues (2021) evidenced a similar relationship in professional soccer players, whereby worse sleep quality derived from the Pittsburgh Sleep Quality Index (PSQI) was associated with worse reaction time as well as degraded perceptual ability [40]. Additionally, this investigation highlighted relationships of poor sleep quality and sleep initiation difficulties with reduced oxygen capacity during cardiopulmonary exercise training. Peacock and colleagues (2018) showed similar relationships between sleep initiation and oxygen capacity as well as measures of physical activity and other indicators of physiological functioning in professional mixed martial arts [20]. Specifically, longer sleep initiation correlated with worse maximum rate of oxygen (VO_{2MAX}), vertical jump, and heart rate recovery, while lower sleep efficiency associated with worse heart rate recovery. Furthermore, Lipert and colleagues (2021) showed the protective effects of sleep quality on physical fitness and performance in professional endurance athletes participating in diurnal fasting during the month of Ramadan [41]. Although all professional endurance athletes experienced performance deficits on the Cooper and Step tests while participating in diurnal fasting during Ramadan, the deleterious effects were significantly less pronounced in those reporting good sleep quality. Additionally, Sargent and colleagues (2022) highlighted that the top 3 finishers in an Australian professional road cycling race obtained significantly more sleep duration during the 5-day competition than the bottom 3 finishers. Although purely observational, this finding aligns with the theory that better sleep health immediately before and during competition will assist in better performance outcomes [42•]. This theory is further substantiated by the work of Jones and colleagues (2019), which analyzed relationships between late-night tweeting, a behavior associated with acute sleep restriction, and next-day game performance in 112 professional National Basketball Association athletes [43]. Using a within-athlete design, late-night tweeting associated with fewer points scored and rebounds, yet this also coincided with less time played per game which could be a result of reduced endurance but also confounds the evidenced reductions in points scored and rebounds due to less opportunities. However, shooting accuracy, which

is not dependent upon playing time, was also significantly decreased following late-night tweeting, with this finding showcasing the deleterious effects of acute sleep restriction on NBA player performance.

Travel and Time Zone Change: Negative Influence on Sleep That Affects Performance

Beyond the aforementioned studies, we have also identified six other investigations that evaluated the effects of travel across time zones on competitive performance outcomes in professional athletes [44–49]. Since sleep health often degrades when traveling across time zones due to factors such as circadian disruption, travel fatigue, and irregular sleep behaviors [50], these findings in this section appear most appropriate for the review. Yet, it is necessary to point out that these investigations are not showing direct relations between variations in sleep health and performance outcomes, rather showcasing the relationships between travel across time zones, a key factor known to principally alter the sleep health of professional athletes, and performance outcomes.

Roy and Forest (2018) showcased the effects of time zone change on global team performance across three major sport leagues in North America, the National Basketball Association (NBA), National Hockey League (NHL), and National Football League (NFL) by analyzing winning percentages from five consecutive seasons (2010–2015) based on direction of travel and game time [44]. The authors found that traveling westward, but not eastward, associated with a significantly worse winning percentage for NBA and NHL, while this was a statistical trend in the NBA. However, this seemingly was only relevant to evening games, as analyses on afternoon games yielded no significant circadian disadvantage or advantage. Also, they utilized regression to evidence a linear reduction in winning percentage for each additional time zone traveled, with this resulting in a statistically significant relationship across all three sports. Charest and colleagues (2021) provided similar results in their study of travel-related effects on back-to-back games in the NBA spanning the 2013 to 2020 seasons [45]. These authors showed a 3.69% lower winning percentage when teams travel westward, relative to eastward travel. Yet, this study also showcased nuance in these relationships since factors beyond just directionality and time zone change of travel, including the sequence of games (e.g., Away-Home, Home-Away, and Away-Away) and distance traveled for the game, also influenced team winning percentage. Glinski and Chandy (2022) provided further evidence on the deleterious effects of westward time zone change on NBA performance in their eloquent study of the impact of jet lag on NBA free throw shooting [46]. Their results showed that teams were significantly more likely to have a lower free throw percentage when jet lagged, defined as games requiring travel across at least three time zones for a game,

than in non-jet lagged games, but this relationship was specific to situations traveling westward and not observed in eastward travel. However, not all the literature supports the notion that time zone change degrades competitive performance strictly in westward travel. Leota and colleagues (2022) evidenced that time zone change in the eastward, but not westward, direction was associated with reduced NBA winning percentage, as well as overall point, rebound, and field goal percentage differential [47]. Similarly, Zacharko and colleagues (2022) concluded that eastward travel across time zones associated with worse performance results than westward travel across time zones in a sample of professional soccer players [48]. Lastly, McHill and Chinoy (2020) evidenced lower winning percentages, as well as decreased shooting accuracy, effort, and defensive performance, when traveling across time zones, regardless of travel direction [49]. However, there was variation in the magnitude of the relationships based on whether travel was eastward or westward. Taken together, their results suggest that time zone change, in any direction, likely degrades competitive performance but highlights the potential for different aspects of basketball performance to be differentially affected based on the amount of time zone change and direction of travel, among other factors. Overall, it is clear that travel across time zones is likely to negatively influence competitive performance, with degraded sleep health—a consequence of travel across time zones—playing a central role in these relationships [51, 52]. Yet, further research is necessary to address contrasting findings among existing studies regarding the unique import of directionality of travel, with inconsistencies across results likely driven by differences in methodologies employed in the investigations as well as sample specific variation (e.g., sport type).

As it evident, poor sleep health—whether acute or chronic—has the potential to directly impact competitive performance in professional athletes through its effects on cognitive, psychological, and physical functioning. However, there remains a deficiency of research within professional athletes directly evaluating the relationship between sleep health and performance abilities and outcomes preceding, during, and following competition. Professional teams and athletes should formulate relationships with researchers to appropriately assess these relationships to better clarify the magnitude of impact of various components of sleep health (e.g., duration, regularity, continuity, and quality) on competitive performance.

