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Poor sleep quality and insufficient sleep of a collegiate student-athlete population

Cheri D. Mah, MD, MS [a,b,*], Eric J. Kezirian, MD, MPH [c], Brandon M. Marcello, PhD [d], William C. Dement, MD, PhD [a]

[a] Stanford Sleep Disorders Clinic and Research Laboratory, Department of Psychiatry and Behavioral Sciences, School of Medicine, Stanford University, Palo Alto, CA, USA
[b] School of Medicine, University of California, San Francisco, San Francisco, CA, USA
[c] USC Caruso Department of Otolaryngology—Head & Neck Surgery, Keck School of Medicine, University of Southern California, Los Angeles, CA, USA
[d] Department of Athletics, Stanford University, Stanford, CA, USA

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ABSTRACT

Objective: Poor and inadequate sleep negatively impact cognitive and physical functioning and may also affect sports performance. The study aim is to examine sleep quality, sleep duration, and daytime sleepiness in collegiate student-athletes across a wide range of sports.
Design: Questionnaire.
Setting: University setting.
Participants: 628 athletes across 29 varsity teams at Stanford University.
Measurements: Athletes completed a questionnaire inquiring about sleep quality via a modified Pittsburgh Sleep Quality Index (PSQI), sleep duration, and daytime sleepiness via Epworth Sleepiness Scale. Sleep quality on campus and while traveling for competition was rated on a 10-point scale.
Results: Collegiate athletes were classified as poor sleepers (PSQI 5.38 ± 2.45), and 42.4% of athletes experience poor sleep quality (reporting PSQI global scores >5). Athletes reported lower sleep quality on campus than when traveling for competition (7.1 vs 7.6, $P < .001$). Inadequate sleep was demonstrated by 39.1% of athletes that regularly obtain <7 hours of sleep on weekdays. Fifty-one percent of athletes reported high levels of daytime sleepiness with Epworth scores ≥10. Teen student-athletes in the first and second year of college reported the highest mean levels of daytime sleepiness. Greater total sleep time was associated with daytime functioning including lower frequency of difficulty waking up for practice or class ($P < .001$) and lower frequency of trouble staying awake during daily activities ($P < .001$).
Conclusions: Collegiate athletes frequently experience poor sleep quality, regularly obtain insufficient sleep, and commonly exhibit daytime sleepiness.

Introduction

Sleep has a critical role in human functioning, physiology, and cognitive and physical recovery. Previous studies have demonstrated that sleep deprivation and chronic sleep loss can negatively impact cognitive functioning, learning and memory, reaction time, auditory vigilance, and mood.[1–3] Insufficient hours of sleep have also been shown to impact metabolism and endocrine function, increase perceived exertion during exercise, and impair performance outcomes such as weight training.[4–6] For athletes, optimal functioning in the aforementioned areas is critical, as sports performance strongly relies on the combination of cognitive, physiological, and physical outputs.

Sleep quality and sleep duration have important roles for athletic training, postexercise recovery, mood, and sports performance[7–10]; however, the current literature characterizing the sleep of athletes is sparse. The available evidence suggests that highly trained rugby and cricket athletes experience poor sleep quality and high levels of daytime sleepiness.[11] Olympic athletes from 4 sports have demonstrated poorer indicators of sleep quality assessed by objective actigraphy than nonathletic controls.[12] Moreover, sleep disturbances and poor sleep prior to competition have been reported among Australian and German individual and team sports.[13,14] Additionally, differences in training demands between sports may impact sleep need.[12] Little is known about the sleep health, including sleep quality and sleep duration, of individual and team sport athletes across a wide range of sports and how their functioning is impacted outside of the laboratory within the context of the psychological, emotional, and physical demands that are present during a competitive season.

The present study therefore aimed to investigate the sleep quality and sleep duration, as well as the subsequent daytime functioning, of an entire collegiate athlete population at a single university. It was

* Corresponding author at: Stanford Center for Sleep Sciences and Medicine, 3165 Porter Drive, Palo Alto, CA 94304. Tel.:+1 650 353 7536.
E-mail address: cherimah@stanfordalumni.org (C.D. Mah).

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hypothesized that athletes experience poor sleep quality, regularly obtain insufficient hours of sleep, and experience daytime sleepiness. Knowledge of sleep behaviors may aid in identifying potential areas for intervention to improve sleep and recovery in athletes.

Methods

Participants

Athletes were recruited from Stanford University, which is a National Collegiate Athletic Association member institution and participates at the Division I level. There are approximately 800 total varsity athletes at Stanford comprising 35 varsity sports teams: 16 for men, 19 for women, and 1 coed (sailing). Athletes were included if they were members of a varsity sports team at Stanford University during the 2011-2012 National Collegiate Athletic Association season. Athletes completed the study questionnaire before or after a regularly scheduled practice session during November and December 2011. Participant age was categorized as ≤18, 19, 20, 21, and ≥22 years old. Athletes were excluded if they did not wish to participate or did not attend the practice session when the questionnaire was administered. The Panel on Human Subject Research approved the study, and written informed consent was obtained from all participants.

