Elite Athletes and Sleep: How Much are they Getting? What Happens when they Don't Get Enough? Why Short Term Sleep Extension might be a Performance Enhancement Strategy

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Sleep plays an important role in the recovery and health of athletes. Sleep supports healthy cognition, mood, metabolism (appetite and weight), tissue repair, immune function, among other important processes in the brain and body. Given the importance of the 2016 season, athletes and coaches are taking a careful look at the details of athletes' daily lives and determining what might be modified to further address performance. This article will review the literature of what we know about the amount of sleep elite athletes get during training and competition, what happens when athletes don't sleep well around competition, the costs associated with getting too little sleep and strategies to address insufficient sleep. A previous *Olympic Coach* (October 2013, Sleep Basics for an Olympic Coach) article detailed sleep needs, what happens when we sleep, and sleep extension and restriction findings. Athletes should be aware that consistent, adequate sleep allows them to wake up a smarter, stronger version of themselves (and in a slightly better mood).

Sleep During Training

Getting insufficient sleep after training short-changes the learning process that the brain goes through to try to download information learned (refinement of technique, new skill development, observation of new patterns, and so forth that are the learning products of training) that day and retain the information in neural networks. During sleep, the brain undergoes important processes for learning (sleep scientists refer to this as sleep dependent learning), two of which are sleep dependent consolidation and sleep dependent plasticity. Just by the terms alone, we can see that learning, in part, depends on sleep. Sleep in one view, is an opportunity for learning to occur, for the brain to download information and integrate it in the memory centers, and for the brain to literally change itself by forging new connections between neurons in order to build the learning into the neural circuitry. Some sleep scientists (Matt Walker and Robert Stickgold in this case) go so far as to say that nighttime sleep or daytime naps may maximize skills by "advancing learning beyond that achieved during initial practice without the need for further task engagement" (2005, pp 316). Of course athletes will further engage in their 'tasks' during ongoing training, but the idea that there is a rebound effect in learning provided by sleep should be highlighted. Eating protein after lifting is a strategy that nearly all elite athletes take advantage of: providing building blocks for muscle repair, protein allows the body to build itself stronger. Athletes should be aware that getting insufficient sleep after training could be analogous to not eating protein after lifting. A lack of understanding of the importance of sleep may lead athletes to prioritize other things over getting adequate sleep and lead to suboptimal learning gains associated with training.

While it is often viewed as the athlete's responsibility to get adequate sleep, coaches, parents, schools and National Governing Bodies should do what is possible to set athletes – particularly adolescents and young adults – up for success. A common strategy used for those wanting to sleep more might be to get to bed early. For those of us who have reached the age of brain maturity (mid-20s for females, late 20s for males) this may be a workable strategy, however for those with brains still in the midst of development, this is difficult. So difficult, the research literature uses the phrase that adolescents are 'biologically incapable' of going to bed earlier, as the drive for sleep does not come until later in the evening. This sleep drive, often called sleep pressure, accumulates slower throughout the day, it is thought, as a byproduct of the vast amount of rewiring that occurs during young adulthood, specifically due to the pruning of neurons. While this may not be true for all adolescents, on average, going to bed earlier is going against biology. During puberty, circadian rhythms shift about two hours, where a pre-teen who typically felt sleepy and went to bed at 8 p.m. would likely have rhythms that shifted to make him sleepy at 10 p.m. as a teen. Studies suggest that falling asleep before 11 p.m. is generally a challenge for adolescents. Even for adults, there is an established "forbidden zone" (as it is called in sleep literature) for bedtime, from 7-10 p.m., where many people have difficulty falling asleep during these hours.

How much sleep do elite athletes need?

The National Sleep Foundation set broad recommendations for hours of sleep for school age children (6-13 years) is 9-11 hours, for teens (14-17 years) is 8-10 hours, for young adults (18-25 years) is 7-9 hours. It is noted that each recommended range has an upper and lower range that "may be appropriate" which stretches the school age range from 7-12 hours, the teen from 7-11 and the young adult from 6-11 hours. Other literature states that adolescents and young adults very specifically need 9.25 hours of sleep per night. Either way, these recommendations are for hours of sleep, not simply hours in bed. Time in bed nearly always exceeds sleep time as it is normal to take some time to fall asleep, to transition in and out of sleep during the night, and to awaken before one's target wake up time. Published data from Stanford student-athletes shows that athletes reported they were getting about an hour more sleep than a sleep measurement device clocked them in at (7.8 hours in self report vs. 6.6 hours according to a sleep watch) during a baseline measurement period, while during an extended sleep period, the student-athletes reported nearly two hours more than the sleep watch (10.4 vs 8.5 hours) (Mah et al., 2011). This data supports the view that time in bed and subjectively reported sleep time typically exceed actual sleep duration.

