SPECIAL ISSUE ARTICLE

The Value of Sleep on Athletic Performance, Injury, and Recovery in the Young Athlete

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ABSTRACT

Adequate sleep can easily become compromised as student-athletes try to balance the multiple demands on their time. People with sleep deficiency are at increased risk for acute illnesses, traumatic sports injuries, and development of chronic diseases. Training sessions or competitions during extremely early or late hours can interfere with circadian and homeostatic rhythms. Adjusting the training schedule to improve sleep duration has a significantly positive impact on several aspects of athletic performance. Pediatricians should increase the time dedicated in well-child visits for sleep hygiene and evaluate for sleep disorders at all ages. Parents, coaching staff, teachers, and pediatricians should advocate for improved education on the importance of sleep during adolescence. Future sleep research specific to adolescent athletes can further delineate requirements specific to sport, gender, training times, and surrounding competitions. **[*Pediatr Ann*. 2017;46(3):e106-e111.]**

Healthy sleep patterns are intimately related to "cognitive performance (learning, memory, decision-making, vigilance), physical health (healing, recovery, metabolism, muscle growth, weight control), and mental health (stress/anxiety, mood/depression, emotional control)."[1] However, sleep is often sacrificed in favor of completing the numerous tasks in our busy lives. Pediatricians are well-versed in the safe sleep initiative during the first year of life, educating families about back to sleep practices. The American Academy of Pediatrics (AAP) also has a guide for children age 6 months to 6 years titled *Brush, Book, Bed*[2] to aid discussions with new parents about regular pre-sleep routines and introducing sleep hygiene at an early age. Although recent AAP recommendations[3] for older children provide guidance regarding the optimum quantity of sleep, there is not a similar program to address adolescent sleep habits, and specifically one that outlines sleep recommendations for different patient populations such as athletes. Sleep duration among adolescents has declined over time. In 1975, adolescents reported 1.5 fewer hours of sleep per night compared to adolescents in 1910.[4] Due to overscheduling, the adolescent athlete today is at an even greater risk of sleep deprivation. In fact, student-athletes surveyed report 2 fewer hours of sleep each night compared to nonathletes.[5] This article outlines the current recommendations for and basic physiology of sleep, reviews the implications of sleep deprivation in student-athletes, and provides practical suggestions for pediatricians caring for this patient population.

GENERAL SLEEP RECOMMENDATIONS

The AAP, the Sleep Research Society, and the American Association of Sleep Technologists support the American Academy of Sleep Medicine's consensus guidelines for pediatric sleep.[6] The guidelines recommend that elementary school children (age 6-12 years) and adolescents/teenagers (age 13-18 years) achieve sleep goals of 9 to 12 hours and 8 to 10 hours, respectively, of sleep per night.[6] However, in reviewing sleep patterns, quality of sleep is just as important as quantity, and this includes appropriate sleep architecture,

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circadian and homeostatic rhythms, and evaluation for underlying sleep conditions.[6]

SLEEP PHYSIOLOGY AND ARCHITECTURE

Circadian rhythms refer to physiological changes that occur over an approximately 24-hour period and are influenced by environmental cues such as exposure to light and dark,[4] whereas homeostatic sleep is an internal drive associated with time since last sleep and that compensates if a person is experiencing sleep deprivation.[4] Each component of healthy sleep can be affected by a person's genetics, behavioral patterns, medical history, and environmental influences.[6]

The architecture of sleep cycles is studied using polysomnography and is divided into two main stages: non-rapid eye movement (NREM) sleep and rapid eye movement (REM) sleep.[7] NREM is dominated by parasympathetic input and further divided into three parts.[4] The period of REM sleep is dominated by the sympathetic nervous system and is characterized by desynchronized electroencephalogram EEG activity, loss of muscle tone, and rapid eye movements.[4]

Through the night, healthy humans complete one NREM–REM sleep cycle approximately every 90 minutes for a total of 5 to 6 cycles per night.[4,8] Yet, the composition of stages within each cycle varies with age and as the night progresses.[7] Young children spend approximately equal parts in REM and NREM, and during NREM they spend a higher percentage in stage 3 rather than stage 2 compared to adolescents.[4] Stage 3 is the dominant component at the beginning of the healthy adolescent's initial sleep cycle,[7] whereas stage 2 and REM sleep dominate the latter half of nightly sleep cycles.[8] REM sleep has wave forms similar to the awake brain and therefore is suggestive of a period of memory consolidation that would be especially important for motor learning in the student-athlete.[5] The sleep spindles of NREM stage 2 are associated with memory consolidation, and the frequency increase seen during adolescence is suggestive of cortical myelination.[7] The sleep-wake cycle matures as other pubertal changes occur, resulting in a faster maturation of sleep cycles in adolescent girls compared to boys.[8]