Questionnaire

The study questionnaire included 2 validated instruments to examine sleep quality and levels of daytime sleepiness. A modified Pittsburgh Sleep Quality Index (PSQI) was used to assess sleep duration, sleep onset latency, subjective sleep symptoms, sleep medications, and disturbances. The PSQI measures a broad range of symptoms of sleep disturbances over a 1-month period. Responses are categorized into 7 component scores; these are then combined to create 1 global score. The total global PSQI score ranges from 0 to 21. The PSQI score was used to create a dichotomous variable, distinguishing poor sleepers (global PSQI score greater than 5), from good sleepers.[15] PSQI questions for time in bed were modified to assess weekday sleep, which was used for the global score, and weekend time in bed was assessed separately. The PSQI question 8 inquires daytime dysfunction specifically trouble staying awake during daily activities. Daytime sleepiness was quantified using the Epworth Sleepiness Scale. The Epworth measures sleep propensity on a 0-3 scale in 8 standardized daily situations. Possible scores range from 0 to 24, with higher scores reflecting greater sleepiness and a score of 10 or greater indicating clinically high levels of daytime sleepiness.[16] The Epworth score was considered a continuous variable. The study questionnaire also included questions regarding sleep quality at the home location on campus vs during travel for games or competition rated on a 10-point scale (1 = poor, 10 = excellent), frequency of tiredness and difficulty waking up using a Likert scale, frequency and duration of routine and precompetition napping habits, sleep environment disturbances, and aids that athletes use to help sleep (Tables 3 and 4).

Statistical analysis

Statistical analyses were performed using Stata/IC10.1 (StataCorp LP, College Station, TX). Linear regression tested associations between sleep duration or age as the independent variable and daytime functioning or Epworth scores as the dependent variable. χ^2 test evaluated association between sexes. *t* test evaluated association between ratings of sleep at home vs while traveling. *P* values < .05 were considered statistically significant.

Table 1
Participant demographics

	Total	Men	Women
	n (%)	n (%)	n (%)
Participants	628	343 (54.6)	285 (45.4)
Ethnicity			
African American	79 (12.6)	55 (16.0)	24 (8.4)
Asian/Pacific Islander	34 (5.4)	11 (3.2)	23 (8.1)
Hispanic	17 (2.7)	10 (2.9)	7 (2.5)
Native American	1 (0.2)	0 (0.0)	1 (0.3)
White	443 (70.5)	240 (70.0)	203 (71.2)
Multiracial	43 (6.8)	22 (6.4)	21 (7.4)
Unknown	11(1.8)	5 (1.5)	6 (2.1)
Age (y)	19.6 ± 1.3	19.7 ± 1.3	19.4 ± 1.2
17	3 (0.5)	1 (0.3)	2 (0.7)
18	149 (23.8)	68 (19.8)	81 (28.6)
19	180 (28.7)	102 (29.7)	78 (27.6)
20	142 (22.7)	76 (22.2)	66 (23.3)
21	105 (16.8)	60 (17.5)	45 (15.9)
22	40 (6.4)	29 (8.5)	11 (3.9)
23	6 (0.9)	6 (1.7)	0 (0.0)
26	1 (0.2)	1 (0.3)	0 (0.0)
Height (m)	1.8 ± 0.1	1.9 ± 0.1	1.7 ± 0.1
Range	1.5-2.1	1.6-2.1	1.5-2.1
Weight (kg)	79.5 ± 18.4	90.1 ± 16.9	66.4 ± 9.5
Range	43.6-163.6	59.1-163.6	43.6-104.5
BMI (kg/m^2)	24.3 ± 3.6	25.9 ± 3.7	22.5 ± 2.3
Range	17.4-42.8	18.9-42.8	17.4-32.6

Data are presented as mean ± standard deviation unless otherwise indicated. BMI, body mass index.

Results

Participants

A total of 628 athletes participated in the study and were members of the following 29 varsity sports teams at Stanford University: men's and women's basketball, golf, gymnastics, rowing, sailing, soccer, swimming & diving, tennis, track & field, volleyball, water polo; men's baseball, football, wrestling; and women's field hockey, lacrosse, lightweight rowing, softball, synchronized swimming. Several track & field athletes also participate on the men's and women's cross country teams but were classified as track & field athletes because they were training for this sport when the questionnaires were completed. Men's sailing and women's sailing were classified as 1 team because they frequently compete together. Table 1 provides demographic information and characteristics of the study population. Nearly all undergraduate students at Stanford University live in on-campus housing in a range of options including dormitories, suites, and small group houses. Only 19 athletes in the study indicated that they live off campus.