Common Sleep Problems in Professional Athletes

The unique challenges that professional athletes experience, which are presented and discussed in later sections, have the potential to negatively influence sleep health, resulting in an increased risk for developing sleep

problems. This section of the review is purposed to merely describe common sleep problems within professional athletes, including poor sleep quality, insufficient sleep duration, insomnia-related characteristics, daytime sleepiness, and sleep-disordered breathing.

Based on the reviewed literature, we identified 18 articles that described sleep characteristics and problems within professional athletes [21, 22, 28•, 38•, 41, 42•, 53–55, 56•, 57–63, 64•]. Poor sleep quality was extremely common across the literature, with most studies relying on the Pittsburgh Sleep Quality Index (PSQI) to assess for sleep quality. Swinbourne and colleagues (2018) showed the commonality of poor sleep quality in a sample of professional rugby players, whereby the average PSQI score in the sample at baseline eclipsed below the established threshold for poor sleep quality (PSQI > 5) [28•]. Teece and colleagues (2021) had a nearly identical finding in a separate sample of professional rugby players, whereby average mean PSQI suggested clinically significant poor sleep quality [22], which also aligned with the findings of Lipert and colleagues (2021) in their investigation of professional athlete sleep quality prior to Ramadan [41]. Further corroboration of clinically significant poor sleep quality in professional athletes, captured by the PSQI, was provided by Khalladi and colleagues (2019) [53] and Facer-Childs and colleagues (2022) [38•]. Khalladi and colleagues (2019) showed that 68.5% of participants in a sample of professional soccer players exceeded the PSQI threshold for poor sleep quality [53]. Facer-Childs and colleagues evidenced a clinically significant average PSQI across a sample of professional Australian Football League athletes, with 38.6% of the sample eclipsing the PSQI threshold for poor sleep quality [38•]. Importantly, Garbelloto and colleagues (2022) evidenced the importance of individual characteristics (e.g., gender) on risk for poor sleep quality in professional athletes, whereby females were more likely to report worse sleep quality than males in their sample of professional cross-country mountain bikers [54].

Based on the National Sleep Foundation guidelines, insufficient sleep duration for adults is characterized by habitual sleep duration less than 7 h per night [65]. Insufficient sleep duration is an extremely common problem among professional athletes. In their sample of professional soccer players, Khalladi and colleagues (2019) concluded that 35.1% of the sample were obtaining insufficient sleep duration [53]. Similarly, Teece and colleagues (2021) showed that insufficient sleep duration was experienced by nearly half of professional rugby sample [22]. Sargent and colleagues (2022) also evidenced an alarming prevalence of insufficient sleep duration, whereby average sleep duration across an entire season fell below 7 h in a sample of professional Australian rules footballers [55].

Additionally, Sargent and colleagues (2022) showed that on average, a sample of professional road cyclists were experiencing insufficient sleep duration during a multi-day race [42•]. Furthermore, Sargent and colleagues (2021) found that habitual sleep duration was insufficient, on average, in a sample of professional cricketers, despite this same sample reporting a nightly sleep need of > 8 h [56•]. Additionally, Facer-Childs and colleagues (2022) demonstrated a 28.1% prevalence of insufficient sleep duration, measured through actigraphy, in a sample of professional Australian Football League athletes [38•]. Importantly, Lastella and colleagues (2021) highlighted the potential influence of individual characteristics on likelihood for insufficient sleep duration [57]. In this investigation of professional female Australian footballers, insufficient sleep duration was not observed in those identifying as a morning or intermediate circadian preference, but rather only in those with evening preference [57].

Insomnia characteristics, which include difficulty falling asleep, difficulty maintaining sleep, and/or difficulties with waking up earlier than intended, are some of the most common sleep-related complaints among the general population, with this also translating to professional athletes [66]. These problems result in notable daytime consequences related to physical, psychological, cognitive, and social functioning, which can have widespread ramifications for an athlete on-and-off the field [66]. Insomnia characteristics are often captured either through prolonged sleep onset latency (SOL) or wake after sleep onset (WASO), with these unique insomnia characteristics globally captured by low sleep efficiency (SE). Additionally, the Insomnia Severity Index (ISI) exists as one of the most widely utilized questionnaires for capturing insomnia characteristics. Research investigations commonly leverage the ISI for the purpose of capturing insomnia prevalence. Using the ISI, Khalladi and colleagues (2019) evidenced 27% of a sample of professional soccer players reported subthreshold insomnia symptoms ($ISI \geq 11$) [67], while also showing that 23.4% of the sample reported clinically significant sleep initiation difficulties ($SOL > 30$ min) [53]. Similarly, Facer-Childs and colleagues (2022) evidenced that 15.2% of their sample of professional Australian Football League were at high risk for having insomnia ($ISI \geq 10$) [38•]. Ballesio and colleagues (2022) also showed a high rate of insomnia characteristics across a different sample of professional soccer players, with 36.6% of this sample reporting at least subclinical symptoms of insomnia ($ISI > 7$) [58]. Furthermore, Conlan and colleagues (2021) showed clinically significant WASO (> 30 min) on average in a sample of professional rugby athletes, regardless of whether it was assessed in a low load training week, high load training week, or match week, which—in turn—coincided with a SE below healthy range (< 85%) [59]. Facer-Childs and colleagues (2022) and Sargent and colleagues (2022) also showed below threshold

SE in two different samples of professional Australian Football League athletes [38•, 55]. Importantly, Lastella and colleagues (2021) evidenced that professional female Australian footballers with evening circadian preference were more likely to experience lower SE, relative to those with morning and intermediate circadian preference [57]. Moreover, Halson and colleagues (2022) demonstrated the impact of individual sleep behaviors on insomnia-related characteristics in a sample of professional athletes across four sports (netball, Australian rules football, rugby league, and soccer), whereby persons with irregular sleep schedules had significantly lower SE, relative to those with regular sleep schedules [64•]. This may be a particularly focal contributing factor to insomnia-related characteristics in professional athletes, as Cameron and colleagues (2021) evidenced worse sleep behaviors (schedule irregularity and maladaptive sleeping environments) in professional athletes, relative to and age-matched non-athlete cohort, which also coincided with significantly more general sleep disturbances [60].

