Title: A Preliminary Investigation of the Relationship between Sleep and Nap Behavior of NCAA Division 1 Football Student-Athletes

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Abstract
Background of Study: Sleep is critical to basic human function, and of utmost importance for recovery and performance for athletes. Student-athletes unique demands of concurrent athletic and academic commitments place further emphasis on the need for adequate sleep quality and quantity. *Objective:* This study describes the sleep and nap behavior of NCAA Division 1 Student-Athletes and assess the relationship between naps and nocturnal sleep. *Method:* A retrospective and observational design was used. Objective sleep data were collected using the OURA ring across two collegiate Football seasons. Results were categorized into sleep and nap occurrences. Univariate linear mixed models were used to assess the relationship between the presence and duration of a nap and a participants sleep. *Results:* The relationship between the presence of a nap ($p = 0.012$) and duration of a nap ($p < 0.001$) and total sleep duration was observed. The presence (0.022) and duration ($p < 0.001$) of a nap also significantly impacted the light phase of sleep. *Conclusion:* The use and duration of naps among student-athletes significantly impacts nighttime sleep, by means of decreasing total sleep duration and light phase sleep duration. These results highlight the need for educational intervention with such cohorts to enhance nighttime sleep and encourage healthy and evidence-based usage of naps.

Keywords
Sports, Team Sports, Post-Exercise Recovery, Sleep Hygiene

1. Introduction

Sleep plays a critical role in basic human function, including underlying physiology, cognitive and physical performance, and recovery. Despite adequate sleep being linked to general health and academic success (Friedrich & Schlarb, 2018), university students are reported to exhibit suboptimal sleep habits (Sargent, Lastella, Halson, & Roach, 2014; Tuomilehto et al., 2017). However, few studies have investigated the sleep habits of a student-athlete population (i.e., collegiate level athletes). Student-athletes are subject to concurrent athletic, academic and social demands (Mah, Kezirian, Marcello, & Dement, 2018), suggesting they are more likely to experience poorer sleep quality and quantity compared to their non-athlete counterparts (Driller, Dixon, & Clark, 2017). Initial research reports student-athletes experience poor sleep quality, habitually obtain insufficient sleep (Mah, Kezirian, Marcello, & Dement, 2018) and have a high variance in sleep patterns (Cédric Leduc, Tee, Weakley, Ramirez, & Jones, 2020). Given the unique demands of this population, a greater understanding of the sleep habits, by means of objective sleep monitoring, of student-athletes may better inform education and intervention protocols from their institutions.

One such strategy to deal with the concurrent academic and athletic demands is napping. Initial research reports 80% of student-athletes use naps to supplement inadequate nocturnal sleep (Roberts, Teo, & Warmington, 2019). Existing literature pertaining to the proposed positive and/or negative effects of naps is mixed. For instance, the effects may be based on nap length, whereby shorter naps (<30mins) may improve subjective and objective alertness (Taub, Tanguay, & Rosa, 1977), subjective sleepiness (Gillberg, Kecklund, Axelsson, & Akerstedt, 1996), reaction time, and sprint performance (Stephenson et al., 2022). Meanwhile, longer naps (>30mins) may pose negative effects on cognition with side effects such as sleep inertia (Neil P Walsh et al., 2021). Most pertinently, frequent, long and/or late napping is reported to diminish nocturnal sleep quantity and quality among college students (Takahashi & Arito, 2000). Assuming athletic populations present greater physical and cognitive demands compared with students not engaged in collegiate athletics, it is unclear whether naps affect this population in the same way. Mah and colleagues (Mah, Kezirian, Marcello, & Dement, 2018) provide the only study investigating this relationship among student-athletes, where pregame naps were common and almost 30% of student-athletes take longer (>30min naps). As such, further research is required to understand the relationship between sleep and napping behavior of the student-athlete population.

The relationship between sleep and athletic performance is complex. There is consensus, among researchers and practitioners alike, that sleep deprivation has significant negative effects on athletic performance (Fullagar et al., 2015b). However, evidence is less clear on partial sleep disturbance, which is more commonly experienced (Fullagar et al., 2015b). A review by Fullagar et al., (Fullagar et al., 2015b) reported that periods of sleep disruption may negatively impact endurance and repeat bout performance, while also compromising most aspects of cognitive function and mood stability. Fullagar and colleagues (Fullagar et al., 2015a) also reviewed the impact of sleep loss on recovery, concluding that disruption of sleep timing, quality and duration results in the hindrance of psychological and physiological recovery. Subsequently, it is critical in understanding the sleep habits of student-athletes to ensure optimal performance, both athletic and academic, and recovery can be achieved. Furthermore, investigation of sleep habits and the use of naps in a student-athlete cohort is required to identify key educational interventions to foster improved sleep as an athlete and their ongoing post-athletic career. As such this case study will 1) describe the sleep and nap behavior of student-athletes utilizing objective sleep monitoring devices and 2) examine the relationship between sleep and nap behavior of student-athletes.