Sleep quality and sleep disturbances

Athletes had a mean PSQI score of 5.38 ± 2.45 (Table 2), and 42.4% of athletes were identified as poor sleepers with PSQI scores > 5. "Fairly bad" or "very bad" sleep quality was reported by 16.6% (104 athletes: 19.5% men vs 13.0% women) on the PSQI, with men reporting worse sleep quality than women, $\chi^2(4) = 11.3$, $P = .02$. Athletes reported lower sleep quality at home on campus than when traveling, 7.1 vs 7.6, $t(557) = -4.97$, $P < .001$. Sleep disturbances that commonly occurred 3 or more times per week included the inability to fall asleep within 30 minutes (9.7%), waking up in the middle of the night or early morning (23.9%), and using the bathroom (17.0%). Table 3 provides the environmental factors that athletes reported impact sleep and aids that athletes use to help sleep. Over the past month, athletes reported using prescription or over-the-

Table 2
Sleep quality and daytime sleepiness assessments

	Total	PSQI	Sleep rating	Sleep rating	Epworth
	n (%)	Mean (SD)	On campus	Traveling	Mean (SD)
			Mean (SD)	Mean (SD)	
All participants	628	5.4 (2.4)	7.1 (1.6)	7.6 (1.7)	9.5 (3.9)
Range		0-18.0	2.0-10.0	1.0-10.0	0-23.0
Sex					
Men	343 (54.6)	5.4 (2.4)	7.1 (1.6)	7.6 (1.7)	9.3 (3.9)
Women	285 (45.4)	5.3 (2.5)	7.2 (1.5)	7.5 (1.7)	9.7 (3.8)
Varsity team					
Men's baseball	36 (5.7)	5.5 (2.5)	7.0 (1.8)	8.1 (1.5)	9.1 (4.2)
Men's basketball	16 (2.5)	4.8 (1.9)	7.3 (0.7)	7.0 (1.7)	9.7 (4.3)
Women's basketball	15 (2.4)	5.9 (4.1)	7.4 (1.7)	7.3 (1.8)	8.5 (3.3)
Women's field hockey	19 (3.0)	5.6 (3.4)	7.2 (1.4)	6.6 (1.7)	9.3 (3.7)
Men's football	109 (17.4)	5.5 (2.5)	7.2 (1.6)	7.9 (1.5)	9.4 (4.1)
Men's golf	9 (1.4)	4.9 (2.3)	6.4 (1.7)	8.3 (1.5)	7.8 (2.9)
Women's golf	7 (1.1)	4.9 (1.8)	7.9 (1.9)	7.1 (1.4)	9.7 (3.0)
Men's gymnastics	13 (2.1)	4.7 (1.8)	7.4 (1.4)	7.0 (1.5)	9.2 (2.4)
Women's gymnastics	13 (2.1)	3.7 (0.9)	7.9 (0.8)	6.6 (1.2)	9.5 (4.1)
Women's lacrosse	21 (3.4)	7.2 (2.3)	6.1 (1.9)	5.7 (2.0)	12.4 (4.6)
Men's rowing	21 (3.4)	5.7 (1.9)	7.5 (1.4)	7.4 (1.9)	9.3 (4.9)
Women's lightweight rowing	15 (2.4)	5.9 (1.3)	6.7 (1.7)	8.3 (1.2)	10.4 (4.2)
Women's rowing	26 (4.1)	5.5 (2.2)	6.8 (1.4)	8.1 (1.4)	9.9 (2.7)
Men's and women's sailing	22 (3.5)	5.1 (2.0)	7.3 (1.1)	8.0 (1.9)	9.2 (4.4)
Men's soccer	24 (3.8)	5.3 (2.1)	6.5 (1.6)	8.1 (1.6)	8.8 (3.1)
Women's soccer	26 (4.1)	4.7 (3.3)	7.8 (1.5)	8.6 (1.5)	8.3 (3.5)
Women's softball	24 (3.8)	4.9 (2.0)	7.3 (1.4)	7.1 (1.9)	9.2 (4.4)
Men's swimming & diving	13 (2.1)	6.2 (2.6)	7.5 (1.8)	7.4 (1.6)	10.7 (3.9)
Women's swimming & diving	31 (4.9)	4.5 (2.2)	7.8 (1.2)	7.3 (1.2)	10.6 (3.8)
Women's synchronized swimming	9 (1.4)	5.4 (2.0)	6.9 (1.3)	6.9 (1.1)	9.2 (3.6)
Men's tennis	8 (1.3)	3.9 (2.5)	7.9 (1.6)	8.6 (1.3)	10.4 (3.9)
Women's tennis	8 (1.3)	4.5 (2.6)	7.4 (1.3)	8.1 (0.9)	9.8 (2.5)
Men's track & field	20 (3.2)	5.4 (2.5)	7.1 (1.6)	6.9 (1.6)	9.4 (3.7)
Women's track & field	28 (4.5)	5.1 (1.9)	7.5 (1.4)	8.0 (1.8)	9.8 (3.7)
Men's volleyball	18 (2.9)	4.7 (1.7)	7.5 (1.3)	6.6 (1.5)	8.2 (4.1)
Women's volleyball	14 (2.2)	6.2 (2.4)	7.1 (1.8)	7.3 (1.2)	9.3 (2.5)
Men's water polo	20 (3.2)	4.6 (2.2)	7.3 (1.7)	8.6 (1.2)	10.2 (4.4)
Women's water polo	17 (2.7)	6.0 (1.8)	6.9 (1.1)	7.1 (1.6)	9.4 (3.9)
Men's wrestling	26 (4.1)	7.0 (3.1)	6.8 (1.8)	6.6 (2.0)	9.5 (3.0)

PSQI, Pittsburgh Sleep Quality Index.

counter medications to help sleep less than once per week (10.8%), once or twice per week (6.1%), and 3 or more times per week (2.6%).

