

# Sleep – A Game Changer in the Athletic World?

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### Abstract

The restorative qualities of sleep are fundamentally the basis of the individual athlete's ability to recover and perform, and to optimally be able to challenge and control the effects of exercise regimes in high performance sport. Research consistently shows that a large percentage of the population fails to obtain the recommended 7–9 hours of sleep per night [17]. Moreover, recent years' research has found that athletes have a high prevalence of poor sleep quality [6]. Given its implications on the recovery process, sleep affects the quality of the athlete's training and outcome of competitions. Although an increasing number of recovery aids (such as cold baths, anti-inflammatory agents, high protein intake etc.) are available, recent years research show the important and irreplaceable role of sleep and that no recovery method can compensate for the lack of sleep. Every facet of an athlete's life has the capacity to either create or take out energy, contribute to the overall stress level and subsequently the level of both recovery and performance. While traditional approaches to performance optimization focus simply on the physical stressors, this overview will highlight the benefits and the basic principles of sleep, its relation to recovery and performance, and provide input and reflect on what to consider when working with development and maintenance of athletic performance.

**Keywords:** Sleep, athletes, sleep deprivation, performance, recovery, fatigue

### Résumé

Les qualités régénératrices du sommeil constituent la base fondamentale de la capacité de récupération et de performance de l'athlète, et son aptitude à appréhender les hautes charges d'entraînement inhérentes au sport de compétition. Les études démontrent de manière répétées que les athlètes peinent à atteindre les 7 à 9 heures de sommeil recommandées et qu'ils souffrent en plus d'une prévalence élevée de perte de qualité de sommeil. Au vu de son rôle dans la récupération, le sommeil impacte la qualité de l'entraînement et les résultats des compétitions. Bien qu'un nombre croissant d'aides à la récupération existent (bains froids, agents anti-inflammatoires, alimentation protéinée, etc.), les études récentes qu'il est impossible de compenser adéquatement un manque de sommeil. Chaque aspect de la vie de l'athlète peut potentiellement contribuer à l'amélioration ou la péjoration du niveau d'énergie, de stress et en conséquence du niveau de récupération et performance. Tandis que les approches traditionnelles d'optimisation de la performance se focalisent sur les stressors physiques, cette revue va mettre en évidence les bénéfices et les principes de base du sommeil, sa relation avec la récupération et la performance, et fournir des informations sur ce que l'on doit prendre en considération dans le travail de développement et maintien de la performance.

**Mots clés:** Sommeil, athlètes, manqué de sommeil, performance, récupération, fatigue

## Introduction

Sleep and fatigue represent some of the most significant pieces of the human performance puzzle, and the relationship between sleep, post-exercise recovery and performance in elite athletes has become a topic of great interest in the sport science and medicine community over the past years. Further, more and more athletes have made the subject a matter of attention. Roger Federer and LeBron James have told that they sleep an average of 12 hours a day. In comparison, the average Australian sleeps less than 7 hours a day. Usain Bolt, Venus Williams, Maria Sharapova and Steve Nash prefer to sleep up to 10 hours a day. Just as athletes need more calories than most people when they are training, they need more sleep too. However, sleep is often compromised by athletes as a result of their busy schedules, matches being played at different times, travel, intrusion of technology, external requirements in their lives such as family and events, mental imbalance, as well as a general lack of useful strategies on how to change behaviour and increase sleep output. These challenges can inhibit normal sleep physiology and promote an increased occurrence of injuries, stress, diseases, under-performance, and demotivation. All together act as barriers for optimal performance. A growing body of scientific evidence has confirmed that there is a critical link between sleep and circadian rhythm factors, cognitive processes and the metabolic function (1–5). Hence, proper sleep is a strategy that contributes significantly to recovery and is an influential factor in avoiding overtraining.