2. Methods

Participants and study design

Data comprising 2286 sleep instances (sleep; n = 1460, nap; n = 826) were obtained from Division 1 Collegiate Football athletes (height = 192.2 ± 10.2cm, weight = 120.4 ± 10.2kg, age = 20 ± 1yr) for this study. All subjects held athletic scholarships with the Football program while undertaking full-time undergraduate study. This project was approved by the university ethics committee (24-03-8448).

This retrospective study was observational in design, with data collected as part of routine sport science servicing across two full competitive seasons of training and competition of an NCAA Division 1 Football team. Data was collected using a commercially available finger-worn multisensory device (OURA Ring, Oulu, Finland) to objectively monitor sleep habits (Appendix 1). The OURA Ring detects pulse rate, variation in interbeat intervals (IBIs) and pulse amplitude from the finger optical pulse waveform (de Zambotti, Rosas, Colrain, & Baker, 2019). Collectively, with these motion, heart rate, heart rate variability and pulse wave variability amplitude measures in combination with machine-learning algorithms, stages of sleep and wake states are able to be identified and quantified (7). In addition, several variables are collated to provide overarching ‘scores’ out of 100 that indicate sleep quality. The OURA Ring provides good agreement with Polysomnography (PSG), the gold standard in sleep monitoring (de Zambotti, Rosas, Colrain, & Baker, 2019).

Data Collection Procedure

Student-athletes were fitted for ring size with OURAs sizing kit and instructed to wear the ring daily, only removing it if required for practice. Data was downloaded daily to the OURA application by the participant and collated at the end of the data collection period into a csv file. Data cleaning resulted in a smaller number of sleep instances. Based on OURAs classification systems, a nap is considered between 15 min and 3 hours in length, with instances greater than 3 hours considered a sleep, while instances less than 15 min were excluded from analysis. Furthermore, night sleep instances reported on the same day were summed into a single record.

Statistical Analysis

Descriptive data are presented as mean (SD) at the group and individual level. A series of univariate linear mixed models were used to examine the relationship between the presence and duration of naps with objective sleep measures. Key variables were used in turn as the dependent variable, with the independent variable being the duration of the nap or presence of a nap (binary variable). The null model with no predictors was fit in order to compute the intraclass correlation coefficient (ICC) for each response. All models were fit using the lme4 (Bates) package in the R statistical programming environment (R Core Team, 2020).

3. Results

Group level descriptive statistics are presented in Tables 1, 2 and Table 3 present individual level descriptive statistics for objective sleep measures and OURA scores, respectively. Results of the mixed model are presented in Table 4. REM Sleep Duration reported the greatest within subject correlation, while total sleep had the lowest. A statistically significant relationship was noted between both the presence ($p=0.012$) and duration ($p<0.001$) of a nap and total sleep duration. Specifically, on average the total sleep duration on nights after a nap was about 18.4-minutes shorter than nights when no nap was taken. Additionally, every one-minute increase in the duration of a nap saw a decrease in total sleep duration at night by 0.5 minutes. Similar associations were found between napping and light sleep duration, whereby the presence ($p=0.022$) of a nap decreased light sleep duration by 13-minutes and for every additional minute of napping ($p<0.001$) light sleep duration decreased by 0.4-minutes.

Table 1. Descriptive Statistics presented as mean ± SD for Objective Sleep Measures by Sleep and Nap