Sleep duration and naps

A total of 39.1% of athletes (Fig. 1) and 58.6% of team averages (17 teams) reported a mean total sleep time <7 hours on weekdays (Fig. 2). The 17 teams included men's and women's teams as well as individual and team sports. Seventy-one percent of the 17 teams that reported <7 hours daily sleep time indicated a team mean wake time before 7:30 AM. Athletes reported 7.54 ± 1.18 hours of time in bed and 6.98 ± 1.02 hours total sleep time on weekdays. On the weekends, athletes reported 8.4 ± 1.2 hours time in bed. For each age category, mean reported weekday sleep time was ≤7 hours, except for 22+-year-old athletes that indicated a mean of 7.4 hours of sleep. Reported sleep onset latency the previous month was 16.8 ± 15.3 minutes, with a range of 0-120 minutes. Total sleep time was predictive of daytime functioning, as greater sleep time was associated with a lower frequency in how often athletes feel tired, $F_{1,625} = 91.8$, $P < .001$; have difficulty waking up for practice or class, $F_{1,625} = 58.6$, $P < .001$; and have trouble staying awake during daily activities, $F_{1,625} = 28.4$, $P < .001$. Athletes regularly used routine naps and pregame/competition naps (Table 4). Eighty percent of athletes nap at least once per week, and at least 11% of athletes on all teams take pregame/competition naps.

Table 3
Sleep environment factors and aids to help sleep

	Total	Men	Women
	n (%)	n (%)	n (%)
Factors that impact sleep			
Noise	427 (68.0)	209 (60.9)	218 (76.5)
Roommate	192 (30.6)	81 (23.6)	111 (38.9)
Sunlight	264 (42.0)	136 (39.7)	128 (44.9)
Temperature	348 (55.4)	180 (52.5)	168 (58.9)
Other	56 (8.9)	40 (11.7)	16 (5.6)
Aids to help sleep			
Computer	23 (3.7)	15 (4.4)	8 (2.8)
Earplugs	87 (13.9)	30 (8.7)	57 (20.0)
Eye mask	57 (9.1)	16 (4.7)	41 (14.4)
Fan	266 (42.4)	174 (50.7)	92 (32.3)
Music	97 (15.4)	51 (14.9)	46 (16.1)
TV	32 (5.1)	23 (6.7)	9 (3.2)
White noise	39 (6.2)	19 (5.5)	20 (7.0)
Other	26 (4.1)	13 (3.8)	13 (4.6)

Daytime sleepiness

Epworth scores ≥10 indicating high levels of daytime sleepiness were reported by 51.0% of athletes. Five of the 6 teams with mean Epworth scores >10 (Table 2) reported mean wake time by 7:00 AM on weekdays. Teen athletes in the first 2 years of college reported the highest mean levels of daytime sleepiness (Fig. 3), and greater age was predictive of lower Epworth scores, $F_{1,624} = 9.4$, $P = .002$. Total sleep time was also found to be predictive of Epworth scores, as greater sleep duration was associated with lower levels of daytime sleepiness, $F_{1,625} = 44.7$, $P < .001$. Athletes reported frequently

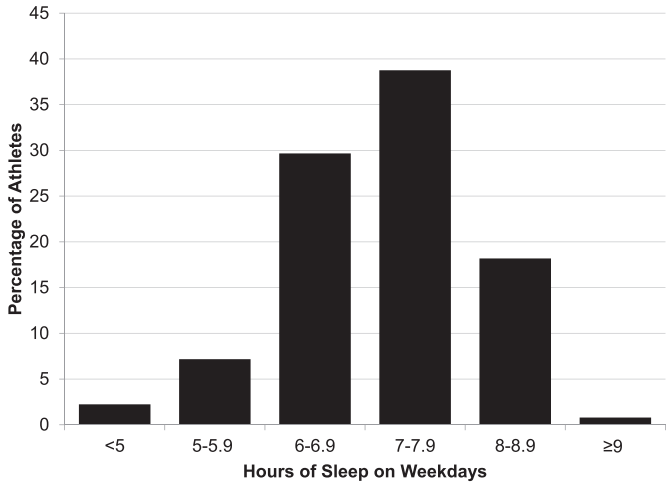

Fig. 1. Reported total sleep time by collegiate athletes on weekdays.

experiencing feeling tired, including 62.1% of athletes indicating that they are "often" or "always" tired, and 0% responded that they are "never" tired. Additionally, 50.6% of athletes reported "often" or "always" having difficulty waking up in the morning for practice or class. Moreover, 85.3% of athletes reported having difficulty concentrating on daily tasks due to being sleepy or tired, and 66.2% indicated having difficulty watching a video because they become sleepy or tired.

