ASMAR Special Issue: Injury Prevention and Rehabilitation

Sleep Quality and Cognitive Skills Impact Neurocognitive Function and Reduce Sports-Related Injury Risk

Brett Haskell, Ph.D., C.M.P.C., Abigail Eiler, L.M.S.W., M.S.W., and Haven Essien, L.L.M.S.W., M.S.W.

Abstract: Injury prevention in sports is critically influenced by cognitive factors, particularly sleep quality and cognitive skills. Research has underscored the role of cognitive processes in injury risk and recovery, highlighting that inadequate sleep and poor cognitive functioning can significantly elevate injury susceptibility. Despite the well-documented benefits of adequate sleep and cognitive training in mitigating injury risk, access to sports psychology expertise is limited among athletes and health care providers. This work reviews the literature on the effectiveness of cognitive skills and sleep training in reducing sports-related injuries. Sleep affects musculoskeletal recovery, cognitive function, and immune response, which may further exacerbate injury risk. Neurobiological processes during sleep are crucial for muscle repair, cognitive function, and immune efficiency, all of which are integral to reducing the injury risk in athletes. Environmental factors such as travel schedules, training intensity, and competitive pressures disrupt sleep and increase the risk of injury. Cognitive Behavioral Therapy for Insomnia has shown promise in addressing sleep disturbances by improving sleep habits and addressing cognitive distress related to sleep. In addition, cognitive skills training, including mental skills training and mindfulness, enhances perceptual awareness, decision making, and reaction times, potentially reducing injury incidence by improving cognitive and motor function. Evidence supports the pivotal role of sleep and cognitive skills in preventing sports injuries. Interventions like Cognitive Behavioral Therapy for Insomnia and mental skills training can effectively address these factors, suggesting that integrating these approaches into athlete training programs could significantly enhance injury prevention strategies. **Level of Evidence:** Level V, expert opinion.

Injury-prevention strategies are crucial for maintaining athletes' health and performance longevity.[1] Research indicates that cognitive factors play a significant role in injury occurrence and recovery.[2] Quality and quantity of sleep are known contributing factors impacting cognitive and physiological factors, affecting injury risk.[3,4] Athletes often experience inadequate sleep, with studies showing that approximately 28% of student-athletes report sleep difficulties and nearly 50% of elite athletes sleep less than the recommended 7 to 9 hours per night.[5] Insufficient sleep correlates with increased injury risk, with athletes who sleep less than 7 to 8 hours per night being significantly more prone to injuries.[6,7] Despite the known benefits of sleep and cognitive enhancement for preventing sport-related injury, few athletes and health care providers have access to experts in sport psychology who can assist in training athletes to achieve high-quality sleep and cognitive skills that reduce the likelihood of injury. This article will review the literature on the benefits of cognitive skills training and sleep training for reducing injury risk in sports.

Prevalence of Sleep-Related Injury in Athletes

Numerous studies indicate that athletes, especially those in high-intensity training or competition periods, often experience insufficient sleep.[1,8-10] A survey of elite athletes found that approximately 28% of student-athletes reported difficulty sleeping.[5] Additional studies reported that approximately 50% of elite athletes

From the National Women's Soccer League, Chicago, Illinois, U.S.A. (B.H.); University of Michigan School of Social Work, Ann Arbor, Michigan, U.S.A. (A.E.); and University of Michigan, School of Social Work, Ann Arbor, Michigan, U.S.A. (H.E.).

Received August 1, 2024; accepted November 17, 2024.

Address correspondence to Brett Haskell, Ph.D., C.M.P.C., National Women's Soccer League, 111 S. Wacker, Suite 1800, Chicago, IL 60606, U.S.A. E-mail: bhaskell@nwslsoccer.com

2666-061X/241251
https://doi.org/10.1016/j.asmr.2025.101077

reported poor sleep quality, with an average sleep duration of less than the recommended 7 to 9 hours per night, with football athletes reporting the least amount of average hours sleeping.[6,7,10,11] Studies consistently show that athletes who sleep less than 7 to 8 hours per night are at a greater risk of injury.[12-14] A study on adolescent athletes found that those who slept fewer than 8 hours were 1.7 times more likely to get injured than those who slept for 8 or more hours each day.[10,11,15] Researchers who have explored optimal sleep quantity to reduce injury rates and improve performance have commonly found athletes need between 8 and 10 hours of sleep per night depending upon training and competition demands and other lifestyle factors.[16,17]