Daytime sleepiness is not necessarily a sleep problem but can be viewed as a proxy into existing sleep problems or disorders as it is a common consequence of unhealthy sleep. Given the high frequency of unhealthy sleep among professional athletes, it is likely that daytime sleepiness is prevalent among professional athletes. Indeed, Khalladi and colleagues (2019) showed that 22.5% of their sample of professional soccer players reported higher levels of daytime sleepiness, as captured by the Epworth Sleepiness Scale (ESS) [53, 68]. Yet, this study relied on a cut-off threshold of $ESS > 8$ to determine daytime sleepiness, which is not traditionally relied upon to classify significant excessive daytime sleepiness [69, 70]. Facer-Childs and colleagues (2022) showed that 29.9% of their professional Australian Football League sample reported higher normal daytime sleepiness, with 11.9% eclipsing the established ESS threshold for clinically significant excessive daytime sleepiness ($ESS \geq 11$) [38•, 68–70]. However, we were unable to find any other literature over the last 5 years that assessed daytime sleepiness in professional athletes. Since daytime sleepiness can serve as a broad-spanning indicator of poor sleep health, leveraging this conveniently capturable characteristic in future investigations evaluating sleep problems in professional athletes is highly encouraged.

Sleep-disordered breathing (SDB), most commonly obstructive sleep apnea (OSA), is a highly prevalent sleep problem, which highlights the likelihood of this being a common problem among professional athletes as well. However, there are likely to be major individual and sport-related differences in terms of SDB prevalence across professional athletes since certain characteristics, such as being male and having thick necks, heighten the risk for SDB. Since SDB not only exists as a contributor to poor sleep health but also is a major risk factor for severe

medical conditions, such as cardiovascular disease, SDB screening should be a focal component of health evaluations in professional athletes, especially those with features heightening risk for SDB (e.g., football and rugby athletes). Somewhat surprisingly, we were only able to identify one study that recently assessed SDB in a sample of professional athletes. Caia and colleagues (2020) assessed a sample of adult professional rugby athletes using home-based polysomnography [61]. Utilizing established severity thresholds for the apnea–hypopnea index (AHI), a valid measure of SDB, 31.8% of the sample ($N=7$) displayed mild SDB (AHI = 5–14 events per hour) and 13.6% ($N=3$) displayed moderate SDB (AHI = 15–29 events per hour). Yet, as an overall sample, average AHI was in the none/minimal range. Importantly, these researchers also evidenced the impact of ethnicity on SDB prevalence, whereby Polynesian athletes accounted for 70% of the total cases of mild or moderate SDB, despite a near equal split between Polynesian and European-Australian professional rugby players in the sample.

As is evident, sleep problems, such as poor sleep quality, insufficient sleep duration, insomnia characteristics, daytime sleepiness, and sleep-disordered breathing, are common among professional athletes. Yet, encouragingly, the relevant literature did not universally showcase poor sleep health or sleep problems among professional athletes. Clemente and colleagues (2019) evidenced generally good sleep quality in a sample of professional basketball players across a full season [62]. Caia and colleagues (2018), Fitzgerald and colleagues (2019), Lastella and colleagues (2021), and Garbellotto and colleagues (2022) showed sufficient sleep duration across samples of professional rugby [63], male Australian Football League [21], female Australian Football League with morning or intermediate circadian preference [57], and professional mountain bikers' athletes [54], respectively. Furthermore, Caia and colleagues (2018) demonstrated healthy SOL and sleep efficiency in their sample of professional rugby athletes, measured through actigraphy [63]. These findings may reflect the increased attention and consideration to sleep health of professional athletes over the recent years. Additionally, these findings concretely showcase that poor sleep health is not a universal problem among professional athletes but rather needs to be analyzed at a more granular level, with recognition of the influence from individual and sport-specific characteristics.

Unique Challenges for Professional Athletes That Can Negatively Influence Sleep

As is evident by the previous section, poor sleep health and sleep problems are common among professional athletes. In the following subsections, we overview unique, focal factors

that exist as challenges to professional athletes' sleep health. Principally, these sections will draw attention to the impact of training, travel, and competition on the sleep health of professional athletes. Additionally, other factors emerged from the literature search, such as physical injury and illness, electronic use, and nutritional habits, that exist as challenges for professional athletes in their pursuit of sleep health.

Training Factors

For professional athletes to perform at their best during competition, consistent and effective training is necessary. Although the training period, frequency, timing, and load will vary across sport, it is often the case that professional athletes train year-round, with variations in the frequency, timing, and load of training based on season status (in-season vs. off-season), number of and proximity to upcoming competitions, and the goal of training (maintenance vs. enhancement). Professional athletes may be more susceptible to degraded sleep health during periods of high training loads, relative to periods of low training loads, due to influence from increased physical and mental fatigue, heightened psychological distress over meeting training demands, and merely due to the fact that increasing the amount of training inherently requires more time commitment and, generally, earlier training sessions that can infringe upon healthy sleep behaviors and sufficient sleep opportunity [13, 71–73].