Discussion

The present study examined collegiate athletes across a wide range of individual and team sports to assess the sleep quality, sleep duration, and daytime sleepiness of a collegiate student-athlete population. The main findings are that collegiate athletes generally experience poor sleep quality, habitually obtain insufficient sleep, and experience substantial levels of daytime sleepiness. These findings have important implications including potentially impaired physiologic and cognitive recovery, increased consequences on physical and mental health, increased injury risk, and impaired performance outcomes.

The present study found that 628 athletes across 29 individual and team sports are poor sleepers with mean PSQI score 5.38 ± 2.45 and reported worse sleep quality when at the home location compared to when traveling for games or competition. This finding extends our understanding of poor sleep quality to a wide range of collegiate athletes and, to our knowledge, is the most comprehensive range of sports reported among studies examining sleep patterns in athletes. Our results are consistent with a study in highly trained rugby and cricket athletes that similarly found athletes experience poor sleep quality with mean PSQI score of 5.9 ± 2.6.[11] Moreover, our finding that 42.4% of individual and team sport athletes are poor sleepers with PSQI >5 is similar to 50% found in the aforementioned team sport athletes. This high prevalence of poor sleepers across sports may also reflect collegiate students in general and has important implications for physical and mental health. In college students, poor sleepers assessed by PSQI have been demonstrated to be associated with more physical illness, higher levels of stress and negative mood, more than twice as likely to report using over-the-counter or prescription stimulant medications to keep them awake, and twice as likely to report using alcohol to induce sleep compared to good sleepers.[17] Our finding that sleep quality ratings in collegiate athletes were worse at the home location is in contrast to one of the few studies comparing sleep quality at home vs travel for competition.[18] Differences in sport-specific training, daily schedules, and travel across time zones may contribute to the observed difference. Nearly all the athletes in the present study lived in on-campus housing, and thus, we speculate that the unique collegiate dorm environment disturbances contributed to worse sleep quality at the home location. This is highlighted by the substantial number of athletes that reported their sleep is impacted by noise (68.0%), temperature (55.4%), and sunlight (42.0%) (Table 3). These disturbances may be modifiable, as some athletes reported using various sleep aids to help sleep including using earplugs (13.9%), a

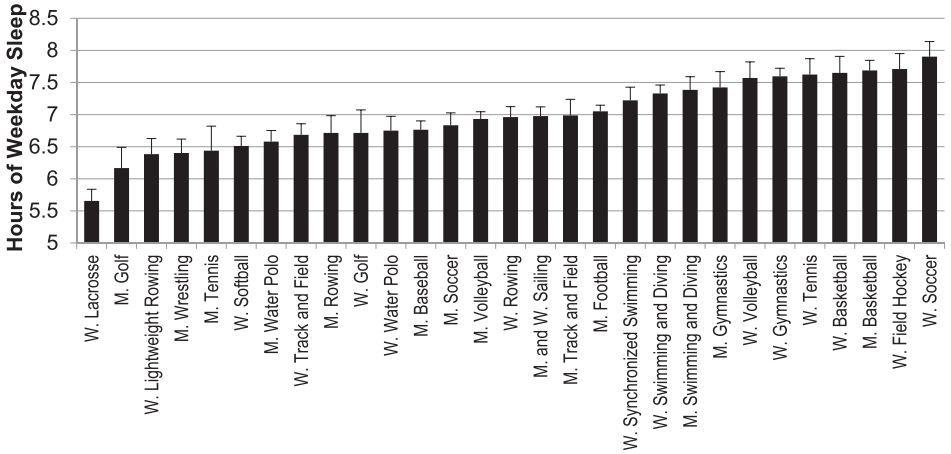

Fig. 2. Reported total sleep time on weekdays increasing from left to right by collegiate varsity team. Data provided as mean with standard error.

Table 4
Napping habits

	Total	Men	Women
	n (%)	n (%)	n (%)
How often do you nap?			
Never	56 (8.9)	23 (6.7)	33 (11.6)
Once a month	73 (11.6)	31 (9.0)	42 (14.7)
Once a week	149 (23.7)	77 (22.5)	72 (25.3)
2+ times a week	234 (37.3)	132 (38.5)	102 (35.8)
Every day	116 (18.5)	80 (23.3)	36 (12.6)
Length of naps			
Don't nap	56 (8.9)	23 (6.7)	33 (11.6)
Less than 10 min	1 (0.2)	1 (0.3)	0 (0.0)
10-30 min	140 (22.3)	70 (20.4)	70 (24.6)
30-60 min	270 (43.1)	154 (44.9)	116 (40.9)
1-2 h	147 (23.4)	86 (25.1)	61 (21.5)
2+ h	13 (2.1)	9 (2.6)	4 (1.4)
Do you take pregame naps?			
Never	274 (43.6)	161 (46.9)	113 (39.6)
Rarely	157 (25.0)	93 (27.1)	64 (22.5)
Sometimes	147 (23.4)	65 (19.0)	82 (28.8)
Often	32 (5.1)	16 (4.7)	16 (5.6)
Always	18 (2.9)	8 (2.3)	10 (3.5)
Length of pregame naps			
No pregame nap	274 (43.9)	161 (47.1)	113 (39.9)
Less than 10 min	19 (3.0)	14 (4.1)	5 (1.8)
10-30 min	160 (25.6)	87 (25.4)	73 (25.8)
30-60 min	121 (19.4)	64 (18.7)	57 (20.1)
1-2 h	47 (7.5)	14 (4.1)	33 (11.7)
2+ h	4 (0.6)	2 (0.6)	2 (0.7)