Several studies have shown that circadian rhythms cause variations in hormones, gene expression, and core body temperature, and have a direct influence on several elements relevant to sports performance, including muscle strength, flexibility, sensory and motor control, and perceptual and cognitive function, creating peak performance times.[9] However, individual circadian preferences (ie, morning-type or evening-type chronotypes) can differ for each athlete.[9]

IMPACT OF SLEEP REDUCTION

Current data from the US Centers for Disease Control and Prevention estimate that approximately 70% of American high school students obtain fewer than 8 hours of sleep per night,[4] which means that the majority of American adolescents are functioning at a baseline of sleep reduction, defined as truncation of sleep at the beginning or end of the night. The adolescent period is a vulnerable time for brain development,[8] and maladaptive sleep can lead to poor long-term outcomes. Sleep effects many physiological components that are a crucial part of biological homeostasis, including the immune system, core body temperature regulation, cardiovascular and respiratory functions,[8] cognitive capacity, glucose metabolism, and appetite regulation.[10] Some studies have shown that even low levels of fatigue can impair reaction times as much, if not more, than having a blood alcohol level above the legal limit for driving a car.[11] Of note, studies on rodents and flies have shown that death due to sleep deprivation occurs sooner than death due to food deprivation.[8] After sleep reduction, plasma levels of interleukin-6 and tumor necrosis factor-alpha are increased, establishing a proinflammatory state.[5] This has the potential to affect a person's resilience against simple respiratory infections and hinder an athlete's school attendance and training potential. Attempts to study plasma cortisol concentration in association with sleep reduction have been inconclusive because its levels vary with time of day, intensity of exercise, and duration of training.[5] The effects of sleep reduction commonly seen in athletes include decreased reaction time, increased errors in pressure or time-sensitive situations, and reduced ability to understand, retain, and implement training or game strategies.[5]

TRAINING SCHEDULES

Circadian rhythm patterns vary, with some people being more alert in the morning and some more alert in the evening, which means an ideal training time for one person may not be ideal for another.[12] Adolescents are unique because they more frequently experience a delay in circadian rhythms due to a desire to push back time of sleep onset and prolong morning arousal.[7] The theories that have been proposed to explain the prolonged sleep latency seen during

puberty include variable intrinsic circadian rhythms, pubertal hormonal changes, and increased sensitivity to evening lights, which is particularly harmful for people using a computer or cell phone screen near bedtime.[4]

Unfortunately, this knowledge has not affected the start time of morning training sessions or school classes.[7] In fact, most school systems in the United States start earlier with each increasing academic level, leading to an inverse in class start times that results in about 90 minutes of cumulative sleep lost per evening between 6th and 12th grade.[7] For swimmers, hockey players, rowers, or triathletes, who have traditionally practiced before school begins, this results in even worse sleep reduction than baseline adolescent behavior described earlier. Other sports, such as basketball, traditionally have night games that delay the athletes' sleep onset because of physiological arousal.[5] Late night training sessions are also associated with increased hydration close to bedtime, which often results in awakenings during the night for urination.[10] Late afternoon training sessions are preferable, as they allow for delayed wake times and cause fewer disruptions in the adolescent circadian rhythm. Previous reports suggest athletes tend to experience lower quality sleep immediately prior to large competitions,[13] but long-term sleep quality or duration across an athletic season or academic year has not been studied. The adults involved in planning youth sports practices and competitions should create schedules that allow for appropriate rest and recovery time between sessions to prevent cumulative sleep loss.