We identified seven articles that were relevant to the impact of training on sleep health in professional athletes [22, 24, 56, 58, 59, 61, 74]. Caia and colleagues (2020) evidenced a significant reduction in sleep duration on training days in a sample of professional rugby athletes [61]. Teece and colleagues (2021) showed a similar relationship between general training and sleep in professional athletes, whereby professional rugby athletes on average displayed a 73-min reduction in nightly sleep duration during preseason training [22]. Since this reduction also coincided with a significant increase in training load and physical fatigue scores, the authors posited that the increased physical fatigue resulting from increased training load was driving the reduction in nightly sleep duration. The negative influence of increased training load on sleep health of professional athletes was further evidenced by Conlan and colleagues (2021) in their study of a sample of professional rugby league athletes [59]. Relative to low training load weeks, sleep duration was significantly reduced by 32 min, which was a product of later bedtimes and earlier risetimes. As such, it is not necessarily the increased physical fatigue associated with increasing training load that is negatively influencing sleep health, but also the timing of training. This can be saliently seen by the work of Sargent and colleagues (2021), whereby professional athletes undergoing an individualized sleep intervention frequently were unable to achieve their prescribed

sleep duration targets due to early morning mandatory training and/or team meetings that inhibited appropriately delaying their wake up time [56•]. Yet, encouragingly, not all the identified literature evidenced negative changes in sleep health associated with training. Serpell and colleagues (2019) found no significant differences in sleep duration or sleep onset latency across a short, 4-day preseason camp for professional rugby union athletes [24]. Somewhat surprisingly, a statistically significant increase in sleep efficiency was observed across the preseason camp period, with this most pronounced when comparing night 2 to night 3. Similarly, Lastella and colleagues (2019) showed in a sample of professional soccer players apart of the 2010 Asian Champions League that sleep duration was above 7 h during typical training days, with these athletes also demonstrating a sleep efficiency above the healthy threshold (> 85%). Yet, sleep duration on training days was still slightly reduced relative to rest days, which was principally driven by earlier wake times, as sleep efficiency remained comparable between the two periods. Lastly, Ballesio and colleagues (2022) did not find a significant association between late night training and insomnia symptom severity, which was surprising given the theoretical belief that late night training should induce pre-sleep arousal which in turn could lead to difficulties falling asleep or maintaining sleep [58].

Thus, it is clear that training has the potential, and is likely, to negatively influence the sleep health of professional athletes through multiple pathways, including increased physical fatigue and earlier wake times. However, the magnitude of degradation on sleep health is going to depend on training characteristics (e.g., timing, frequency, and load), with this further moderated by differences in training styles and demands between sports as well as across individual athlete characteristics.

Travel Factors

Professional athletes often have to travel frequently, which creates a unique challenge for sleep health due principally to disruption of the circadian rhythm as well as travel fatigue that impacts both mental and physical function [50–52, 71]. The circadian rhythm is often referred to as the “biological clock” since it operates at nearly a 24-h cycle and regulates the timing and expression of many physiological processes central to sleep and wake functionality. Circadian disruption, most commonly through the form of travel across time zones resulting in “jet lag,” has the potential to negatively influence one’s sleep ability and quality given the mismatch between timing of entrained, internal biological processes, and the clock time of the external environment. Given that many professional athletes frequently are subjected to travel across time zones, especially during competitive season, constant

circadian disruption is inevitable which leaves these individuals vulnerable to degraded sleep health that has the potential to negatively impact performance. Additionally, frequent travel is mentally and physically fatiguing, which can result in degraded sleep health as well as performance deficits [50].

We were only able to identify three studies that directly analyzed the effects of travel on sleep health in professional athletes [74–76]. Lastella and colleagues (2019) showed that long-haul air travel, despite minimal change across time zones, significantly disrupted the sleep–wake behaviors and degraded sleep health of professional soccer players [74]. Specifically, sleep initiation was delayed by 3.5 h, sleep duration was reduced by 3.6 h, and athletes reported significantly poorer sleep quality when experiencing long-haul air travel. The authors posited that physical factors associated with travel, such as exposure to mild hypoxia as well as cramped conditions, long layovers, and restricted movement that increase fatigue, were likely driving these changes in sleep–wake behaviors and sleep health given the minimal circadian disruption associated with this specific long-haul travel. Smithies and colleagues (2021) showed similar effects of long-distance transmeridian travel (LDTT) on sleep duration in a sample of professional Super Rugby athletes, with LDTT defined as travel across more than 3 time zones [75]. This investigation followed a Super Rugby team through a 5-game stretch that required travel from Perth, Australia, to Durban, South Africa, and from Durban, South African, to Buenos Aires, Argentina, before returning to Perth, Australia, which summated into ~ 36,600 km traveled across 29 days and four different LDTT events. Significant irregularities in the timing of sleep onset and offset, as well as sleep duration, were observed across travel periods. Although variation was observed across the paradigm, likely due to influence from circadian acclimation and competition-related factors, sleep duration generally was significantly reduced when experiencing LDTT. Additionally, the reductions in sleep duration associated with LDTT generally persisted for at least a day following the travel. Lastly, Lo and colleagues (2022) showed similar relationships in their study of four different professional Super Rugby teams traveling overseas for competition [76]. Three of the four teams showed a substantial reduction in sleep duration when overseas, which the authors explained as a combination of travel fatigue, jet lag, and disruption of normal sleep behaviors.

Competition Factors

Beyond travel, there are other factors connected to professional athletic competition which have the potential to negatively impact sleep health, such as timing of competition, problematic congestion of match/game schedules, and psychological distress associated with competition [50].

Although competition start times will vary notably across sports, competitions often occur in the late evening for professional sports to maximize viewership. The late start times of competition likely drive delayed sleep behaviors. Additionally, competition is likely to result in heightened pre-sleep arousal given the timing of physical exertion and psychological response post-competition, which could negatively influence sleep ability and quality. Furthermore, competition periods often vary in the number of matches/games over a period of time, and it is likely that greater competition schedule congestion will coincide with worse sleep health due to a multitude of factors, including potential need for frequent travel, physical fatigue accumulation, and continued exposure to heightened psychological stress. Pre-competition psychological worry and post-competition psychological distress over undesired outcomes are two other competition-related factors that may degrade sleep health.