fan (42.4%), and an eye mask (9.1%). Furthermore, poor sleep prior to competition at home or away may affect competition outcomes. In a study of 632 individual and team sport German athletes, 62.3% reported poor sleep prior to competition in the last year, and of these athletes that indicated experiencing sleep issues, 12.9% perceived a direct impact on their game performance.[13] Future studies are needed to elucidate the impact of perceived or objective differences in sleep quality on competition performance. In short, our findings suggest poor sleep quality is common in athletes, and this may have consequences for athlete physical and mental well-being and athletic performance. Thus, management of poor sleep quality both at home and while traveling, including minimizing environmental factors and daily behaviors that can negatively impact sleep while maximizing good sleep hygiene practices, is recommended.

Inadequate sleep is highlighted by the 39.1% of collegiate athletes that reported obtaining less than 7 hours of sleep on weekdays (Fig. 1). This finding that many collegiate athletes obtain insufficient sleep is consistent with a study by Lastella et al that demonstrated 124 elite Australian athletes across individual and team sports obtained on average 6.8 hours of sleep per night assessed objectively via wrist actigraphy.[19] Importantly, regularly obtaining 7 hours of sleep per night is the minimum recommended hours of sleep for adults to prevent health risks and performance decrements.[20] Therefore, although 60.9% of athletes reported obtaining the 7 hour per night minimum recommendation on weekdays, more than a third of collegiate athletes in this study did not meet the minimum daily sleep requirement for adults. This inadequate sleep may result in critical consequences that impair athletes' ability to maintain optimal reaction time, alertness, and athletic performance. Chronic sleep restriction to 5 or even 7 hours of sleep per night for 1 week has been shown to slow reaction speed and increase daytime sleepiness by 42% that stabilized after several days, although at a reduced level.[21,22] One night of acute sleep loss can also impair sport-specific execution. In elite tennis players, 1 night restricted to 5 hours of sleep decreased tennis serving accuracy by approximately 25%.[23]

Chronically restricted hours of sleep also has important implications for potential injury,[24] accurate concussion assessment,[26] and susceptibility to infectious illness.[27] Regularly obtaining <8 hours of sleep has been demonstrated to have 1.7 times greater risk for injury compared to athletes that obtained ≥8 hours of sleep.[25] Furthermore, acute illness may impact proper physiologic recovery and effective sports training. Thus, attention to prioritizing acute and chronic sleep needs is important to minimize injury and illness risk, as well as avoid decrements in alertness and potentially athletic performance.

Our findings demonstrated a high prevalence of routine naps, with 80% of athletes taking a nap at least once per week. Short naps may also provide performance benefits and have implications for subsequent games or competition. The most frequently reported response for a pregame nap was 10-30 minutes, which is consistent with previous studies that have demonstrated that a 10- to 30-minute nap is beneficial for alertness and performance.[28,29] Twenty-eight percent of athletes, however, indicated taking a pregame nap longer than 30 minutes, which may result in sleep inertia and impaired performance upon awakening.[28]

In the current study, 51.0% of athletes reported Epworth scores of 10 or greater, suggesting clinically significant levels of daytime sleepiness. This finding indicates that more than half of athletes in

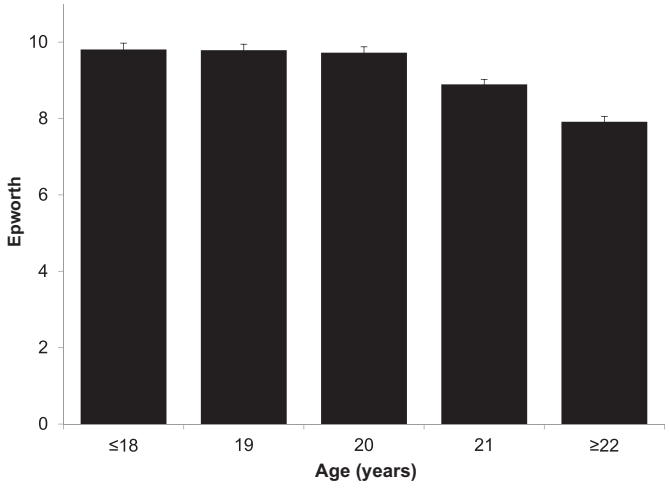

Fig. 3. Epworth Sleepiness Scale in collegiate athletes by age. Data provided as mean with standard error.

individual and team sports experience high levels of daytime sleepiness, which is notably greater than 28% found in 175 team sport athletes and 25% previously reported in 1125 American undergraduates.[11,17] In the context of another operational setting, United States Navy crewmembers with elevated Epworth scores >10 demonstrated 60% slower reaction times compared to individuals with normal Epworth scores.[30] Furthermore, the mean Epworth score of 9.5 ± 3.9 in this study is greater than that found in rugby and cricket athletes (Epworth score = 8.5) and among American college students (Epworth score = 6.8).[11,17] This daytime sleepiness affects daytime functioning, and it is notable that nearly two-thirds of athletes in this study reported being regularly tired and had difficulty with daily tasks because of sleepiness. In particular, teen student-athletes reported the highest mean levels of daytime sleepiness. Therefore, it may be beneficial to initially provide sleep education and management for first and second year collegiate athletes to help establish good sleep practices for their collegiate career. The high prevalence of elevated levels of sleepiness and impairment in daytime activities in collegiate athletes warrants attention and further investigation.

