DIFFERENCES IN SLEEP QUALITY IN COMPETITIVE YOUTH ATHLETES DURING AND AFTER THE COMPETITIVE SEASON

A Thesis
by
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Abstract

DIFFERENCES IN SLEEP QUALITY IN COMPETITIVE YOUTH ATHLETES
DURING AND AFTER THE COMPETITIVE SEASON

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Purpose: Our study investigated the differences in sleep architecture and health in and out of a competitive season in tumbling and trampoline and diving. **Methods:** Nine competitive youth athletes between the ages of 12 and 16 who compete for either the tumbling and trampoline team or the diving team and who train for an average of 10 hours a week, were recruited for this study. Sleep data was collected for 3 consecutive nights during competition and for 3 consecutive nights during post season. Data were then analyzed using the Sleep Profiler™ scoring software. All data are expressed as Mean ± SEM. **Results:** Mean nocturnal pulse was statistically higher during in season versus post season ($p = 0.049$; 66.8 ± 9.6 bpm in season versus 61.7 ± 6.3 bpm post season). Sleep efficiency, wake after sleep onset (WASO), and spindle duration were similar during in season and post season. Sleep latency, rapid eye movement (REM), and non-rapid eye movement (NREM) sleep though not statistically different from in season to post season have a strong correlation. **Conclusion:** These data demonstrate a significant decline in mean heart rate when an athlete moves from competition season to the non-competitive season. These data show that gymnastic training in addition to competition training may lead to unwanted cardiovascular changes. Future studies should elucidate the impact and volume of training a youth athlete undertakes and the benefits and risks on physiological and psychological well being.

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Lastly I would like to thank my friends. Our friendship will always be something I value and could not have made it through these years without your support. The memories we have made will be cherished beyond our time at Appalachian.

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Foreword

This thesis will be submitted to Medicine & Science in Sports & Exercise, an international peer-review journal owned by the American College of Sports Medicine, and published by Lippincott Williams & Wilkins; it has been formatted according to the instructions to authors for that journal.

Introduction

Sleep is a natural recurrent suspension of consciousness used by the body to restore itself through muscle repair, the release and regulation of hormones, as well as memory solidification (1). Insufficient sleep may result in inadequate time to complete muscle repair, memory strengthening, and the release of growth hormones (1). Sleep is regulated by the body's sleep-wake homeostasis, which tracks the body's need for sleep (2). This homeostatic drive for sleep reminds the body to sleep and controls the intensity of sleep based on the number of hours awake since the last sleep cycle (2).

Sleep architecture follows an alternating pattern between non-rapid eye movement (NREM) and rapid eye movement (REM) sleep, and repeats itself roughly every ninety to one hundred and ten minutes (3). During sleep, we spend about 75% of the time in NREM sleep and the other 25% in REM sleep. The cycle follows a natural progression of NREM stages 1-3 and then REM sleep. NREM is divided into three stages with stage 1 (N1) being the lightest form of sleep, stage 2 (N2) being the onset of sleep, and stage 3 (N3) the deepest sleep (3). When falling asleep, we first enter N1 and then N2 sleep. During N2 we begin to disengage from our surroundings, breathing and heart rate become regular, and our body temperature decreases (3). Upon entering N3, the deepest and most restorative form of sleep, blood pressure drops, breathing slows, muscles relax, tissue growth and repair occurs, energy is restored, and hormone release increases (3). REM sleep follows N3, usually 70 to 90 minutes after initial sleep onset and lengthens throughout the night (3). Unlike N3, REM is characterized by an increased, irregular, and shallow breathing pattern, rapid and jerking eye movement, temporary limb paralysis, and increased blood pressure (1, 3). Insufficient sleep has been widely reported to negatively alter not only mental and emotional health, but long-term physical health (4). For an athlete, both physical and mental performances are of great importance, making good quality sleep a necessity (5).

Both sleep quality and quantity are important, affecting most aspects of daily functioning from physical appearance, wellbeing and task performance (3). Considering sleep affects both physical and mental health, it can greatly impact overall quality of life. Recommendations for sleep quantity are age-dependent. Adolescents require an average of nine hours of sleep per night, although 87% of adolescents are estimated to receive less (3,6). Sleep quality directly influences cardiac activity and insufficient sleep manifests as sympathetic up-regulation on cardiovascular tone.