Metric	**Sleep**	**Nap**
Bedtime Start	10:04pm ± 3.7hrs	4:43pm ± 4.4hrs
Bedtime End	8:12am ± 2.9hrs	3:55pm ± 5.2hrs
Time in Bed (minutes)	453.3 ± 158.8min	32.27 ± 31.6min
Total Sleep Duration (minutes)	376.1 ± 134.3min	10.51 ± 21.9min
Awake Duration (minutes)	77.3 ± 37.3min	21.76 ± 16.2min
Efficiency (%)	81.52 ± 8.8	23.54 ± 21.3
Deep Sleep Duration (minutes)	119.99 ± 48.3min	4.32 ± 12.7min
Light Sleep Duration (minutes)	203.0 ± 83.6min	5.54 ± 10.2min
REM Sleep Duration (minutes)	53.07 ± 34.1min	0.65 ± 3.0min
Sleep Midpoint (minutes)	198.34 ± 101.5min	12.69 ± 15.6min
Sleep Onset Latency (minutes)	9.91 ± 8.6min	3.03 ± 7.1min
Got ups	0.10 ± 0.32	0.01 ± 0.09
Wake ups	10.08 ± 4.5	0.08 ± 0.44
Average Heart Rate (beats/min)	57.45 ± 6.4	67.31 ± NA
Heart Rate Variability (ms)	91.06 ± NA	62.3 ± NA
Lowest Heart Rate (bpm)	51.01 ± 7.1	65.6 ± NA
Average Breath	16.5 ± 0.90	16.65 ± 1.2
Average Breath Variation	2.99 ± 0.54	3.08 ± 0.34

Table 2. Descriptive Statistics presented as mean ± SD for Objective Sleep Measures by Participant and Sleep Type

	Participant 1		**Participant 2**		**Participant 3**	
Metric	Sleep	Nap	Sleep	Nap	Sleep	Nap
Bedtime Start	10:48pm ± 3.4hrs	4:20pm ± 4.2hrs	12:08am ± 1.6hrs	4:34pm ± 4.5hrs	8:53pm ± 3.9hrs	4:10pm ± 4.2hrs
Bedtime End	8:48am ± 2.8hrs	5:31pm ± 5.2hrs	8:03am ± 2.1hrs	5:46pm ± 5.7hrs	7:50am ± 3.2hrs	5:08pm ± 4.5hrs
Time in Bed	489 ± 142.4min	33.73 ± 31.0min	475.2 ± 81.1min	36.7 ± 41.8min	422.6 ± 179.7min	28.11 ± 26.2min
Total Sleep Duration	409 ± 121.5min	11.32 ± 23.4min	403.1 ± 65.3min	8.3 ± 22.9min	345.5 ± 150.2min	10.39 ± 19.0min
Awake Duration	79.92 ± 38.0min	22.42 ± 14.7min	72.03 ± 31.7min	28.37 ± 24.3min	77.1 ± 38.2min	17.72 ± 11.7min
Efficiency	82.97 ± 7.9	22.47 ± 22.4	85.12 ± 4.9	14.5 ± 14.0	79.45 ± 9.7	29.3 ± 20.8
Deep Sleep Duration	108.7 ± 39.9min	4.49 ± 11.5min	153.9 ± 26.1min	4.87 ± 19.1min	117.4 ± 53.8min	3.84 ± 10.4min
Light Sleep Duration	227.5 ± 79.7min	5.84 ± 11.4min	222.7 ± 53.2min	3.09 ± 6.3min	180.4 ± 87.6min	6.26 ± 9.9min
REM Sleep Duration	72.78 ± 35.0min	0.99 ± 3.6min	26.59 ± 19.6	0.365 ± 2.6	47.66 ± 29.1min	0.30 ± 2.0min
Sleep Midpoint	228.7 ± 85.5min	13.7 ±15.4min	191.9 ± 97.7min	12.19 ± 18.7min	179.6 ± 107.7min	11.46 ± 14.2min
Sleep Onset Latency	8.75 ± 8.5min	2.59 ± 6.2min	14.27 ± 10.4min	2.14 ± 7.3min	9.39 ± 7.6min	4.08 ± 8.0min
Got ups	0.143 ± 0.4	.015 ± 0.12	0.04 ± 0.2	0.008 ± 0.09	0.89 ± 0.3	0 ± 0.0
Wake ups	11.2 ± 4.3	0.09 ± 0.5	8.88 ± 2.8	0.06 ± 0.34	9.67 ± 5.0	0.06 ± 0.43
Average Heart Rate	63.80 ± 4.22	74.16 ± NA	49.32 ± 3.7	59.24 ± NA	55.6 ± 3.7	61.17 ± NA
Heart Rate Variability	42.11 ± NA	37.54 ± NA	214.4 ± 31.8	138.6 ± NA	87.06 ± 21.0	69.47 ± NA
Lowest Heart Rate	57.73 ± 4.5	72.44 ± NA	41.78 ± 2.7	57.18 ± NA	49.22 ± 4.9	59.61 ± NA
Average Breath	17.34 ± 0.66	17.37 ± 0.80	15.45 ± 0.68	15.53 ± 0.84	16.24 ± 0.52	16.23 ± 0.57
Average Breath Variation	2.83 ± 0.32	3.00 ± 0.60	3.25 ± 0.28	3.34 ± 0.51	3.02 ± 0.31	3.06 ± 0.42