The study findings taken together of poor sleep quality, insufficient hours of sleep, and high levels of daytime sleepiness may have critical implications for effective sports training, competition outcomes, academics, injury risk, and overall health in collegiate athletes. Although many athletes and coaches believe that sleep is a part of the recovery process, current sports performance regimens often do not address sleep quality or prioritize adequate daily sleep duration. Ironically, in many instances, adequate sleep is sacrificed because of scheduling limitations, because of prioritization of other sports preparations over sleep, or simply because sleep is currently not widely accepted as a critical component to sports performance. Notably, several studies examining sleep enhancement via sleep extension in athletes have shown improved athletic performance. Following 1 week of sleep extension, collegiate tennis players demonstrated 6.1% increased serving accuracy and decreased levels of daytime sleepiness.[31] In our prior study in collegiate basketball players, 5-7 weeks of sleep extension resulted in 0.7-second faster sprint time and 9% increase in free throw and 3-point field goal percentages.[32] Additional sleep enhancement management includes strategies to minimize jet lag during travel, improve sleep habits and the sleep environment, and identify sleep disorders in athletes.[33,34] Both periodic assessment and regular management of sleep quality and sleep duration would likely benefit athletes both at their home location as well as during travel for games and competition.

Limitations

The current study used self-reported assessments of sleep quality and sleep duration. These self-reports may differ from objective measures of sleep, and in particular, self-reported sleep duration may be overestimated. Secondly, the study was conducted during the late fall and early winter when some collegiate teams were in-season whereas other teams were in the off-season. Sleep outcomes may differ during the regular season vs off-season, and future studies can examine sleep outcomes at other times of the year. Thirdly, this study examined collegiate athletes at a single university. Sports training, daily schedules, and other lifestyle choices may be different in other environments, with potentially different impacts on sleep. A fourth limitation is that a nonathlete group was not included for comparison with the collegiate athletes. Additionally, sleep disorders can impact sleep in athletes and were not specifically assessed in this study. Lastly, the PSQI may have limited concordance with clinical assessment of sleep quality in elite athletes.[35] The modified PSQI inquired weekday sleep duration for the global score; therefore, it did not include weekend sleep patterns.

Conclusions

The current study examined sleep quality, sleep duration, and levels of daytime sleepiness in 628 collegiate athletes across a wide range of 29 individual and team sports. Our findings indicated that collegiate athletes experience poor sleep quality, regularly obtain inadequate hours of sleep, and experience substantial daytime sleepiness. These results have important implications potentially leading to increased consequences on mental and physical health, increased injury risk, and impaired daytime functioning and performance outcomes. Athletes and coaches should consider daily sleep needs and promote training and travel schedules that support good sleep quality and regularly allow for sufficient hours of sleep.

Disclosure

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References

1. Angus RG, Heslegrave RJ, Myles WS. Effects of prolonged sleep deprivation, with and without chronic physical exercise, on mood and performance. *Psychophysiology*. 1985;22(3):276–282.
2. Van Dongen HP, Maislin G, Mullington JM, Dinges DF. The cumulative cost of additional wakefulness: dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. *Sleep*. 2003;26(2):117–126.
3. Walker MP, Stickgold R. Sleep-dependent learning and memory consolidation. *Neuron*. 2004;44(1):121–133.
4. Martin BJ. Effect of sleep deprivation on tolerance of prolonged exercise. *Eur J Appl Physiol Occup Physiol*. 1981;47(4):345–354.
5. Reilly T, Piercy M. The effect of partial sleep deprivation on weight-lifting performance. *Ergonomics*. 1994;37(1):107–115.
6. Spiegel K, Leproult R, Van Cauter E. Impact of sleep debt on metabolic and endocrine function. *Lancet*. 1999;354(9188):1435–1439.
7. Blumert PA, Crum AJ, Ernsting M, et al. The acute effects of twenty-four hours of sleep loss on the performance of national-caliber male collegiate weightlifters. *J Strength Cond Res*. 2007;21(4):1146–1154.
8. Fullagar HH, Skorski S, Duffield R, Hammes D, Coutts AJ, Meyer T. Sleep and athletic performance: the effects of sleep loss on exercise performance, and physiological and cognitive responses to exercise. *Sports Med*. 2015;45(2):161–186.
9. Leger D, Metlaine A, Choudat D. Insomnia and sleep disruption: relevance for athletic performance. *Clin Sports Med*. 2005;24(2):269–285 (viii).
10. Samuels C. Sleep, recovery, and performance: the new frontier in high-performance athletics. *Neurol Clin*. 2008;26(1):169–180.
11. Swinbourne R, Gill N, Vaile J, Smart D. Prevalence of poor sleep quality, sleepiness and obstructive sleep apnoea risk factors in athletes. *Eur J Sport Sci*. 2016;16(7):850–858.
12. Leeder J, Glaister M, Pizzoferro K, Dawson J, Pedlar C. Sleep duration and quality in elite athletes measured using wristwatch actigraphy. *J Sports Sci*. 2012;30(6):541–545.
13. Erlacher D, Ehrlenspiel F, Adegbesan OA, El-Din HG. Sleep habits in German athletes before important competitions or games. *J Sports Sci*. 2011;29(8):859–866.
14. Juliff LE, Halson SL, Peiffer JJ. Understanding sleep disturbance in athletes prior to important competitions. *J Sci Med Sport*. 2015;18(1):13–18.