Cardiac activity is controlled by our central nervous system, which controls heart rate and its variability (7). There is a bidirectional relationship between sleep and our autonomic nervous system (ANS); autonomic changes can alter sleep regulation and sleep disturbances can alter cardiac autonomic modulation (8).

Athletes experience three main challenges to their sleep; training, travel, and competition (9). These three factors interfere with an athlete's ability to maintain a consistent sleep schedule as they can induce stress and cause poor cognitive and emotional responses putting them at risk for sleep disturbances (10). Due to the nature of an athlete's life revolving around the training/competition cycle, they are exposed to an increased risk of disrupted sleep and characteristics of insomnia. The current literature reinforces that elite athletes experience a high amount of sleep disturbances characterized by longer sleep latencies, non-restorative sleep, higher sleep fragmentation, and exaggerated daytime fatigue (9). In general, elite athletes experience high levels of insomnia symptomology with a notable difference between type of sport, with individual sports reporting the highest level of sleep disturbances (9).

The demanding requirements for year round training can lead to overtraining as well as an increased risk of overuse injuries. As much as 50% of injuries seen in pediatric sports medicine are due to overuse, therefore the appropriate amount of quality sleep is imperative for the body's natural recovery process (11).

The National Council of Youth Sports survey found that in the United States in 2014, over 60 million children, ages 6 to 18, participated in organized sports and 44 million of those children participated in more than one sport (12). With many children participating in organized sports in addition to school and home-life responsibilities, it is of considerable importance to gain a better understanding of their sleep and the implication of sports on sleep. There is currently paucity of quantitative literature available investigating changes in sleep architecture and sleep quality in a student athlete population that examines the influence of competition and training on sleep in adolescent athletes. It is important for us to elucidate if excessive athletic stress that youth competitive athletes often experience is affecting their sleep. Overtraining is a combination of hormonal, psychological, physiologic changes that result in a decreased sports performance (11). Over-trained elite youth athletes are more at risk for upper respiratory track infections, sleep disturbances, muscle soreness, loss of appetite, and anxiety and depressive symptoms (13).

The present study aimed to investigate the seasonal variation of sleep during and out of competition in young athletes. This will help advance an understanding of the differences present in sleep architecture resulting from combined competition and training versus training only in young athletes. It was hypothesized that sleep quality would decrease during their competitive season versus out of competition season, in the same individual.

Methods

Subjects. Nine competitive youth athletes between the ages of 12 and 16 who compete for either the tumbling and trampoline team or the diving team were recruited from a competitive gym in central North Carolina for this study. Subjects were excluded from this study is they were unable to wear the sleep equipment for all six nights; three night during the competitive season and three nights in the non-competitive season. A power calculation was done post-hoc using mean pulse as the outcome variable with an alpha set at 0.05, beta at 0.02, and a sample size of 9 to give a power of 0.8.

Procedure. All experimental procedures were approved by The Appalachian State University IRB. All nine subjects completed the sleep architecture data collection for the total six nights. During visit 1, subjects reported to the gym, where subjects and their parents voluntarily signed written informed consents, were familiarized with the Sleep Profiler™ and were given instructions to maintain their regular sleep routine before taking the ambulatory sleep equipment home. Based on unpublished data demonstrates that the 3^{rd} night of 3 consecutive nights using the Sleep Profiler™ is the most reliable and indicative of baseline values. Therefore, subjects wore the Sleep Profiler™ for three consecutive nights, Thursday through Saturday, in their own home. After the three consecutive nights of sleep monitoring, the subjects reported back to the gym for equipment retrieval. Data was downloaded from the equipment, stored on a computer and analyzed using the Sleep Profiler™ software. This procedure was repeated during the athlete's non-competitive (training only) season.

Treatment of Data. All data were analyzed for outliers via visual inspection, and descriptive statistics were determined for each category (SPSS, v.24, Chicago, IL, USA). Sleep data were analyzed using a paired samples student t-test (pre-, post-) to determine any differences in group measures. Paired samples correlations were run between pre- and post-variables.