**Figure 1:** The connection between sleep challenges and underrecovery.

General recommendations suggest that 7–9 hours of sleep is adequate for psychological and physiological recovery [17]. Additionally, it has been suggested that athletes require and benefit from a greater quantity of sleep, requiring closer to 9–10 hours of sleep in order to recover sufficiently from injuries, intense training periods, and competitions [18,21].

At the same time, a recent systematic review of the literature has found that athletes have a high prevalence of poor sleep quality [6]. Other research [7,8,9,10] confirms that sleep deprivation is considered common amongst athletes, where

sleep duration and sleep quality is often neglected when optimizing recovery and competition performance. As an example, a study of precompetitive sleep behaviour in 103 athletes found that the majority slept less than 8 hours, and 70% reported worse sleep quality than usual, largely attributable to mood and anxiety disturbances before competition [20]. Sleep deprivation leads to poor performance, reduced motivation and arousal levels, and reduced cognitive processes leading to poor attention and concentration, and heightened levels of perceived exertion and pain perception. Limitations to physiological processes include disrupted glucose metabolism and neuroendocrine functioning, a compromised immune system, and reduction in cardiovascular performance [14].

This alludes to the need of greater attention and education of not only the athletes, but the medical- and performance staff working with them, as subsequently, sleep deprivation leads to disruption of training intensity and performance at competition [11].

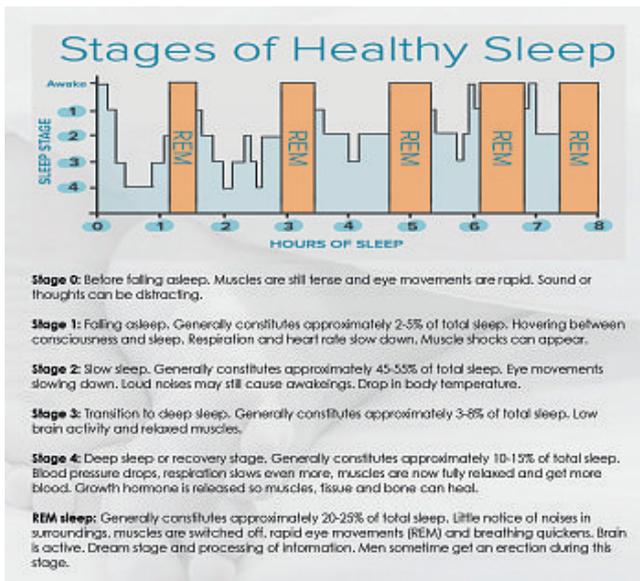
The aim of this overview is therefore to provide basic knowledge about sleep and its link to recovery and performance with reference to recent research. Further, the overview will provide some hands on strategies and recommendations to help athletes optimize their sleep and recovery, so it becomes a consistent focus in their performance enhancement.

## The Basic Physiology of Sleep

### *Sleep cycle and key sleep stages*

Sleep is an active process during which key physiological, neural and psychological recovery processes take place. Normal human sleep consists of 5 individual stages, involving varied levels of consciousness and brain activity, occurring over consecutive phases [16]. When a person lies in bed after turning the light off, his mind is still active and brain and eye activity indicate that he is still awake. As he drifts towards sleep, the brainwaves slow down and take on regular patterns, indicating a relaxed, but still awake state. The stage is termed the alpha stage of sleep. After a short time in this stage, the brainwaves and breathing rate start to slow as stage 1 sleep is begun.

Sleep begins in non-rapid eye movement (NREM) and progresses through deeper NREM stages (2, 3 and 4 using the classic definitions or stages N2 and N3 using the updated definitions) before the first episode of rapid eye movement (REM) sleep occurs approximately 80–100 minutes later. Thereafter, NREM sleep and REM sleep cycle with a period of approximately 90 minutes. NREM stages 3 and 4 (or stage N3) are concentrated in the early NREM cycles, and REM sleep episodes lengthen across the night [22].