We identified eight pieces of literature that pertain to the influence of competition factors on sleep health in professional athletes [55, 60, 62, 74–79]. In a sample of professional athletes across rugby, netball, and soccer, Cameron and colleagues (2021) evidenced the perception of significant, negative effects of competition on sleep [60]. 68.5% of the sample reported having difficulties sleeping after a competition. The authors theorized that precognitive arousal following competition plays a key role in this finding. Sargent and colleagues (2022) demonstrated the effects of competition and competition timing on sleep health in a sample of professional Australian rules footballers [55]. Bedtime was delayed while risetime was advanced on nights following competition, relative to nights prior to competition, which resulted in about 2.5 h of reduced sleep duration on competition nights. Furthermore, these relationships were moderated by competition start time, with athletes obtaining about 40 min less sleep on nights of evening competition, relative to nights of day competition. Lastella and colleagues (2019) showcased the identical relationship between competition and bedtime/risetime in sample of professional soccer players [74]. Bedtime was the latest on nights following competition while risetime was the earliest on mornings following competition, relative to other conditions (training, rest, and pre-competition), which resulted in significantly reduced total sleep time. Furthermore, sleep efficiency was significantly reduced (~3%) on competition nights, relative to other conditions. Smithies and colleagues (2021) also showed significantly shorter sleep duration on night's after competition, with their sample of professional Super Rugby athletes displaying a reduction of about 70 min of sleep duration following competition [75]. Some of the reduction in sleep duration for this sample was due to earlier risetimes necessary to meet early travel departure following competition. Caia and colleagues (2022) further showcased the unique, deleterious effects of competition on sleep behaviors, ability, and quality in a sample of professional rugby league

athletes [77]. Specifically, these athletes displayed significantly delayed bedtime, shorter sleep duration, greater sleep onset latency, and worse sleep efficiency on competition nights. The authors theorized that pre-sleep arousal principally contributed to these outcomes and emphasized the role of caffeine use prior to and during competition as a contributor to pre-sleep arousal. The relationships between competition timing and delay of behaviors likely to negatively influence sleep was also shown by Falkenberg and colleagues (2021) in a sample of professional Australian football players, where meal timing was delayed on competition days which seemingly contributed to later bedtimes and increased wake after sleep onset [78]. Lo and colleagues (2022) also showed significantly reduced sleep duration on competition nights in a sample of professional rugby athletes, with these results recognizing competition-related psychological stressors as one factor contributing to the reduction in sleep duration [76]. When considering the congestion of competition on sleep, Clemente and colleagues (2019) saliently showcased the exacerbating nature of more competition congestion on sleep health in professional athletes [62]. Congested weeks associated with lower sleep quality ratings, relative to regular weeks. However, Doeven and colleagues (2021) showed contrasting findings in a sample of professional basketball players, whereby sleep quality was comparable in weeks with 1 versus 2+ matches [79]. Differences in methodology may explain inconsistencies in findings, as each study utilized a different questionnaire to capture sleep quality. There are also granular factors that contribute to the relationships between match congestion and sleep health, such as the locational sequence of matches, travel to accommodate match congestion, and timing of competition within the congested match schedule. As such, it is likely that increased competition congestion heightens the deleterious impact of competition on sleep health, yet research that accounts for the nuances moderating these relationships is necessary.

Other Factors: Physical Injury and Illness, Electronic Use, and Nutritional Habits

Training, travel, and competition factors are certainly the primary, unique challenges that professional athletes regularly navigate which has the potential to negatively affect sleep health. Yet, there are other factors, such as regularity and magnitude of physical injury and illness, timing of electronic use, and nutritional habits (e.g., meal timing and composition), that are not necessarily unique to professional athletes but may be more common in professional athletes given their demanding lifestyles and schedules.

We identified five articles that pertain to other factors with the potential to negatively impact sleep health that may be particularly common among professional athletes [21, 43, 58, 77, 78]. Due to many influences, such as constant physical toil and frequent psychological stress, professional

athletes are likely at an increased risk for developing illness, which has the potential to negatively influence sleep health. Indeed, Fitzgerald and colleagues (2019) showed that Australian football professional athletes experiencing either acute or chronic illness were at a significantly increased likelihood of having lower sleep duration and reduced sleep quality [21]. Somewhat surprisingly, we were unable to find literature evaluating the impact of physical injury and/or pain on sleep health in professional athletes, yet it is likely that these problems common to professional athletes create challenges for sleep health in a similar manner to that of illness. Evening electronic and social media use are common factors among modern life that have the potential to greatly disrupt healthy sleep behaviors as well as degrade sleep ability and quality. Given that professional athletes often have evening competition start times, with games/matches continuing in the last hours of a day, they may be at an increased risk for negative sleep health due to the inherent delay and timing of their electronic and social media use in response to competition scheduling. Although Jones and colleagues (2019) did not directly assess the influence of timing of electronic and social media use on sleep health of professional athletes, they posit that degraded competitive performance in NBA professionals following late-night tweeting behaviors was a direct consequence of restricted sleep and/or worsened sleep quality resulting from the electronic and social media engagement [43]. Nutrition habit, such as the timing and composition of meals, is another factor that has the potential to influence sleep health of professional athletes [80]. Falkenberg and colleagues (2021) showed the negative impact of meal timing following competition on sleep health in Australian football professional athletes [78]. Specifically, this study evidenced a relationship between a delay in meal timing, often associated with competition, and delay in bedtime. Furthermore, results from this investigation suggested that increased daily protein intake associated with significantly worse sleep efficiency and increased wake after sleep onset. Moreover, increasing daily caloric intake associated with increased WASO. Lastly, this study suggested that increasing evening caloric intake associated with longer sleep onset latency and highlighted the deleterious effects of evening sugar intake on sleep duration, sleep efficiency, and wake after sleep onset. Caffeine and other stimulant use is another component of nutrition that can have a negative influence on sleep health, especially in professional athletes given that these are often leveraged before and during competition to enhance performance. The findings from Caia and colleagues (2022) suggested that caffeine supplementation prior to and during professional rugby league competition resulted in increased post competition salivary caffeine concentration, which—in turn—correlated with a more delayed bedtime, increased sleep onset latency, and reduced sleep efficiency [77]. The