How much sleep are elite athletes getting?

There is no easy formula for understanding how much sleep elite athletes need. A few studies with elite athletes have been published over the last several years, and they are summarized below to provide an idea of the current sleep habits of elite athletes. The sleep of Team Great Britain Olympic athletes was tracked with the goal of understanding of what "normal" sleep looks like in elite athletes in a 2012 study. The athletes wore sleep watches at home for four nights during a typical training phase (as opposed to nights during competition or during the off season). The athletes were in bed for an average of 8.5 hours per night with seven hours of sleep. A measure of sleep

efficiency, or a measure of minutes asleep out of minutes in bed, in this case is 81 percent. In this study, athletes were compared to non-athlete controls. The non-athletes spent about 30 minutes less in bed, but got about 15 minutes more of sleep per night, bringing their sleep efficiency up to 89 percent. (Leeder et al., 2012)

In a 2015 study in Australia of athletes competing at the national and international level, athletes wore sleep watches for a minimum of seven nights during a training phase. On average, elite athletes spent 8.4 hours in bed with 6.8 hours asleep. Sleep efficiency was 86 percent The aver-age bedtime was approximately 11 p.m. with a wake up time of 7:15 a.m. There was a difference between individual and team sport athlete total sleep time, with individual athletes reporting going to bed earlier and waking earlier, and sleeping 6.5 hours as opposed to team sport athletes going to bed later and waking later with a seven-hour sleep time (Lastella et al., 2015). A different study examined sleep in Australian Rules football players and found longer sleep durations among the athletes of approximately 8.5 hours per night across five nights. (Richmond et al., 2014).

A 2014 study conducted in Australia with elite youth soccer players (average age of 18.5 years) showed that athletes slept an average of 7.5 hours with an 89 percent sleep efficiency over the 18 nights monitored. The study examined the impact of early evening high intensity training on sleep and found no effect on sleep (Robey et al., 2014). A 2015 study of Asian, adolescent, high-level athletes showed that athletes are getting 6.1 hours of sleep on week days and 7.1 hours on week-ends. (Suppiah et al.). This study was conducted in Singapore with athletes at high performance sport academies, training in the sports of bowling and badminton. There were 11 participants. We don't know if we can assume the same about American adolescent high level athletes based on this study, however in a 2014 study of American high school student athletes, 77 percent reported getting less than eight hours of sleep per night (Milewski et al.), and a 2006 National Sleep Founda-tion poll found that 45 percent of teens get less than eight hours, 31 percent get between eight and nine, and 20 percent get nine or more hours. The poll found that as teens got older, they slept less: the average sixth-grader got 8.4 hours compared to the average 12th-grader getting 6.9 hours. A different stream of literature tracking screen time and social media use among teens would suggest that teens are using screens more in 2016 than in 2006, and some of the additional time devoted to screen time cuts into sleep time. A safe assumption might be that the 45 percent of teens report-ing less than eight hours of sleep per night in 2006 has grown to become the 77 percent of student athletes in 2014, and the percentage may be higher in 2016.

The change in sleep duration reported in the Singapore athletes from weekday to weekend is called 'social jet lag' and is a worldwide phenomenon observed among adolescents. Collegiate student athletes may have a similar pattern in conjunction with 'training jet lag' if they have morning workouts. In a small study of swimmers conducted during a high intensity training camp before the Beijing 2008 Games, a 'training jet lag' effect was observed between days with and without morning swims. Time in bed on training days was 7.7 hours, and 9.3 for rest days. Sleep time was 5.4 hours on training days and 7.1 on rest days. The sleep efficiency for training days is 71 percent and rest days 77 percent (Sargent et al., 2014). The authors of this study concluded that the early morning swim times severely restricted the amount of sleep of the athletes, noting that habitually getting

less than six hours of sleep per night is associated with difficulties in physiological and psychological functioning. It might also be possible that inadequate sleep during high training loads moves athletes closer to overtraining rather than functional overreaching.