Table 3. Descriptive Statistics presented as mean ± SD of OURA Scores at the Group and Individual level

Metric	Group	Participant 1	Participant 2	Participant 3
Overall Score	72.25 ± 8.1	74.37 ± 8.85	67.55 ± 6.15	72.37 ± 7.31
Alignment Score	76.2 ± 30.04	71.36 ± 30.89	93.00 ± 34.54	87.1 ± 21.91
Deep Sleep Score	94.42 ± 11.2	89.26 ± 15.66	98.92 ± 2.47	96.66 ± 6.95
REM Sleep Score	46.77 ± 23.6	61.49 ± 22.03	20.77 ± 15.29	45.12 ± 17.87
Latency Score	77.42 ± 12.6	74.8 ± 11.84	79.04 ± 16.72	78.79 ± 11.02
Efficiency Score	79.22 ± 11.5	81.12 ± 11.33	83.44 ± 11.37	76.28 ± 10.98
Total Sleep Score	70.64 ± 25.0	75.07 ± 16.32	65.86 ± 14.58	69.05 ± 13.08
Disturbances Score	67.76 ± 7.4	69.02 ± 5.79	71.57 ± 6.38	65.44 ± 7.97

Table 4: Mixed Model Regression Results

		Presence of Nap		Duration of Nap	
	ICC	Estimate	p-value	Estimate	p-value
Total Sleep	0.098	-18.424	0.012	-0.484	<0.001
Deep Sleep	0.293	-4.280	0.239	-0.043	0.481
Light Sleep	0.164	-12.864	0.022	-0.398	<0.001
Awake	0.164	-5.054	0.142	-0.109	0.060
REM	0.360	-1.398	0.594	-0.046	0.298

4. Discussion

This case study described the sleep and nap behavior of Division 1 student-athletes while also examining the relationship between nap presence and duration, and nocturnal sleep. The primary finding was that both the presence and duration of a nap significantly impacted total sleep time. Additionally, the presence and duration of naps specifically altered sleep architecture. Finally, the participants displayed sub-optimal sleep duration and quality. These findings suggest that student-athletes' nap behaviors detract from their nocturnal sleep, thus potentially interfering with psychophysiological recovery, as well as academic and athletic performance.

Athletes commonly nap to increase the amount of sleep obtained in a 24hr cycle, with the perception that this may reap recovery and performance benefits (Lastella, Roach, Halson, & Sargent, 2015). However, this case study indicated that the presence and duration of a nap significantly detracts from nocturnal sleep. Specifically, total sleep duration on the night that a nap was present was 18-minutes shorter than when a nap was not taken. Furthermore, every one-minute increase in the duration of a nap (beyond 15-minutes) led to the total sleep duration that night decreasing by 0.5-minutes. Hypothetically, a 90-minute nap may take 37 minutes away from nocturnal sleep. Given that a typical sleep cycle lasts approximately 90-minutes (Fullagar et al., 2015b), a long nap can potentially interfere with the makeup of a sleep cycle and the phases of sleep within it. Additionally, we report that participants took naps on average at 4:43pm, which can be considered too late in the day (Lastella, Halson, Vitale, Memon, & Vincent, 2021). Given the average nap duration was 32-minutes, it is likely that the proximity of the nap to nocturnal sleep is the cause for diminished sleep duration. This reduction in total sleep duration may detract from non-REM phase of sleep, resulting in inadequate time for protein synthesis which is critical for the repair of muscle damage in athletes (Fullagar et al., 2015a; Fullagar et al., 2015b). Such sleep disruptions may also interfere with REM sleep, which is suggested to be critical for memory consolidation (Fullagar et al., 2015b), which are imperative to student-athlete populations' academic performance. This suggests that naps, if not planned or executed appropriately, can interfere with more substantial and effective forms of recovery, being nocturnal sleep. Subsequently, best use of naps should be an educational priority for student-athlete cohorts.

The presence and duration of naps were also shown to influence the duration of the light sleep phase. Light sleep duration decreased by 13-minutes due to the presence of a nap, while each minute increase in nap duration reduced nocturnal light sleep by 0.4-minutes. The light phase of sleep is often mistaken to be unimportant, however it is a key stage of sleep that benefits the body and brain, comprising approximately 50-60% of total sleep duration (Neil P Walsh et al., 2021). Reductions in light sleep duration may limit memory consolidation and creative thinking (Lacaux et al., 2021) while also interfering with physical restoration (Fullagar et al., 2015a). Education as a catalyst for behavior change may be most beneficial for this cohort to ensure napping doesn't diminish nocturnal sleep opportunities and sleep architecture.