Sleep duration is significantly decreased on both training and non-training days when practices routinely take place between 6 am and 8 am.[14] Sargent et al.[10] evaluated Australian elite swimmers' sleep quantity during a 2-week high-intensity training period and found average sleep duration of 5.4 hours on training days and 7.1 hours on rest days. On nights prior to training days the swimmers adjusted with earlier bedtimes, but this action alone did not fully compensate for total sleep loss because they took longer than normal (ie, 20 minutes) to fall asleep on these nights. In adults, sleep efficiency (percentage of time asleep with respect to time in bed[4]) is typically 90%, whereas the average sleep efficiency for the swimmers in this study was 77% on nights before rest days and only 70% on nights before training days.[10] Daytime naps were used by many swimmers in this study to increase the quantity of sleep in 24 hours,[10] and prior research has shown napping can also aid in sleep deprivation recovery.[14] Adolescents are often involved in multiple sports, resulting in cumulative sleep deprivation secondary to athletic training schedules throughout the academic year.

TRAVELING ACROSS TIME ZONES

Athletes are also traveling farther and more frequently for tournaments, and in some cases across time zones, which has effects on the circadian rhythm. Jet lag symptoms, most often seen after crossing two or three time zones, typically include mental and physical fatigue, reduced motivation, decreased/altered appetite, confusion, dizziness, irritability, and constipation,[5] all of which have the possibility of affecting athletic performance and require at least 1 day for each time zone crossed for full resolution.[15] A cluster of irregular cognitive, emotional, and physical performance continues until a person has resynchronized circadian rhythm to local time.[15] It has been noted that even core body temperature associated with circadian rhythms has a prolonged transition after traveling across time zones, and as a result, some have attempted to overcome core body temperature variation by increasing the intensity or duration of athletic warm-ups.[15] Training times for the visiting team can also be adjusted to facilitate the transition to the destination time zone.[15] For example, teams traveling east may benefit from start times consistent with their original time zone training schedule, although when teams travel from west to east for a late night game, it is possible that the visiting athletes are competing at their daily peak performance associated with the origin's late afternoon timing.[15] Athletes are less affected by westward travel, as human circadian rhythm is adjustable because it is based on a 25-hour baseline rhythm.[15] Additional environmental disruptions, such as changes in diet and meal times or other psychosocial life changes that can accompany travel, can add to the disruption of integration between the endogenous circadian clock and metabolic processes.[10]

EMOTIONAL IMPACT OF ATHLETIC COMPETITION

Juliff et al.[13] evaluated the subjective impact an upcoming important competition had on an athlete's sleep. In this study of Australian athletes age 16 to 47 years, an astounding 64% of athletes had difficulty sleeping the night prior to competition. The most common reason for sleep difficulty was related to ner-

vousness, and although coping strategies were used more by "individual sport" athletes rather than by those in "team sports," it still varied between people.[13] Education regarding coping strategies could help athletes appropriately manage heightened periods of stress around important competitions and implement a routine maintenance program aimed at minimizing crisis situations.

INJURY

A sports-related injury, the most common cause of injury in the school-age population,[16] can range from acute season-ending or career-ending trauma to repetitive microtrauma (ie, overuse). Adolescent athletes who slept on average fewer than 8 hours per night were 1.7 times more likely to have had an injury compared with athletes who slept for 8 hours or more.[17] A separate study revealed that injury rates in youth athletes increased during games that followed a night of fewer than 6 hours of sleep.[16] When athletes are fatigued more quickly, not only is there an increase in the potential for injury, there is also an increase in the number of decision-making errors and training errors.[5] These additional errors also independently increase the risk for injury. This has a great impact on our youth, as approximately 60 million of them age 6 to 18 years participate in organized athletics, and each year more than 3.5 million young children and an additional 2 million high school students present for medical treatment of sports-related injuries.[18]

Studies have shown that sleep is one of the best forms of recovery available for the elite athlete, and therefore is assumed to play an important role in youth athlete recovery as well as safety, especially after taking into account their chronic sleep deprivation.[14] During NREM sleep, the pituitary gland secretes growth hormone, which plays a substantial role in tissue regeneration and repair from daily use. NREM sleep is also associated with decreased oxygen consumption, building proteins, and transporting free fatty acids, the combined effects of which have the potential to accelerate healing.[5] In addition, fit adolescents often experience an increased percentage of slow wave sleep and longer average sleep duration than their peers who are not fit,[5] thereby theoretically providing an increased recovery state.