Role of Sleep in the Likelihood of Injury

Although today's athletes have access to extensive training and evaluation tools aiding in their sport development, one of the most critical variables often remains overlooked by their coaches and trainers—quantity and quality of sleep.[4,6,18] Sleep has a profound impact on musculoskeletal, cognitive, and learning development.[14] Importantly, each of these factors mediate the relationship between sleep and sport-related injury. During sleep, several neurobiological, neuroendocrine, and neurocognitive processes occur, which impact mental acuity, perceptual awareness, reaction times, soft-tissue repair, and immune function.[10,11,19] Sleep is crucial for muscle recovery, repair, and growth. During deep sleep stages, the body releases human growth hormone, testosterone, and prolactin, which facilitate tissue repair and muscle growth, reducing the likelihood of overuse injuries and improving the musculoskeletal systems' response to dynamic movement in sport.[20] Poor sleep impairs sensorimotor processes (balance), motor coordination, and retention of newly learned motor skills.[4,21] In combination with reduced soft-tissue recovery rates, these neuromuscular impairments dramatically increase the risk of injury for otherwise-healthy athletes.[14,22]

Similarly, during light stages of sleep, including REM sleep, various neurocognitive processes occur to both restore and build cognitive functions that directly affect the likelihood of injury.[14] During REM sleep memory is consolidated, synaptic connections are built, and procedural memories (how to do things) are laid down.[23-25] When sleep is impaired either in quantity (truncated) or quality (impaired sleep stages), these neurocognitive processes are altered, impacting our working memory function when awake and, for athletes, performing in sport. Specifically, athletes experience a reduced ability to perceive and process information in their environment, reaction times are slowed, they are more distracted, tasks take longer to complete, they are more emotionally impulsive, and they are more likely to make high-risk decisions as they overestimate the likelihood of a positive outcomes.[14,26-29]

Finally, sleep deprivation can create problems related to immune function. Immune cells peak in concentration during slow-wave sleep; therefore, when sleep is truncated and or sleep stages are altered, immune functioning is weakened.[30,31] A weakened immune function makes athletes more susceptible to illness and prolonged recovery times, which can indirectly increase injury risk and decrease recovery rates.[14,32,33] As demonstrated in Figure 1, dysregulation in sleep pattern stemming from cognitive distress, poor sleep habits, and sleep disorders can increase the risk of injury in athletes.

Barriers to Sleep for Athletes

Although the benefits of sleep quantity and quality are clear, there are still many environmental factors and sleep disorders that place athletes at heightened risk for sleep complications. Athlete travel schedules are a leading cause of sleep disruption, causing chronic sleep-related issues for athletes.[28] Travel across time zones can cause jet lag, and inconsistent sleep schedules resulting from changing travel times can disrupt sleep patterns like circadian rhythms which help regulate the sleep process.[34] In addition, Samuels[34] found that changing game times from afternoon to evening, sometimes starting as late as 9 PM, has stimulating

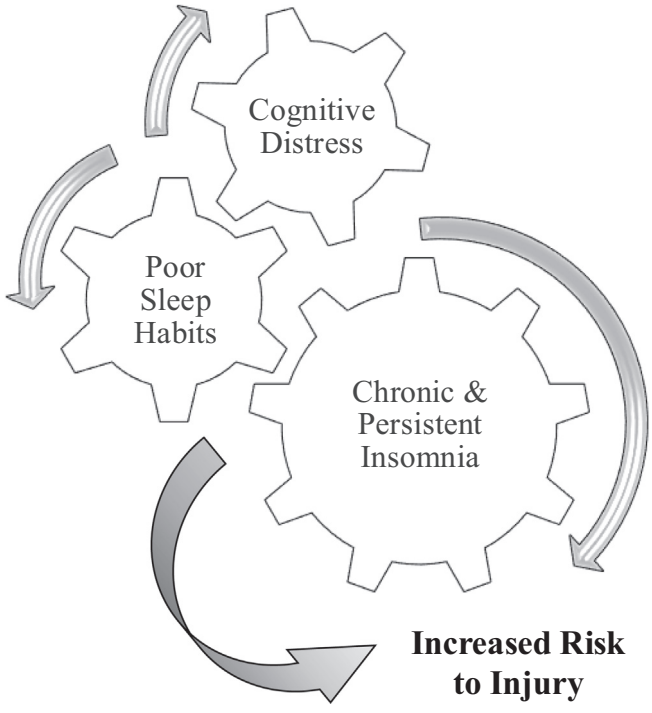

Fig 1. Factors influencing sleep quality and recovery.