heightened insomnia characteristics, such as elongated sleep onset latency and reduced sleep efficiency, associated with caffeine use was also evidenced by Balesio and colleagues (2022), whereby consumption of stimulants (caffeine, nicotine, and chocolate) was associated with insomnia-related characteristics in a sample of professional soccer players [58]. The relationships between nutrition, meal timing, and sleep health are understudied generally, yet improving clarity on these dynamics may be particularly relevant to professional athletes given their unique dietary needs and obstacles that constrain meal timing behaviors.

Strategies and Interventions to Assist with Sleep in Professional Athletes

Considering the paramount role of sleep health in the training, recovery, performance, and overall well-being of professional athletes, the unique challenges faced by professional athletes that negatively impact sleep health, and the high prevalence of sleep problems and disorders among professional athletes, there is a clear need for accessible, tailored, and effective strategies and interventions to enhance sleep health in professional athletes.

At a foundational level, sleep health education should be provided not just to athletes, but also to individual coaches, professional teams and their supporting staff, and professional organizations. Providing education on sleep health to athletes would not only improve the knowledge of sleep health, sleep problems, and factors that interfere with healthy sleep but also may contribute to enhanced prioritization of healthy sleep behaviors. For example, Caia and colleagues (2018) showed that sleep hygiene education improved the sleep behavior of athletes in a sample of professional rugby league athletes [63]. However, the durability of the effects was limited, which suggests that additional strategies and efforts are necessary. Beyond providing sleep education to athletes, education to coaches and teams should be prioritized as this could result in modifications to training and travel schedules purposed to limit the deleterious effects of these factors on the sleep health of their affiliated professional athletes. Additionally, by educating organizations on the import of sleep health and factors that degrade sleep health in professional athletes, adjustments to competition schedules (e.g., frequency, timing, and location of competition) intended to provide athletes with better ability to achieve healthy sleep could be made. Furthermore, education to organizations and teams could result in increased allocation of resources for screening professional athletes for sleep problems and disorders as well as connecting them with the appropriate care, when necessary. Ultimately, there is a major need for enhancing the accessibility and quality of sleep health screening and monitoring among professional athletes.

Education is a necessary strategy but is unlikely to be sufficient for the needs of all professional athletes. Rather, the development of accessible sleep health interventions for professional athletes is warranted. Given the sizeable variation in training, travel, and competition demands across sport types, as well as variation in individual characteristics across sport types, interventions should be constructed to be delivered in a personalized manner. Sargent and colleagues (2021) showcased the benefit of personalized sleep interventions [56•]. In their study among professional cricketers, athletes were randomly assigned to either a control group or intervention group. Sleep was monitored for 2 weeks across each condition, with all athletes receiving feedback on compliance after week 1. However, the intervention group received additional, individualized provision of sleep (e.g., bedtime, wake time, and sleep duration) after week 1 to serve as targets for week 2. Unsurprisingly, the intervention group displayed significantly better change in sleep health characteristics related to bedtime, time in bed, and total sleep time, relative to the control group, when comparing differences between week 1 and week 2 data. Furthermore, there is major variation across the calendar year that highlights the need for sleep-focused interventions to be dynamic in their ability to adapt to the challenges being faced at a given time in a competition schedule (e.g., congested competition weeks; periods with frequent travel across time zones) and off-season training (e.g., different training intensity and loads). As such, future work is warranted to develop and evaluate interventions, appropriately tailored to the lifestyle and demands of professional athletes across various sport types, that can not only be delivered in a personalized manner but also dynamically adjust to differential challenges and constraints faced by professional athletes across a calendar year. Research efforts purposed to evaluate these interventions should measure the impact of improved sleep health on competition-related outcomes as well as those beyond competition (e.g., well-being) to further emphasize the downstream benefits on-and-off the field. Lastly, interventions need to be appropriately designed for professional athletes given the idiosyncratic nature of their lifestyles and, as a result, their sleep [81]. Treating insomnia is a salient example of the need to tailor traditional sleep interventions for professional athletes. Cognitive behavioral therapy for insomnia (CBT-I) is the gold standard treatment for insomnia. Despite CBT-I being highly effective for treating insomnia, some CBT-I components and principles are potentially problematic for or incongruent with a professional athlete's needs. For example, avoidance of daytime napping is a principle of CBT-I, since daytime napping is viewed as a perpetuating factor for insomnia. However, napping is extremely common among professional athletes and is recognized as a viable, effective strategy for helping a professional athlete navigate accumulated sleep debt [82,

83]. Teece and colleagues (2022) highlighted the commonality of napping in professional rugby union athletes, whereby 86% of the sample reported using naps prior to a match, with the sizeable majority also reporting that they believed naps helped their match performance [82]. As such, universally providing the recommendation of avoiding daytime naps would appear to be inappropriate in this context. Furthermore, sleep restriction therapy (SRT) is a key component of CBT-I. When undergoing SRT, a trained provider structures a sleep opportunity window that is intentionally restricting sleep duration so that a client increases their homeostatic need for sleep which in turn results in extinguishing insomnia characteristics. Over time, the sleep opportunity window is gradually expanded to a healthy duration absent of insomnia characteristics, but this may take multiple months. Utilizing this strategy during an off-season may be viable, but attempting to implement this during the competition season would be impossible, given the need to maintain a strict sleep-wake schedule and the factors that interfere with schedule consistency. Additionally, professional athletes are generally functioning under a high homeostatic need for sleep, which seemingly negates the rationale for this strategy. Thus, universally delivering CBT-I in its traditional form for treating insomnia in professional athletes appears unwarranted, especially during competition season. Rather, there is a major need to identify which components of existing interventions are appropriate and useful for professional athletes, with these integrated into novel sleep interventions tailored specifically to the needs, challenges, and lifestyle of professional athletes.