15. Buysse DJ, Reynolds CF, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index (PSQI): a new instrument for psychiatric practice and research. *Psychiatry Res*. 1989;28(2):193–213.
16. Johns MW. A new method for measuring daytime sleepiness: the Epworth sleepiness scale. *Sleep*. 1991;14(6):540–545.
17. Lund HG, Reider BD, Whiting AB, Prichard JR. Sleep patterns and predictors of disturbed sleep in a large population of college students. *J Adolesc Health*. 2010; 46(2):124–132.
18. Richmond LK, Dawson B, Stewart G, Cormack S, Hillman DR, Eastwood PR. The effect of interstate travel on the sleep patterns and performance of elite Australian Rules footballers. *J Sci Med Sport*. 2007;10(4):252–258.
19. Lastella M, Roach GD, Halson SL, Sargent C. Sleep/wake behaviours of elite athletes from individual and team sports. *Eur J Sport Sci*. 2015;15(2):94–100.
20. Watson NF, Badr MS, Belenky G, et al. Recommended amount of sleep for a healthy adult: a joint consensus statement of the American Academy of Sleep Medicine and Sleep Research Society. *Sleep*. 2015;38(6):843–844.
21. Carskadon MA, Dement WC. Cumulative effects of sleep restriction on daytime sleepiness. *Psychophysiology*. 1981;18(2):107–113.
22. Dinges DF, Pack F, Williams K, et al. Cumulative sleepiness, mood disturbance, and psychomotor vigilance performance decrements during a week of sleep restricted to 4-5 hours per night. *Sleep*. 1997;20(4):267–277.
23. Reyner LA, Horne JA. Sleep restriction and serving accuracy in performance tennis players, and effects of caffeine. *Physiol Behav*. 2013;120:93–96.
24. Luke A, Lazaro RM, Bergeron MF, et al. Sports-related injuries in youth athletes: is overscheduling a risk factor? *Clin J Sport Med*. 2011;21(4):307–314.
25. Milewski MD, Skaggs DL, Bishop GA, et al. Chronic lack of sleep is associated with increased sports injuries in adolescent athletes. *J Pediatr Orthop*. 2014;34(2): 129–133.
26. Silverberg ND, Berkner PD, Atkins JE, Zafonte R, Iverson GL. Relationship between short sleep duration and preseason concussion testing. *Clin J Sport Med*. 2016; 26(3):226–231.
27. Prather AA, Janicki-Deverts D, Hall MH, Cohen S. Behaviorally assessed sleep and susceptibility to the common cold. *Sleep*. 2015;38(9):1353–1359.
28. Milner CE, Cote KA. Benefits of napping in healthy adults: impact of nap length, time of day, age, and experience with napping. *J Sleep Res*. 2009;18(2): 272–281.
29. Waterhouse J, Atkinson G, Edwards B, Reilly T. The role of a short post-lunch nap in improving cognitive, motor, and sprint performance in participants with partial sleep deprivation. *J Sports Sci*. 2007;25(14):1557–1566.
30. Shattuck NL, Matsangas P. Psychomotor vigilance performance predicted by Epworth Sleepiness Scale scores in an operational setting with the United States Navy. *J Sleep Res*. 2015;24(2):174–180.
31. Schwartz J, Simon Jr RD. Sleep extension improves serving accuracy: a study with college varsity tennis players. *Physiol Behav*. 2015;151:541–544.
32. Mah CD, Mah KE, Kezirian EJ, Dement WC. The effects of sleep extension on the athletic performance of collegiate basketball players. *Sleep*. 2011;34(7): 943–950.
33. Simpson NS, Gibbs EL, Matheson GO. Optimizing sleep to maximize performance: implications and recommendations for elite athletes. *Scand J Med Sci Sports*. 2017; 27(3):266–274.
34. Samuels CH. Jet lag and travel fatigue: a comprehensive management plan for sports medicine physicians and high-performance support teams. *Clin J Sport Med*. 2012;22(3):268–273.
35. Samuels C, James L, Lawson D, Meeuwisse W. The Athlete Sleep Screening Questionnaire: a new tool for assessing and managing sleep in elite athletes. *Br J Sports Med*. 2016;50(7):418–422.