In sum, adult elite athletes report spending about 8-8.5 hours in bed with about seven hours of sleep. Adolescents and student athletes report about 6.5 hours of sleep on average, from small sample studies. A majority of teens report less than eight hours of sleep per night. These shorter than recommended sleep durations are not unique to sport: a study of professional ballet dancers showed that dancers slept seven hours per night on average with 81 percent sleep efficiency (Fietze et al., 2009). It is not known how much sleep elite athletes need according to age or sport demands, however scientists are working to better understand this question. Six and a half to seven hours of sleep may not provide adequate recovery time to support high performance training. It also may allow a large sleep debt to build, which could be exacerbated by poor sleep around travel and competition, becoming a burden on an athlete's mood, brain and body.

Sleep During Competition

As nearly any athlete or coach would report, sleep prior to competition is likely different from sleep during training. A 2011 study examined the question of how different is sleep prior to important competitions (Erlacher et al., 2011). Sixty two percent of athletes (in this case they were more than 600 German athletes, with an average of 11.5 years of experience training 11 hours per week) reported poor sleep prior to an important competition in the previous year. Eighty percent stated they had difficulty falling asleep due to a variety of factors, including thinking about the competition (77 percent), pre-competition nerves (60 percent) and a lack of familiarity with travel surroundings (29 percent). In spite of a majority of athletes experiencing difficulties with sleep around competition, 57 percent believed that these difficulties had no influence on their performance. Twenty-seven percent did report an increase in daytime sleepiness, 18 percent reported a bad mood, and only 13 percent reported poor performance in a competition due to poor sleep.

As a side note, for those readers who wear sleep bands and see their sleep efficiency score in the high 80s to mid 90s, fight the urge to reach 100 percent and keep your scores where they are. A sleep efficiency goal of 100 is not an efficient goal. It is usually a sign that the person is very tired and is not devoting adequate time in bed. If you are in bed five hours and asleep five hours, this is 100 percent sleep efficiency. If you are in bed 10 hours and asleep nine, you are at 90 percent. Your sleep efficiency should be considered in tandem with total time in bed.

A similar study was conducted in Australia with elite athletes (defined as competing at the international or professional level) (Juliff et al., 2015). Sixty-four percent of athletes reported worse sleep on at least one occasion in the nights leading into an important competition in the previous year. The cause of the poor sleep was due to thoughts about the competition (82 percent) and pre competition nerves (44 percent), and 47 percent believed that poor sleep had no influence on their performance. There was a difference between individual and team sport athletes in their agreement with the statement that poor sleep would have no influence on performance. Sixty-four percent of individual sport athletes agreed with this, yet only 40 percent of team sport athletes agreed that poor sleep would have no impact on performance. There may be differences in how sleep

loss impacts performance in different sports. We know generally from sleep restriction studies that mood declines first, then cognition, then physical performance. For sports that include complex skill execution, or fast and accurate decisions, then short term sleep loss may have a greater effect. There was also a difference between athletes in reporting of strategies to promote sleep. Fifty-nine percent of team sport athletes and 32 percent of individual sport athletes reported having no strategy. From these two studies, we can conclude that sleep difficulties around competition are common in athletes. They are likely common in one's competitors as well. It seems worthwhile to learn strategies to help with getting to sleep, including breathing exercises, relaxation exercises and using a notebook to write down ruminations (these are in addition to developing the habit of going through a check list of what will be needed the next day for competition-or training-and reviewing this prior to bed time).