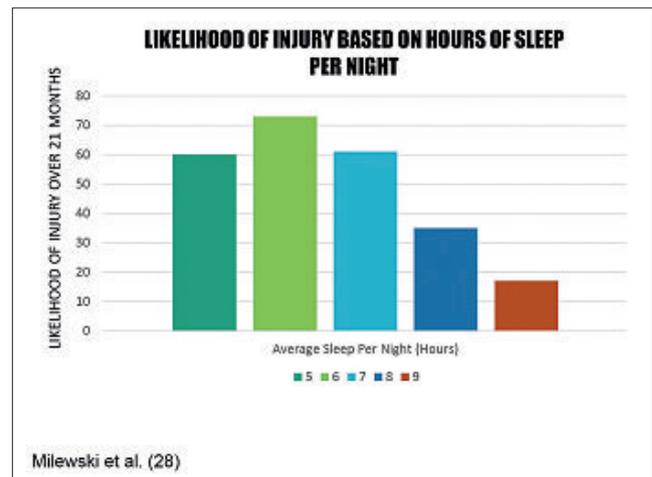


**Figure 2:** Sleep stages

Stage 1 lasts for between 10 seconds and 10 minutes, where the individual is still consciously aware of any environmental change, meaning there is a high potential for awakenings to occur, highlighting the need for an optimal sleeping environment (no loud sounds, lights off etc.). Before stage 1 occurs and the onset of sleep begins, the body must be at a relaxed state for 5–20 minutes, outlining the need for athletes to avoid any form of stimulating activity (e.g. using electronic devices) before beginning sleep. Stage 2 lasts for 10–20 minutes and is the beginning of actual sleep, followed by stages 3 and 4. Altogether, these are the deepest sleep stages. After 30–40 minutes of deep sleep, the process reverses through stages 2 and 3 and enters the REM stage [16,22]. During the deep sleep stage, muscle relaxation is complete and blood supply at its lowest, allowing for optimal tissue growth and repair. At the same time, growth hormone release is at its greatest. Together the three factors allow for the restorative processes required for physiological recovery to take place. During REM sleep the sympathetic nervous system is at its most active, and blood flow to the brain at its greatest. At this time the eyes dart back and forth, despite being closed, hence the name Rapid Eye Movement. It is at this stage that dreams are most common and most vivid. REM sleep is essential for optimal brain functioning and contributes to psychological and emotional recovery. Additionally, it contributes to physical recovery on a neural rather than physiological level, with the replenishment of neural transmitters (the chemical messengers that allow neurons to communicate) [16,22]. Without REM sleep the ability to function on a physical, psychological and emotional level is compromised. As the greatest amount of REM sleep comes in the later cycles, a continuous period of uninterrupted sleep is essential for optimal functioning in these areas. REM sleep is important at all times, but especially important during periods when high neural stressors are present, such as during skill development or periods of high-intensity exercise.

## Why Sleep is Important to Success in Athletic Performance

Several studies in sports have demonstrated that success in training and competition is related to increased sleep duration and quality [6,18,19], as optimal sleep affects multiple physiological and psychological pathways and so is fundamental for recovery and ultimately performance. Recent evidence confirms this aspect by highlighting that impaired or decreased sleep is associated with an increased risk of injury. In a study of middle and high school athletes, Milewski et al. [28] found that those individuals who slept less than 8 hours per night on average were 70% more likely to report an injury than those who slept more than 8 hours (*see figure 3*). In addition, a recent study of 496 adolescent athletes from 16 different individual and team sports found that increased training load and decreased self-reported sleep duration were associated with an increased risk of injury. In fact, the greatest risk of injury resulted when training load increased and sleep duration decreased simultaneously, as it is often seen in competition related travel and training camps [29]. The underlying mechanism for the relationship between sleep loss and injury is unclear, but may be related to resulting impairments in reaction time and cognitive function after sleep deprivation that could predispose to acute injury [29]. Also, impaired sleep may contribute to higher levels of fatigue that can similarly contribute to injury risk in athletes (*see figure 1*).