Although there is an imminent need for appropriately tailored sleep interventions for professional athletes, there are existing interventions for improving sleep health among professional athletes that have been previously shown to be efficacious among professional and non-professional athletes [81]. Among the existing interventions, sleep extension paradigms, implementation of structured, supplementary daytime naps, sleep hygiene practices, and circadian-based strategies are most common. Sleep extension paradigms are employed to assist athletes with achieving sufficient sleep duration across their main sleep period. Supplementary daytime naps can also be useful for helping athletes navigate periods when achieving sufficient sleep duration is not viable due to factors related to travel and competition timing. Additionally, daytime naps may be helpful for improving vigilance prior to competition. Yet, the duration of daytime naps and proximity to competition start times are key factors that must be considered. Prolonged naps (> 60 min) have the potential to result in feeling worse upon awakening and are most likely to interfere with sleep ability and quality at night. Furthermore, completing a nap immediately prior to competition will likely result in worse performance due to residual sleep inertia. Thus, a fruitful avenue for research is

to determine the best practices for duration and timing of daytime napping that leaves the athlete refreshed and vigilant for competition. Yet, there will be a need to account for differential scenarios, such as napping prior to competition on a day with travel versus one without travel. Similarly, the timing of competition must be considered, as a nap prior to a midday or early afternoon competition seems potentially more harmful than helpful compared to a nap prior to a late evening competition. Sleep hygiene is another common intervention to assist with sleep health in professional athletes. Fundamentally, sleep hygiene is a set of recommendations that help entrain healthy sleep behaviors and practices (e.g., schedule regularity and avoiding caffeine after noon). Indeed, sleep hygiene can have positive effects on the sleep health of athletes, but the effects are likely limited due to absence of provision and reliance on self-accountability, as well as the fact that sleep hygiene may not enhance sleep ability or quality as a standalone intervention due to other existing sleep problems and disorders. Caia and colleagues (2018) showcased both the strengths and limitations of a sleep hygiene intervention in professional rugby league athletes [63]. The sleep hygiene intervention initially resulted in significant increases in time in bed and total sleep time, yet sleep quality, as captured by sleep efficiency, was degraded. Furthermore, the positive effects on time in bed and total sleep time were not maintained at a 1-month follow-up post sleep hygiene intervention, which highlights the poor durability of sleep hygiene as a standalone intervention. This study suggests that sleep hygiene has a role as a component in interventions to enhance sleep health among professional athletes, but standalone administration is unlikely to produce desired short-term or long-term effects. Lastly, circadian-based strategies, such as chronotherapy and prescribed use of melatonin, are useful to help athletes shift their circadian rhythm prior to travel for competition as well as mitigate the effects of jet lag and enhance acclimation to a novel time zone. These strategies are not only helpful for reducing the negative effects of travel on performance but also are critical for regulating physiology to improve likelihood of good sleep ability and quality when adjusting to a novel circadian environment. Beyond the literature related to the sleep hygiene intervention in professional rugby athletes, we were unable to identify any other literature over the recent 5 years that directly analyzed the effects of sleep extension, napping, or circadian-based strategies on the sleep healthy of professional athletes. As such, it is critical for future research to clarify the efficacy of these interventions within diverse samples of professional athletes to determine which interventions should be employed for different sport types, individual characteristics, and competition scenarios. Additionally, this type of research can help identify which interventions are appropriate for professional athletes in their current form, as well as identify gaps in existing

interventions that can be filled by tailoring previously utilized approaches or developing novel sleep interventions tailored to professional athletes.

Conclusion

In summary, sleep health plays a critical role in a professional athlete's ability to train, recover, and perform, as well as prominently influences their overall well-being. See Fig. 1 for a graphical depiction of these relationships. Unfortunately, sleep problems and disorders, such as poor sleep quality, insufficient sleep duration, insomnia-related difficulties, obstructive sleep apnea, and heightened daytime sleepiness, remain common among professional athletes. Encouragingly, there is evidence that poor sleep health is not a universal problem among professional athletes, which may be an emerging trend due to enhanced attention to sleep health of professional athletes among individual athletes, coaches, teams, and organizations. However, professional athletes still navigate a multitude of unique challenges related to training, travel, competition, and other factors (e.g., nutrition) that interfere with healthy sleep behaviors and have the potential to degrade sleep health. As such, there is a major need for initiatives purposed to adjust factors interfering with the sleep health of professional athletes, as well as the development of novel, accessible, and athlete-appropriate interventions that can be delivered in an individualized manner and are constructed to dynamically adapt to the variation in training, travel, and competition across a professional athlete's calendar year.