ATHLETIC PERFORMANCE

Previous efforts have focused on coaching, nutrition, conditioning, and training to improve athletic performance. There are, however, a few studies that have evaluated the effect of increased sleep duration. For instance, Schwartz and Simon[19] evaluated baseline sleep habits for 1 week in seven collegiate tennis players age 18 to 22 years, then implemented increased sleep recommendations to the team. These modifications resulted in an observed noticeable improvement in the players' serving accuracy.[19] Mah et al.[20] similarly evaluated Division 1 collegiate basketball players over a 5- to 7-week period during the season. These high-level athletes' baseline sleep quantities were observed for 1 to 2 weeks and then they were asked to increase sleep quantity to 10 hours in bed per night. Post-intervention athletic evaluations showed improvements in sprint times and in both free throw and three-point shooting percentage by 9%.[20] The players also had improved subjective ratings of physical and mental well-being.[20] When repeated with Division 1 collegiate swimmers, it was reported that many were beating long-standing personal, school, or national bests.[21] Mah et al.[20] propose that the improved athletic performance is a reactivation of memories during REM sleep or possibly the athlete's perception of improved wakefulness.[20] However, the study did acknowledge confounders, including caffeine intake, timing of testing, cyclical core body temperatures, individual adaptation to chronic sleep loss, emotional resilience, and expected improvements during the course of a season.[5]

CLINICIAN MANAGEMENT

Many athletes have the perception of performing at their highest quality, but Mah et al.[20] and Schwartz and Simon[19] describe the great impact that sleep has on athletic performance. Simply taking a sleep history and adding anticipatory guidance regarding sleep to routine well-child visits can make a tremendous difference, especially for athletes. Screening tools, such as the BEARS (Bedtime problems, Excessive daytime sleepiness, Awakenings during the night, Regularity and duration of sleep, and Snoring) sleep screening algorithm, can help with getting key details about a patient's sleep quality.[22] The BEARS instrument is divided into five major sleep domains, providing a comprehensive screen for the major sleep disorders affecting children age 2 to 18 years. Each sleep domain has a set of age-appropriate "trigger questions" for use in the clinical interview. An important initial step is differentiating behavioral sleep loss from a pathological diagnosis, such as insomnia, depression, and anxiety. Body habitus should also be evaluated, especially in sports where size

TABLE 1.

Sleep Hygiene Recommendations

- Bright morning light helps reset teenage circadian rhythms to earlier schedule[7]
- Maintain consistent bedtime on both weekdays and weekends[7]
- Avoid evening light exposure from technology (eg, television, smart phones, tablets) as this will delay sleep onset. Turn off all electronic devices at bedtime to prevent environmental sleep disruptions[5,6]
- Maintain an optimal bedroom sleeping temperature (60-67° F)[8]
- At least 30 minutes before set bedtime, engage in activities to relax and prepare for bed (eg, listen to soft music, meditate, plan morning routine, read)[5,7]
- Limit caffeine intake, especially in the afternoon and evening[7]

is valued such as in football, wrestling, and weightlifting, taking care to evaluate for conditions such as obstructive sleep apnea. There are many research surveys to evaluate types of sleep disturbance, but none have been validated yet for routine clinical work.[4] For those without disease, initial treatment should include a detailed sleep hygiene review (**Table 1**) and introduction of coping mechanisms. Athletes and their parents should also be educated on the need for at least 2 hours of rest and recovery for each hour of high-intensity training or competition.[16]

Parents should be empowered to discuss these recommendations with coaching staff or competition event planners.[16] It is highly valuable to have a continuous process of review for 48 hours of training in regard to its intensity, age of athlete, and sport played to determine if adequate rest, recovery, nutrition, and travel time has been allotted.[16] For instance, a simple helpful change involves avoiding early morning training sessions after an evening competition.[16] Many aspects of sleep requirements in youth athletes are currently extrapolated from adult studies; however, the youth and adolescent brain is still developing and at a unique transition; therefore, further research is needed in this population.

Going beyond our care for patients, as pediatricians our work could extend to providing community outreach educational sessions in which we address the duration, quality, timing, and environment of sleep for student-athletes to parents, coaches, and school staff.[6] In addition, pediatricians can reach out to public policy makers on a variety of levels in government, such as the school system or sporting organizations, to advocate for optimal training and competition schedules to maximize athletes' sleep.[6]

SUMMARY

Student-athletes are a population at an especially high-risk to experience sleep disturbances, as they not only face the same issues unique to their age group, but additional challenges from the demands of their sport. Loss of sleep can potentially affect their health, recovery, fitness, mental well-being, and athletic performance,[1] making it critical for us as providers to address their sleep needs.

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