**Fig. 3:** Likelihood of injury based on hours of sleep per night.

During sleep recovery is promoted largely through hormone activity [25]. The sleep hormone melatonin is produced by the neurotransmitter serotonin, which is stimulated by darkness and subsequently released from the pineal gland during the night to prompt sleep. Melatonin regulates the circadian rhythm in response to light and dark cycles with low and high levels of secretion respectively [27]. In addition to acting as an antioxidant, melatonin activates other pro-inflammatory enzymes to neutralize oxidative radicals which harm cells and promote tissue inflammation. Immune function is also modulated through melatonin through both the nervous and endocrine systems. Sleep promotes the restoration of the immune- and endocrine system, and research shows that decreased sleep has been shown to be immunosuppressive and increase susceptibility to upper respiratory infections in particular [26]. Athletes also may be at increased risk for certain medical conditions associated with impaired sleep. Although

it is estimated to affect only 4% of the general population, sleep-disordered breathing has been estimated to be present in 14% of professional football players [37]. Given the detrimental effects that sleep-disordered breathing and obstructive sleep apnea can have on both health and athletic performance, a high index of suspicion should exist, particularly among athletes with increased body mass and large neck circumference. Restless legs syndrome is increasingly recognized as an important cause of poor sleep, perhaps more so in athletes than previously suspected. Although moderate exercise is recommended for individuals with restless legs syndrome, a single survey of 61 marathon runners found that 13% met the criteria for restless legs syndrome, suggesting that this may be a more prevalent condition among athletes than previously suspected [38].

Furthermore, it is within the deep sleep (stages 3 and 4) that growth hormones and androgens are released. These are essential for muscle repair, muscle building, bone growth and promoting the oxidation of fats [30].

The capacity to learn is essential to athletic development and performance, and sleep is critical for memory consolidation. This has important implications for tactical development in athletic training and may be particularly important among young athletes, who must concomitantly meet both academic and athletic demands [31]. Although there are large interindividual differences in the effect of sleep loss on executing function, sleep deprivation is associated with cognitive lapses and may significantly undermine tasks that require flexible thinking. One night of sleep deprivation also has been found to have significant negative effects on inhibitory control [32], potentially undermining decision-making during athletic competition. Further sleep loss has been found to have a negative effect on a number of measures of subjective well-being, including fatigue, mood, soreness, depression and confusion [33].

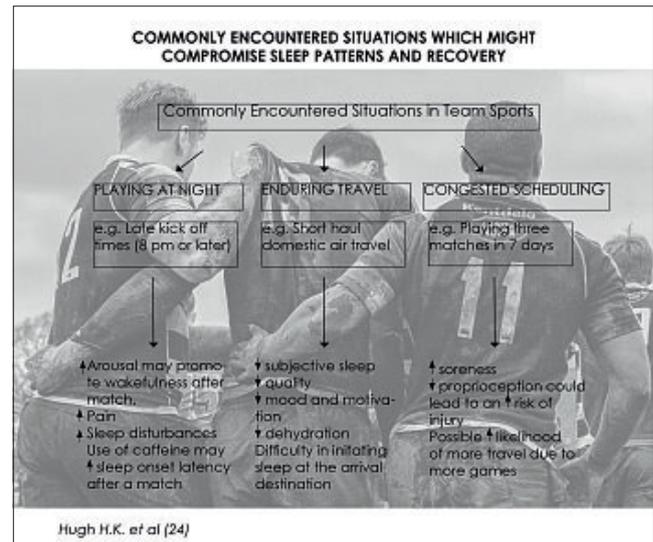
#### To recap: Poor sleep in athletes has been linked with