Significance was set at $p \leq 0.05$, and all data are reported as mean ± standard error of the mean (SEM).

Results

Of the nine subjects who completed all 6 nights of data collection, there were 8 females and 1 male with a mean age of 13.7 ± 0.5 years.

Sleep efficiency, wake hours, sleep latency, stage 3 sleep latency, wake after sleep onset, movement arousals per hour, awakenings and spindle duration showed no significant differences between in season and post season (Table 1).

Table 1. Changes in SL, W, S3L, MA, Awks, SD, ST, and SN from the competitive season to the post season.

Season	SL (min)	W (hrs)	S3L (min)	MA/hr	Awks/hour	SD (min)	ST (hrs)	SN
In Season	9.6 ± 7.2	1.1 ± 0.5	14 ± 2.7	5.4 ± 1.0	4.3 ± 0.4	18.6 ± 5.6	7.1 ± 0.7	7.9 ± 4.8
Post Season	25.3 ± 7.8	0.99 ± 0.2	17 ± 6.4	3.9 ± 0.5	4.3 ± 0.6	15.1 ± 4.2	7.1 ± 0.4	3.3 ± 1.3

All data are reported as mean ± SE.

SL = sleep latency, W = wake, S3L = stage 3 latency, MA = movement arousals, Awks = awakenings, SD = spindle duration , ST = sleep time, SN = Snoring.

Mean pulse (bpm) during sleep was significantly higher during the competitive versus post season at 66.8 ± 9.6 bpm and 61.7 ± 6.3 bpm, respectively (Figure 1).

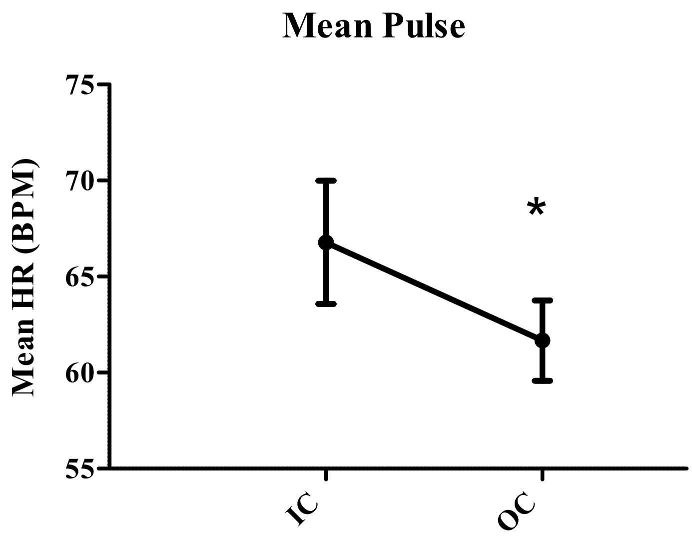

Figure 1 - Mean pulse during sleep for in season and post season. * denotes significance (p = 0.49).

Sleep efficiency of the athletes during in season and post season was similar at 86.4 ± 5.2 percent and 87.7 ± 2.4 percent, respectively (Figure 2).

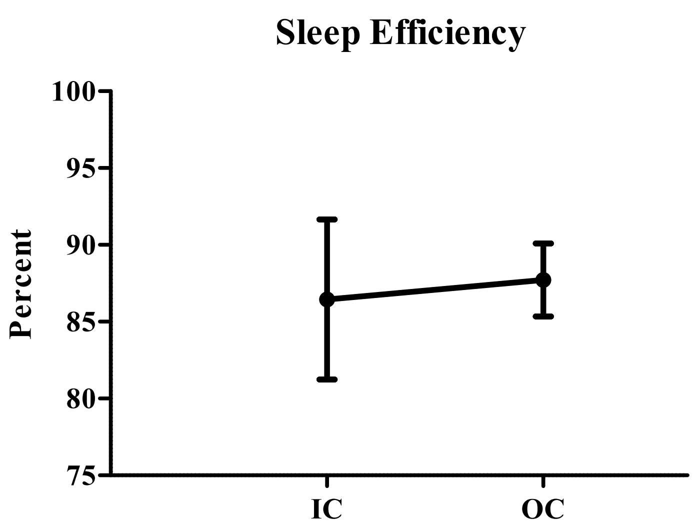

Figure 2 - Percent of sleep efficiency in season and post season.