effects that prohibit athletes from falling asleep quickly when it is finally time to go to sleep. Similarly, the intensity and training load an athlete is experiencing can cause physiological discomfort that also leads to sleep disruptions. Finally, and perhaps most importantly, the chronic stress caused by pressures related to competition, social approval, and performance anxiety can create impairments in autonomic nervous system (ANS) functioning and ruminative worry promoting sleep-related disorders such as insomnia.[14,35,36]

Given the foundational nature of sleep to the neurocognitive and perceptual performance and soft-tissue recovery, it is clear ensuring effective sleep is the single most critical cognitive prevention strategy to reduce injury risk. Athlete schedules, stressors, and workload all create significant boundaries to achieving efficient and effective sleep at worst causing clinical sleep disorders and at best reducing the overall quantity and quality of sleep for athletes. These environmental barriers prime athletes for sleep problems and disorders, making cognitive behavioral training for insomnia a key prophylactic intervention to reduce risk for sport-related injuries.

Interventions to Improve Sleep

Cognitive Behavior Therapy for Insomnia (CBTi) is a structured and evidence-based treatment strategy to address sleep behavior challenges and clinical sleep disorders. CBTi can be provided by licensed mental health providers with specific training. In addition, there are telehealth self-paced module CBTi treatment interventions for the most determined and conscientious patients. Herein, we will detail the theory behind CBTi and the core components of pathogen CBTi with a brief description of each intervention technique.

Two underlying factors have been identified within the literature as the likely etiologic pathogens for transient and clinical insomnia.[37-40] The first potential cause is cognitive distress, which prevents someone from achieving a parasympathetic state and neurocognitive brain wavelength conducive to falling asleep.[37,38] These worries may be because of personal life stress or even just worry about getting enough sleep or being able to fall asleep. Likewise, with a series of sleepless nights, a person's desire to get sleep and worry about not getting it intensifies, further perpetuating the problem.[37,38,41] This is why cognitive interventions become a central treatment strategy to alter unhelpful thinking patterns that contribute to ongoing worry about sleep.

The second potential cause is poor sleep habits and behaviors (sleep hygiene), which cause dysregulated circadian rhythms, making it difficult for the brain to anticipate when sleep should happen and subsequently mobilize the brain and body for sleep.[37,39] Behaviors contributing to poor sleep hygiene include irregular bedtimes and wake times, engaging in stimulating activities before bed, light exposure before bed or early in the morning, and engaging in nonsleep-related activities in your bed.[37] Behavioral interventions target altering these disruptive habits and creating increased consistency improving hypothalamic-pituitary and neurocognitive conditions that support high quality and quantity sleep (Supplemental Figure 1).

It is critical to note that both behavioral and cognitive factors impacting insomnia do so through the neurobiological arousal model.[37] Specifically, thoughts and stimulating behaviors induce activation in the sympathetic branch of the ANS, which directly competes with parasympathetic activation necessary for both falling asleep and staying asleep.[37,41-43] Therefore, cognitive behavioral interventions like CBTi are intended to improve relaxation and reduce the stimulation that triggers the sympathetic nervous system.[44] Because cognitive and behavioral actions can trigger sympathetic nervous system arousal, treatment must target thoughts, somatic experiences, and behaviors to achieve successful outcomes.[37,41]

Cognitive interventions primarily target dysfunctional beliefs about sleep that perpetuate the insomnia process (Supplementary Figure 2).[45] Specifically, cognitive reframing is used to mine for the patient's negative, dysfunctional, or irrational beliefs about sleep and to confront those beliefs with more rational statements that reduce sleep pressure causing sympathetic activation. For example, a female patient who believes they will not be able to perform successfully at all as the result of missing 3 hours of sleep (from lying awake) would challenge this thought by acknowledging all of the times she did successfully perform on little sleep. She would then be instructed to remind herself with a cue statement, "I don't need a perfect night's sleep or even great sleep to perform well."