- An increased incidence of fatigue related injury (12,28,29)
- Hormonal and metabolic disturbances (13,14)
- Elevated sympathetic nervous system activity (15)
- Immunosuppressive and increased the risk of infection (26)
- Reduced reaction times (34)
- Negative performance outcome for endurance based exercise (35)
- Increase in unstable emotional states (19)
- Reduced cognitive functions (31,32,33)

#### Barriers to Optimal Sleep among Athletes

Previous research has highlighted how common poor sleep quality is among the athletic population. In a group of Olympic athletes significant reductions in actual sleep ( $84.3 \pm 5.7$  versus  $89.7 \pm 3.3$ ) and efficiency ( $80.6 \pm 6.4$  versus  $88.7 \pm 3.6$ , repeated stages of sleep cycle leading to optimal volume of REM sleep) were identified in comparison to the control group of a non-athletic population (9). Research has also explored the difference between habitual sleep patterns of individual and team athletes, indicating that individual athletes slept and awakened earlier and gained less sleep than team sport athletes [8].

There are a number of barriers to proper sleep that should be considered when attempting to optimize sleep and improve performance. Particularly in endurance disciplines, training days can result in increased daytime fatigue and reduced total sleep time [6]. Moreover, in modern sports athletes' sleep patterns often have to be adjusted due to travel and scheduling requirements, fx late play off times, which can trigger sleep disturbances and insomnia issues. Some of the obstacles are described in Hugh H.K. et al [24] schematic presentation of the commonly encountered situations in team sports that may compromise sleep patterns and potentially recovery.



**Figure 4:** Commonly encountered situations which might compromise sleep and recovery among athletes in team sports.

Travel for competition may directly interfere with performance due to alterations in sleep schedules and dissociations with circadian rhythms. In addition to anxiety and stress related to travel itself, transmeridian travel and the associated jet lag are linked with fatigue, disorientation, impaired sleep, and general discomfort, all of which are a threat to athletic performance [39].

Today's athlete lives in a world where time and energy demands are greater than ever. In addition to being athletes on a daily basis, they have other roles and need to balance many things. Hence, their energy requirements are above and beyond those of the athletic world. Every facet of the athlete's life has the capacity to either create or take out energy, contribute to the overall stress levels, and subsequently the levels of both recovery and performance. Sleep is part of the holistic whole and important for the athlete's foundation. It is not only important to observe a player's "sleep" (what he/she does at night), but also to determine the content of the athlete's circadian rhythm, i.e. the behavior and choices (lifestyle) he/she makes throughout the day, which leads to whether or not he is sleeping well.

It is important to note, that athletes have been found to demonstrate poor self-assessment in terms of sleep need, duration, and quality, potentially making them less likely to seek guidance or medical help when needed (23). In addition, certain cultures appear to idealize the ability to function with minimal sleep, potentially further inhibiting athletes from obtaining adequate sleep or seeking help.

### Commonly encountered challenges among athletes

- Get too few hours of sleep per night (Sub 7 hours/night on average)
- Inconsistent sleep rhythm (No fixed bed/awake times)
- Poor sleep hygiene (Sleep in too warm rooms, too high light exposure, use of electronics before and in bed, sleep in the wrong clothes)
- Suffer from a racing mind (inability to actively disengage leading to a prolonged sleep latency and ultimately compromised sleep performance with regards to both duration and quality)
- Long sleep latency (use more than 20 minutes (sometimes hours) to fall asleep. Occasionally have full nights where they never get to sleep)
- Challenged to sleep post competition/game
- Uncontrolled napping (over-napping during the day)
- Uncontrolled intake of caffeine
- Unbalanced nutrition

Based on "in field work" – West, A, Sleep2perform

### Input on "How to unlock human potential through sleep"

Given the significant implications for performance, health and general well-being, a number of recommendations have been suggested to monitor and improve sleep in athletes [40,41,42]:

- *Make "sleep" a part of the performance optimization strategy. Invest in sleep like you invest in performance:* Athletes should be educated and more important learn to prioritize sleep and ensure both duration and quality. Research has highlighted that athletes need more sleep than the general population regardless of age. To facilitate these adequate sleeping hours (optimal range 8–10 hours per night), routines must be made where sleeping and waking times are consistent, napping controlled, strategies on "active disengagement" (ability to turn your mind off to ease the "falling asleep" process) are learned, ultimately stimulating the quality and quantity of nightly sleep. Improving sleep quality reduces sleep latency and enhances transition through the sleep stages, promoting volume of REM sleep and therefore optimizing recovery and wakefulness [16]. Sports medicine professionals and coaching staff should prioritize and support these factors by providing proper scheduling, travel protocols, and favor time- and stress management, and sleep hygiene around athletes to help them improve overall health and performance.
- *Determine environmental and individual sleep challenges and create strategies:* Athletes in general and in particular those who complain of poor sleep or excessive daytime fatigue should be screened for medical conditions such as insomnia, sleep disordered breathing, restless legs syndrome, depression, anxiety, or concomitant illness. Athletes may experience stress from a number of sources both in and out of sport, and this may be especially true of adolescent athletes who are attempting to manage both academic and athletic demands within an already highly pressurized social environment [42]. Early identification and management of mental health issues in athletes are critical for improved sleep, health and performance. A

common approach to measure sleep within a performance setting is to have the athletes complete sleep questionnaires such as the Pittsburgh Sleep Quality Index (PSQI), or the Athlete Morningness/Eveningness Scale (AMES) to determine individual as well as team challenges. The method is predominant in previous research, however, mainly focusing on specific sleep components (disturbance, sleep duration, time for falling asleep and time for waking up) and recent research by Samuels, C. et al in 2017 [43] have highlighted that these measures are inadequate for subjective sleep screening of an elite athlete population, leading to the development of The Athlete Sleep Screening Questionnaire (ASSQ) [43]. Longitudinal monitoring of training load, napping routines, nightly sleep, fatigue, stress and mood might be a less cost efficient method, however can help identify individual risk of burn out and improvements in sleep, well-being and performance aligned with interventions and aid in the development of individualized sleep recommendations and enhanced performance [41]. See figure 5 for input on how to enhance sleep.



Figure 5: Sleep hygiene – Things for athletes to consider when optimizing Sleep

### Conclusion

An increasing body of scientific evidence suggests that sleep optimization can have a significant influence on optimal performance across a range of athletic activities. However, psychological, physiological and social stresses placed on elite athletes often result in an increased stress/fatigue state and presents a phenomenon which may result in an inability to gain appropriate sleep. Improvements in sleep duration and sleep quality appear to improve reaction time, accuracy, and endurance performance. In addition, poor sleep may increase the risk of injury and illness, reducing training availability and undermining overall health. Athletes consistently demonstrate insufficient sleep and poor sleep quality, and experience a number of obstacles to proper sleep, including training and competition schedules, travel, fluctuations in training load, anxiety or stress associated with sporting events, and competing scholastic demands in younger athletes. Sleep is important to all humans and even more so to athletes. Longitudinal monitoring of sleep quality and quan-

tity can aid in detecting poor sleep patterns, and improving an athlete's sleep hygiene is seen as a key strategy that could have powerful implications for athletic performance.

Recommendations and support for athletes should be specific to each individual, and continuous focus and education should lead to athletes prioritizing sleep as a repeated performance enhancer. Peak competitive performance can only occur when an athlete's sleep is optimal.