Wake after sleep onset (WASO) was similar from in season and post season was 55.7 ± 79.7 minutes and 36 ± 27.9 minutes, respectively.

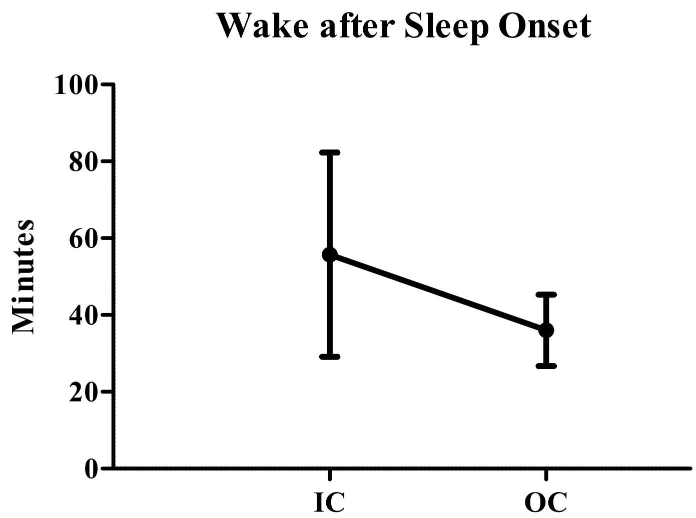

Figure 3 - Time in minutes of wake after sleep onset during in season and post season.

Hours of rapid eye movement (REM) sleep for in season and post season was 1.3 ± 0.8 hours and 1.1 ± 0.7 hours, respectively (Figure 4).

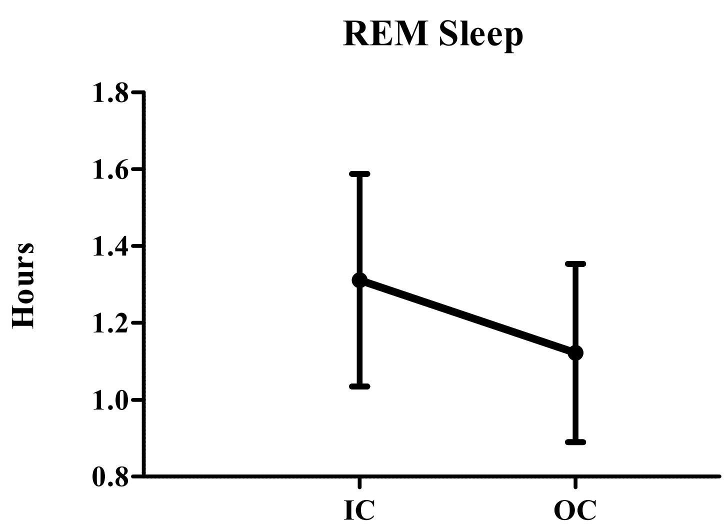

Figure 4 - Hours of rapid eye movement (REM) sleep during in season and post season.

Hours spent in each phase of non-rapid eye movement (NREM) sleep, N1, N2, and N3, during in season were similar at 0.5 ± 0.2 hours, 2.5 ± 1.2 hours, and 2.7 ± 0.8 hours, respectively. Hours spent in NREM phases N1, N2, and N3 during post season were similar at 0.5 ± 0.2 hours, 2.7 ± 0.9 hours, and 2.8 ± 1.1 hours, respectively (Figure 5).