The path to novel initiatives and interventions purposed to improve sleep health among professional athletes requires addressing current shortcomings in the research of sleep health within professional athletes. Despite an uptick over the recent years in empirical attention to sleep health within professional athletes, this area of research is still relatively understudied. Thus, a focal priority to move forward this critical area of research would be for athletes, teams, and organizations, across a variety of sport types, to form partnerships with independent sleep researchers and clinicians. These partnerships would not only benefit the amount of research available to guide initiatives and intervention development/application, but also the quality of the research. Professional researchers can extend their expertise in methodology to design longitudinal studies, ideally across the full calendar year, that leverage the best available, modern measurement tools for subjectively (e.g., digitally delivered questionnaires/sleep diaries) and objectively capturing the multidimensional components of sleep health while athletes navigate variations in training, travel, and competition, as well as other changes in mental and physical well-being. Increasing the amount and quality of research is necessary

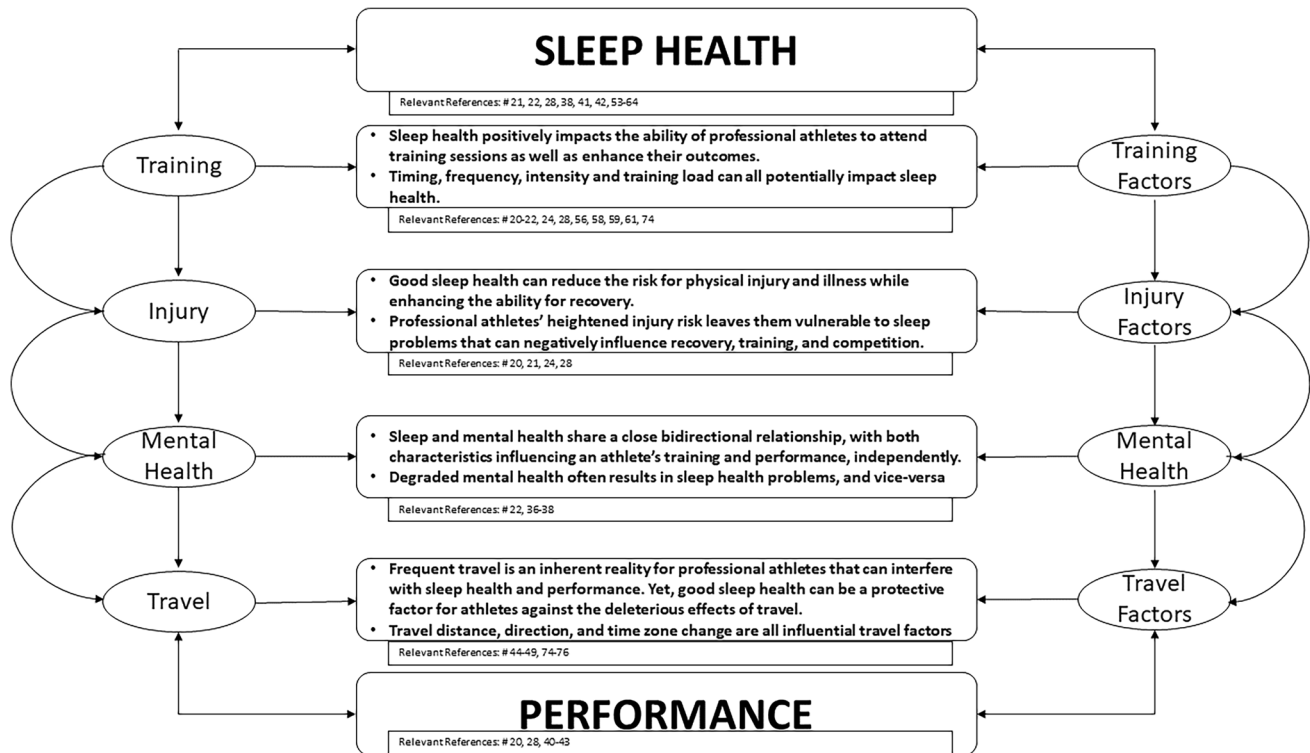


Fig. 1 A schematic depiction of the complex, bidirectional relationship between sleep health and performance, along with the core influencing factors. Beyond actual physical and cognitive performance during competition, sleep health can improve performance through more consistent and higher quality training, reduced risk for injury and better recovery, enhanced mental health contributing to better motivation, attention, emotional regulation, and other psychological characteristics beneficial to performance, and resiliency to the dele-

terious effects of travel. Yet, professional athletes experience unique challenges related to training demands, heightened injury risk, constant pressure and stress that can degrade mental health, and travel-related factors (e.g., physical and mental fatigue from long distance travel; circadian misalignment) that have the potential to negatively influence sleep health and performance directly and indirectly. Relevant references to focal literature are included, with these numbers corresponding to the order listed in the references section

for determining more confident conclusions through techniques such as meta-analysis. However, heterogeneity among investigation approach is another existing shortcoming that would need to be addressed for enhancing the utility of meta-analysis. As such, there is a need for standardized guidelines on research methodology within professional athletes that would not only afford better ability to make comparisons across studies but also provide the ability for productive meta-analysis due to increased congruency between studies. Sleep measurement is a major point of heterogeneity among studies in professional athletes, which highlights the need for these standardized guidelines to emphasize tools most appropriate for measuring sleep in professional athletes, such as the athlete sleep screening questionnaire, as well as overview the strengths and limitations of using other commonly relied on sleep measurement tools for the specific purposes of assessing sleep in this unique population.

Presently, it is clear that sleep health plays a principal role in the training, recovery, performance, and wellness of professional athletes, but professional athletes also exist as a highly vulnerable population to poor sleep health due to

unique challenges related to training, travel, and competition. Advancing the quantity, quality, and utility of available research, through partnerships between athletes, teams, and organizations with independent researchers as well as improved, standardized methodological approaches and rigor, is a critical step for elucidating key sport-specific and individual (e.g., sex, gender, age, race/ethnicity, and chronotype) differences that can be leveraged to inform important sport-based initiatives and guide the development of individualizable, dynamic, and tailored interventions. These off-the-field efforts have the potential to drastically enhance on-the-field performance and, more importantly, the overall well-being of professional athletes.

Declarations

Conflict of Interest Jesse Cook serves as a consultant to Cerno Health© and Somni© and previously served as a consultant to Bodymatter, Inc., with these affiliations unrelated to the current study. Jonathan Charest serves as a consultant to Apeiron Life and has work funded by Mitacs, with these affiliations unrelated to the current study.

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