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### References

- Postolache TT, Hung TM, Rosenthal MM, et al. Sports chronobiology consultation: From the lab to arena. *Clin Sports Med* 2005;24:415-56.
- Marquet P. The role of sleep in learning and memory. *Science* 2001;294:1048-52.
- Sharma S, Kavuru M. Sleep and metabolism: an overview. *Int J Endocrinol* 2010;2010:pii:270832.
- Knutson KL, Van Cauter E. Associations between sleep loss and increased risk of obesity and diabetes. *Ann N Y Acad Sci* 2008;1129:287-304.
- Jones K, Harrison Y. Frontal lobe function, sleep loss and fragmented sleep. *Sleep MED Rev* 2001;5:463-75.
- Gupta L, Morgan K, Gilchrist S et al. Does Elite Sport Degrade Sleep Quality? A Systematic Review. *Sports Med*. 2017;47(7):1317-1333. doi: 10.1007/s40279-016-0650-6.
- Erlacher D., Ehrlenspiel F, Adegbesan OA. Sleep habits in German athletes before important competitions or games. *J Sports Sci* 2011; 29:859-866.
- Lastella M, Roach GD, Halson SL, Sargent C. Sleep/Wake behaviors of elite athletes from individual and team sports. *Eur J Sport Sci* 2015;15:94-100.
- Leeder J, Gleiter M, Pizzoferro K, Dawson J, Pedlar C. Sleep duration and quality in elite athletes measured using wristwatch actigraphy. *J Sports Sci* 2012;30:541-545.
- Venter RE, Potgieter JR, Barnard JG. The use of recovery modalities by elite south african athletes. *South Afr J Res Sports Phys. Education Recreation* 2010;32:133-145.
- Souissi N, Chtourou H, Aloui A, Hammouda O, Dogui M, Chaouchi A et al. Effects of time of day and partial sleep deprivation on short team Maximal performances of judo competitors. *J Strength Cond Res* 2013;27:2473-2480.
- Luke, A, Lazaro, R, Bergeron, M.F, Keyser, L, Benjamin, H, Brenner, J et al. Sports-related injuries in youth athletes: Is overscheduling a risk factor? *Clin. J Sport Med*. 2011;21,307-314.
- Imeri, L.; Opp, M.R. How (and why) the immune system makes us sleep. *Nat. Rev. Neurosci*. 2009;10,199-210.
- Halson, S.L. Sleep in elite athletes and nutritional interventions to enhance sleep. *Sports Med*. 2014;44 (Suppl. 1),13-23.
- Spiegel, K.; Leproult, R.; Van Cauter, E. Impact of sleep debt on metabolic and endocrine function. *Lancet* 1999;354,1435-1439.
- Jenum P, Kempfner J. Metoder til bestemmelse af søvn og vågenn (Kapitel 2). In: Søvn, Jenum, P. Munksgaard, København; 2013;p27-37.
- National Sleep Foundation, USA. National Sleep Foundation Recommends New Sleep Times. <https://www.sleepfoundation.org/press-release/national-sleep-foundation-recommends-new-sleep-times/page/0/1> (Accessed 29 October 2018)
- Mah,C.D, Mah, K.E, Kezirian, E. J, Dement, W.C. The effects of sleep extension on athletic performance of collegiate basketball players. *Sleep* 2011;34(7):943-950.
- Juliff, L.E, Halson S.L, Peiffer J.J. Understanding sleep disturbance in athletes prior to important competitions. *J Sci Med Sport* 2015; 18(1):13-8.
- Lastella M, Lovell GP, Sargent C. Athletes' precompetitive sleep behaviour and its relationship with subsequent precompetitive mood and performance. *Eur. J. Sport Sci*. 2014;14(Suppl 1):S123Y30.
- Bird SP. Sleep, recovery, and athletic performance: a brief review and recommendations. *Strength Cond. J*. 2013;35:43Y7.
- Carskadon, M. A, Dement W.C. Monitoring and staging human sleep (Chapter 2 – Normal Human Sleep: An overview. In: *In principles and practice of sleep medicine*. 5th edition. Kryger M. H, Dement W.C, T Roth. Elsevier Saunders. St. Louis 2011;pp. 16-26.