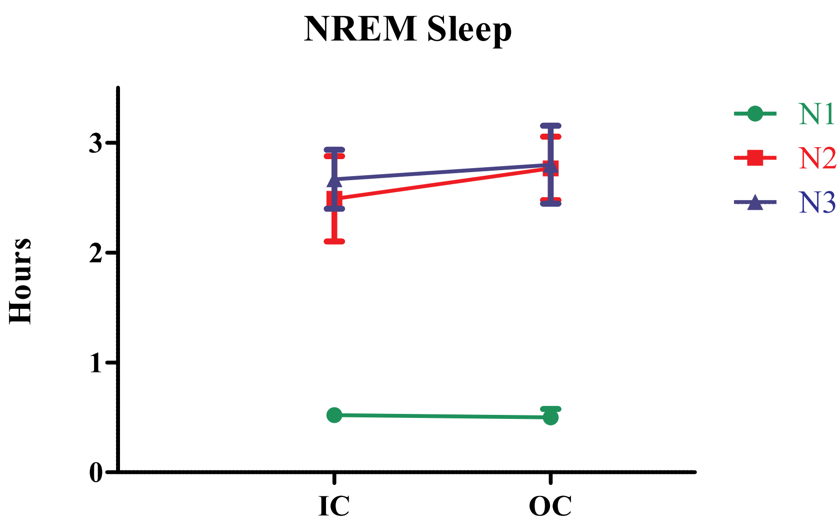

Figure 5 - Hours spent in non-rapid eye movement (NREM) sleep in season and post season.

Discussion

To this author's knowledge, this is the first study to examine the effects of in-season versus out of season training on adolescent athlete's sleep architecture within the subject's own bed. The main finding of this study was the significant increase in nocturnal heart rate by 5 bpm during the competitive season compared to the post season (see Figure 1). Gymnastics is a sport that presents characteristics of overtraining which in youth athletes presents with increased HR, fatigue, and immune dysfunction (14). Overtraining is defined as an imbalance between recovery and stress (15). Overtraining is characterized by both physiological and psychological symptomology with the five main signs being; alterations of the circulatory system, unexplained weight loss, excessive thirst, alteration of sleeping patters, and psychological unease (16). Exercise has been shown to improve both sleep quality and quantity, although too much exercise, overtraining, could lead to deleterious changes in sleep architecture (17, 18). With an increased nocturnal heart rate (HR) of 5 bpm being characteristic of the overtraining state, overtraining during the competitive season could be why a significant increase in resting HR was observe during the competitive season in the present study (16). Resting HR is a predictor of cardiovascular health (19). An increase in resting heart rate increases the likelihood of other risk factors such as cardiovascular disease (CVD), high blood pressure, metabolic syndrome, and all cause mortality (20). An increased resting heart rate over a prolonged period, such as a 6-month competitive season, may have a negative outcome on overall health. Long term sleep disturbances may lead to increased risk of CVD, hypertension, metabolic syndrome, and obesity (21).

HR is controlled by the ANS, with dual control via parasympathetic (PNS) and sympathetic nervous systems (SNS). HR is accelerated when the SNS releases catecholamines, epinephrine (epi) and norepinephrine (NE), and is slowed by the PNS when acetylcholine is released (22). During distress, the SNS dominates over the PNS due to increases in stress hormones like NE and cortisol which are released from the adrenal glands, and ultimately lead to an increase in both daytime and nocturnal HR which are indicative of heart health, the ANS, and hormone levels (23, 24, 25). Prolonged states of stress and associated high cortisol levels can lead to negative effects both psychologically and physiologically, including fatigue and depression (25). Cortisol acts as a vasoconstrictor and NE elicits increases in HR, together causing an increase in BP and potentially leading to deleterious long-term health issues (26). Prolonged elevations in cortisol levels have been correlated with decreased sleep quantity and quality, as well as with a chronic increase in HR. This may lead to a chronic strain on the cardiovascular system and increased cardiovascular risk and incidence of comorbidities including heart attacks and strokes (27, 28).

Sleep architecture differed from competitive season to post season, although values were not significant yet there was a trend in the data that suggested out of season athletes did not wake as much and had slightly more N3 sleep with slightly less N1, which is indicative with better quality sleep architecture. This shift could be the result of overtraining from the 10 hours of training per week done by the athletes (29). When there is an imbalance between competition, training, and recovery overtraining can occur (30). This population has to balance competition, 10 hours of training a week, and recovery in addition to the demands of school, homework, family responsibilities, and social lives.