In addition to these findings, this case-study describes the sleep habits of student-athletes and is in agreement with existing literature that suggests athletes don't achieve adequate sleep duration (Neil P Walsh et al., 2021). It is hypothesized that athletes have a higher sleep drive due to their increased physical exertion, and in this cohort academic stressors (Halson, 2013; Lastella, Roach, Halson, & Sargent, 2015). Despite this, athletes of varying age and level of competition continue to report inadequate sleep. Furthermore, despite an average bedtime of 10:04pm, a standard deviation of 3.7hrs suggests poor sleep consistency. Smaller variations in bedtime and wake time (i.e., consistent sleep schedule) are critical in developing healthy sleep habits and ensuring adequate sleep quantity and quality is achieved (Halson et al., 2022). Ongoing sleep monitoring in the form of objective sleep monitoring or subjective sleep journal may assist athletes in optimizing their sleep schedule and maintaining schedule regularity.

While this case-study provided novel insight into the relationship between naps and nocturnal sleep of student-athletes, it has some limitations. With three total subjects, it is a small sample size. In addition, this is just a snapshot of student-athletes from one sport/team, and due to the individual nature of sleep and potential variance of training and academic schedules, these results may not be generalizable to a broader population.

5. Practical Applications

These results may help guide practitioners' educational interventions for student-athletes, placing an emphasis on how to best utilize naps to supplement nocturnal sleep. Practitioners may wish to advise student-athletes to avoid naps later in the day, limit naps to less than 90-minutes and only use them as a supplement to poor nocturnal sleep, rather than a replacement. In addition, general sleep education may assist in obtaining regular sleep/wake cycles to enhance sleep quantity and quality.

6. Conclusion

The current case-study showed that nap presence and duration can significantly impact the duration and architecture of nocturnal sleep within Division 1 student-athletes. In addition, this study provided further evidence of inadequate sleep duration among athletic populations, while also highlighting the individual nature of sleep.

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Authors' Contributions

RH, ML, FH, JR and AA participated in the design of the study and contributed to data collection. JL, MC and SC participated in data collation and reduction. JL, SC, AH, JPW and CJM participated in the data analysis, interpretation of results and production of the manuscript. All authors have read and approved the final version of the manuscript.

Data Availability

The data that support the findings of this study are available on request from the corresponding author (JL). The data are not publicly available due to their containing information that could compromise the privacy of research participants. Data will be made to reasonable requests following permission being provided by the institution.

Ethical Approval

This project was approved by the university ethics committee (24-03-8448).

Appendix 1. Definitions of sleep and OURA Score variables included in the analysis.

Sleep-Based Variables		OURA Scores	
Variable	**Definition**	**Variable**	**Definition**
Bedtime Start	Time of sleep onset	Overall Score	Contributed to by each of the below scores
Bedtime End	Time of wake onset	Score Alignment	Compares the period of time that you were asleep with nature's 24-hour circadian cycle
Time in Bed	Total time spent in bed, including both sleep and wake duration	Deep Sleep Score	Measures the percentage of time spent in Deep Sleep
Total Sleep Duration	Total amount of sleep (REM + light + deep) registered during the time in bed (period between light-off and lights-on)	REM Sleep Score	Measures the percentage of time spent in REM
Awake Duration	Duration of wakefulness occurring after sleep onset	Disturbances Score	A measure of how soundly you slept through the night.
Efficiency	Percentage of total sleep time over total time in bed; calculated as TST/TIB	Efficiency Score	Time asleep compared to time awake
Deep Sleep Duration	Total minutes spent in deep sleep	Latency Score	The time it takes to fall asleep
Light Sleep Duration	Total minutes spent in light sleep	Total Sleep Time Score	Total sleep time for last night, compared with the recommended total sleep time for a person the same age
REM Sleep Duration	Total minutes spent in REM sleep		
Sleep Midpoint	The median point of the total sleep duration		
Sleep Onset Latency	Detected latency from lights-off to the beginning of the first five minutes of persistent sleep		
Restlessness	Movement detected during sleep		
Heart Rate	Frequency of the heartbeat measured by number of heartbeats per minute (BPM)		
Heart Rate Variability (HRV)	Degree of fluctuation in time between successive heartbeat		
Lowest Heart Rate	Minimum heart rate recorded during a specific period of time		
Average Breath	Rate of one cycle of air inhalation and exhalation		
Average Breath Variation	Degree of fluctuation in breathing pattern over a specific period of time		

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