An interesting study was conducted with marathon runners, where athletes were asked on the morning of a race how they slept the night before, and then provided an estimation of how well they would run that day. Seventy percent of athletes reported poorer sleep than usual, however there was no difference between the athletes' actual performance and what they estimated prior to the race (Lastella et al., 2014). Of course, they could have artificially elevated their times as a sort of psychological cushion knowing they didn't sleep well, but in the case that they didn't the results are interesting. There was no impact on the next day performance when the athletes had a not so great night sleep. They did report worse moods – with more tension and fatigue – and these were connected to total amount of sleep, specifically, less sleep was associated with more tension and more fatigue. One takeaway for athletes and coaches is that a night of bad sleep before a competition shouldn't necessarily affect performance – it will more likely negatively affect mood and increase how tired one feels. Expecting and being prepared for mood and energy consequences of poor sleep around competition, and knowing that these are not necessarily connected to performance outcomes, might allow athletes to perform well in spite of them.   One final note on sleep restriction studies, and translating to performance – while getting consistent adequate sleep is important, a few nights of poor sleep won't completely derail performance. In studies where performance has been assessed after one night with no sleep, findings include that submaximal – not maximal – efforts are affected, mood deteriorates before strength, and perceived exertion increases while endurance decreases slightly (although this last finding was from a study of active people, not runners). Assuming athletes will exert maximal effort, can manage suboptimal mood and have strategies to monitor exertion outside of their own perception, they can work with themselves to perform in the face of sleep loss.

The Cost of Sleepiness on Athletic Performance

Assessments of sleepiness done with MLB and NFL players suggests that increased sleepiness is associated with decreased career longevity (searching the internet for Chris Winter's work on these topics can bring up more detailed summaries). It seems that on average, lower levels of daytime fatigue is a sort of protective factor against attrition. Getting adequate sleep at night buffers against injuries in high school student athletes. In a 2014 study, chronic lack of sleep was associated with increased sport injuries in adolescents. High school athletes reporting eight or more

hours of sleep per night were 68 percent less likely to injure themselves than their peers who report-
ed sleeping less than eight hours (Mileweski et al., 2014).

Sleep Extension as a Strategy to Enhance Performance

A sleep extension study conducted with the Stanford University basketball program previously
elaborated upon in the 2013 "Sleep Basics" Olympic Coach article was associated with significant
improvements in sprint times, shooting performance and self-ratings at practice and during games.
Similar studies have been conducted with other sports with a baseline period where athletes sleep
their usual amount for two weeks, then for six weeks, athletes spend a longer time in bed (ap-
proximately 10 hours). Sport skills are assessed during the baseline and sleep extension periods.
In swimming, sleep extension findings included improved speed (.51 seconds faster in a 15-meter
sprint), reaction time (0.15 seconds faster off blocks), turn time (0.1 second faster) and kick strokes
(five kicks more in stroke frequency). In tennis, faster sprint times, improved valid serves and hitting
in depth drills were observed. In football, speed in a 20-yard shuttle improved from 4.71 to 4.61 sec-
onds, and in a 40-yard dash, times decreased from 4.99 to 4.89 seconds. It is unknown if the find-
ings from these studies, all conducted with Stanford student-athletes, are generalizable to athletes
competing at different levels in other sports, however sleep extension seems a worthwhile strategy
to explore for athletes at all levels. It can be done in one chunk, the way the Stanford studies were
conducted, or done strategically throughout the season, with extending sleep the two weeks prior
to travel or a major event. Sleep extension has no known side effects for healthy sleepers, however
for those who struggle with insomnia (consistent difficulty falling asleep/staying asleep) spending
more time in bed is not a helpful strategy as it does not address the ability of the brain to obtain more
sleep. This issue is best addressed with the help of a sleep specialist.

In summary, athletes and coaches should be aware of the important role sleep plays in recovery,
and have an appreciation for the role of sleep in learning. Sleeping after learning allows the brain
and body to capitalize upon the effort put forth during training and integrate the new information into
memory centers and the brain's networks. Across the handful of publications examining sleep in
elite athletes, it seems that athletes are getting 6.5-7 hours of sleep on average per night, with more
hours, somewhere near seven or eight hours in bed. While these may be 'typical' amounts, it does
not mean that they are 'ideal' amounts. Sleep loss affects mood, motivation, perception of effort, in
addition to reaction time and decision making. While there is limited evidence of performance decre-
ments in elite athletes in competitive settings with short-term sleep deprivation studies, chronically
getting slightly insufficient sleep may be more of a performance barrier. Athletes should understand
the importance of getting adequate sleep during training, and allow for the possibility for worse sleep
around competition. Sleep extension can be a near term performance enhancement strategy via
reducing sleep debt and allowing athletes to more fully recovery, maximize learning gains and expe-
rience skill improvements.

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