Another novel finding of this study was sleep onset latency (SOL) was shorter, although not statistically significant, during the competitive versus post season, with an SOL of 9.6 ± 7.2 minutes and 25.3 ± 23.3 minutes, respectively. When appropriate sleep is not being reached, SOL can be shortened from a normal time of approximately 15 minutes (31, 32). The restorative properties of good quality and quantity sleep for maintaining homeostasis and bodily functioning are well recognized. We see the relationship between sleep quality and quantity with sleep efficiency and SOL. When SOL is delayed, shortened, or when it's difficult to stay asleep it can lead to a lessened sleep efficiency (32).

Sleep efficiency shows the ratio between the time spent in bed and the time spent asleep (32). This study did not show a significant difference in sleep efficiency between competitive and post season, being close to normal values of 85-90%, and WASO, though not significant, was higher during the competitive season (32). WASO indicates any awakenings after SOL and should comprise ≤ 30 minutes of a person's total time during sleep at night to be considered normal, with higher values indicative of disrupted sleep (33). This study showed WASO to be shorter post season versus the competitive season with values of 36 ± 27.9 and 55.7 ± 79.7 minutes, respectively. Both values are higher than normal, but the competitive season is almost double the normal values, potentially resulting from increased stress during the competitive season. Sleep quality and quantity can be impacted by training schedules, travel, and pre-competition anxiety (34). Although stress and anxiety of the athletes was not measured in the present study, previous research has shown that competitive sport can induce a stress response, especially in those with anxiety, which may prompt overtraining (35).

Sleep efficiency can also be affected by snoring, which is considered an abnormal sleep phenomenon and is usually characteristic of increased upper airway resistance (36). Upper airway resistance is turbulence in the upper airway that occurs because of a decrease in airway diameter (37). Snoring is defined as “loud upper airway breathing, without hyperventilation or apnea, caused by vibrations in the pharyngeal tissues” by The American Sleep Disorders Association (ASDA) (38). Snoring is considered to be the first symptom of upper airway dysfunction, which can lead to sleep apnea (38). If left unresolved, snoring can lead to apnea and CVD (39). This study showed athletes snored more during the competition season, although not significant, than they did during the post season with snoring at 7.9 ± 4.8 percent and 3.3 ± 1.3, respectively.

A further consideration of sleep efficiency are sleep spindles, characteristic of NREM, predominantly in stages N2 and N3 (40, 41). Sleep spindles are thought to assist in several sleep functions, like cortical development and development of memory (40). Spindle duration is indicative of the amount of time spent in N2 sleep, making it a part of total sleep time and sleep efficiency. When reduced, individuals are more likely to experience insomnia symptoms, particularly when stress is a factor (40, 42). Although this study showed no significant differences in NREM, there was a non-significant decrease in REM from the competitive season to the post season. REM sleep is characterized by rapid eye-movements, skeletal paralysis, and dreams. REM sleep is critical for providing energy and for daytime performance, which is crucial for competitive athletes (3).

The National Sleep Foundation recommends an average of 9-11 hours of sleep for children, ages 6 to 13 and 8-10 hours of sleep for adolescents ages 14-17 (43). Athletes in the present study slept 7.1 ± 0.7 hours during the competitive season, not meeting the recommended sleep time average. Sleep duration and health have a bidirectional relationship with insufficient sleep playing a role in the development of several health conditions including, hypertension, cardiovascular disease (CVD), diabetes, and increased all cause mortality (44). Although sleep was similar between in season to post season, (7.1 ± 0.7 hours and 7.1 ± 0.4 hours), athletes did not meet the recommended amount of nightly sleep during either season.

In conclusion, the present study is of the first data characterizing sleep in this population with the main finding being that sleep is potentially a predictor of overall health and risk factors. This study also indicates that during competitive season, adolescent athletes realized a 5 bpm increase in HR throughout the night, which may be considered detrimental since the systemic arterial circuitry is not realizing a drop in nocturnal BP. An increase in nocturnal HR and a decrease in N3 sleep may also impair hormone secretion (45).

Limitations of this study include a small sample size and that there was no measurement of stress and/or anxiety experienced by the athletes. Future research should consider incorporating measurement of overtraining and psychological characteristics associated with overtraining when comparing sleep across competitive seasons, such as psychological unease and changes to the cardiovascular system. Future research should recruit a larger sample size to account for sex and sport differences, as well as considering training volume and time.

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Vita

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