- 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;26:117Y26.
- Hugh H.K. Fullagar, Rob Duffield, Sabrina Skorski, Aaron J. Coutts, Ross Julian, and Tim Meyer. Sleep and Recovery in Team Sport: Current Sleep-Related Issues Facing Professional Team-Sport Athletes. *International Journal of Sports Physiology and Performance*, 2015,10, 950-957.
- Halson S.L, Jeukendrup A.E. Does overtraining exist? *Sports Med*. 2004; 34:967-981.
- Cohen S, Doyle WJ, Alper CM, et al. Sleep habits and susceptibility to the common cold. *Arch. Intern. Med*. 2009;169:62Y7.
- Hannibal, J, Martiny, K. Døgnrytmer og det circadiane system (Kapitel 4). In: Søvn, Jenum, P. Munksgaard, København; 2013 pp 51-58.
- Milewski MD, Skaggs DL, Bishop GA, Pace, J.L, Ibrahim, D.A, Wren T.A et al. Chronic lack of sleep is associated with increased sports injuries in adolescent athletes. *J. Pediatr. Orthop*. 2014;34:129Y33.
- von Rosen P, Frohm A, Kottorp A, Fridén C, Heijne, A. Multiple factors explain injury risk in adolescent elite athletes: applying a biopsychosocial perspective. *Scand. J. Med. Sci. Sports*. 2017.
- Betts, J.A, Stokes, K.A, Toone, R.J, Williams, C. Growth hormones responses to consecutive exercises bouts with ingestion of carbohydrate plus protein. *Int J Sports Nutr Exercis Metab* 2013;23:259-270.
- Taylor L, Christmas BC, Dascombe B, et al. Sleep medication and athletic performance—the evidence for practitioners and future research directions. *Front. Physiol*. 2016;7:83.
- Rossa KR, Smith SS, Allan AC, Sullivan KA. The effects of sleep restriction on executive inhibitory control and affect in young adults. *J. Adolesc. Health*. 2014;55:287Y92.
- Watson A, Brickson S, Brooks A, Dunn W. Subjective well-being and training load predict in-season injury and illness risk in female youth soccer players. *Br. J. Sports Med*. 2017;51(3):194-199.
- Skein, M, Duffield, R. Edge, J, Short, M.J, Mundel, T. Intermittent sprint performance and muscle glycogen after 30 h sleep deprivation. *Med Sci Sports exerc* 2011;43:1301-1311.
- Oliver, S.J, Costa R.J, Laing, S.J, Bilzon, J.L, Walsh, N.P. One night of sleep deprivation decreases treadmill endurance performance. *Eur J Appl Physiol*. 2009;107:155-161.
- Walker, M. To sleep (chapter 1). In: *Why we sleep*, Walker, M. Penguin, New York; 2017;pp.1-12.
- George CF, Kab V, Kab P, et al. Sleep and breathing in professional football players. *Sleep Med*. 2003;4:317Y25.
- Fagundes SB, Fagundes DJ, Luna AA, et al. Prevalence of restless legs syndrome in runners. *Sleep Med*. 2012;13:771.
- Ronsen, O. Adjustment to travels across time zones (Kapitel 5). In: *IOC Handbook of Sports Medicine and Science: Cross Country Skiing*, Rusko, H. Blackwell Science, Oslo; 2003 pp 1-12.
- Fullagar HH, Skorski S, Duffield R, et al. Sleep and athletic performance: the effects of sleep loss on exercise performance, and physiological and cognitive responses to exercise. *Sports Med*. 2015; 45:161Y86.
- Simpson NS, Gibbs EL, Matheson GO. Optimizing sleep to maximize performance: implications and recommendations for elite athletes. *Scand. J. Med. Sci. Sports*. 2017; 27:266Y74.
- Taylor L, Christmas BC, Dascombe B, et al. The importance of monitoring sleep within adolescent athletes: athletic, academic, and health considerations. *Front. Physiol*. 2016;7:101.
- 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*. Published Online First May 22, 2015 as 10.1136/bjsports-2014-094332.