As the result of increasing psychoeducation for athletes around the importance of sleep for sport performance and training, along with wearable devices that increase sleep awareness, sometimes to a level of obsession, increasing numbers of athletes are losing sleep over their worries about sleep. Lopes Dos Santos et al.[46] found that the pressures athletes feel from themselves, their athletic trainers, coaches, and wearable devices often can trigger the stress that directly prohibits achieving the necessary amount of activation in the parasympathetic nervous system (PNS) to get to sleep and stay asleep . The risks associated with becoming obsessed with sleep, also referred to as orthoinsomnia, should be part of good sleep education programming and may need to be directly addressed in CBTi with athletes.[41,47]

Given the onset of insomnia is often a direct byproduct of personal or sleep stress and worry, which then triggers ANS arousal in the PNS branch, combining cognitive

interventions with autogenic training strategies is often a very successful combination of interventions to reduce time awake in bed.[14,48-51] These types of somatic interventions function to reduce physiological signs of stress and activate the parasympathetic branch of the ANS.[43,52] Some techniques may include paced breathing exercises, in which a person counts time on inhaling, exhaling, and holding one's breath. Guided relaxation techniques like a body scan focused on letting go of any tension notices, or progressive muscle relaxation where one progressively tightens and relaxes muscle groups throughout the entire body. These techniques pair well with cognitive strategies to aid patients in observing early success in treatment, increasing motivation, and capitalizing on placebo effects, which inherently make treatment more effective.[52]

Behavioral interventions to improve sleep quality and quantity in CBTi begin with environmental conditions and habits and become increasingly aggressive to decondition associations that directly impact the nervous system's arousal states.[37,41,53] During sleep hygiene education, patients explore all of the factors in their sleep environment that may be prohibitive to sleep, such as lighting, temperature, in-room distractions (animals or partners), bed comfort, and electronic use. Along with the guidance of a treatment provider, patients then develop a sleep game plan outlining a sleep routine to remind their brain and body to wind down sufficiently for sleep. Likewise, patients conduct an inventory of their sleep environment to address any barriers to sleep they can modify.

Often, good sleep hygiene and a sleep routine instills the confidence in patients that they can get good sleep to address transient bouts of insomnia; however, some cases of clinical insomnia can be resistant and require more aggressive strategies. One such strategy includes stimulus control.[54] Stimulus control uses principles of classical conditioning to extinguish any associations the brain and body have made between one's bed and not being able to sleep. Kim et al.[52] report that those with insomnia often lay in bed for long periods of time, becoming increasingly agitated and activated, with their beds becoming a trigger for stress when they lay down, triggering a stress response instead of a relaxation response in the ANS . Stimulus control reduces time spent in bed awake or stressed by instructing patients to get out of bed after 15 to 20 minutes awake and do something relaxing until they feel drowsy again and can try to return to their bed for sleep. They are encouraged to continue this process until they successfully fall asleep. This intervention uses the principles of classical conditioning to extinguish the problematic association and can be effective for treating both initial and middle parainsomnia.[37]

Similarly, another behavioral intervention sometimes used in CBTi is paradoxical intention.[53] During this practice, the patient is instructed to try to stay awake as long as possible. This has 2 mechanisms of action: first, cognitively it reduces irrational beliefs about "needing to fall asleep," thereby reducing feelings of pressure that are prohibitive to achieving a parasympathetic state. Second, it increases the level of fatigue in a patient by the time they do go to bed, reducing risks of negative associations with the bed that result from lying awake.[37]

For the most resistant forms of insomnia, sleep restriction may be prescribed. Sleep restriction includes reducing the amount of time a person plans to sleep to only the average amount of sleep they are currently getting.[55] The patient is then instructed to select a bedtime that is that amount of hours before their desired waketime. For example, if a person is only sleeping an average of 5 hours per night because of initial insomnia, and need to wake up at 6 o'clock in the morning, they would be instructed to set a bedtime of one in the morning to ensure they fall asleep quickly and obtain consolidated sleep. In combination with sleep hygiene practices, the patient is then gradually instructed to increase their bedtime in increments to slowly train their brain and body to sleep for longer stretches and feel drowsy earlier and earlier in the evening.

Sleep interventions should be a provider's first line of defense for reducing the risk of injury in large part due to the tremendous impact sleep has on neurocognitive function which is often the mediator for sport-related injury.[4,11,28,56] If a patient is sleeping sufficiently already, additional cognitive training exercises can be implemented to improve perceptual awareness, response times, and decision making, which further support the safety of athletes competing in sport.[57]

How Cognitive Skills Impact Injury Risk/ Prevalence

Cognitive training often is referred to as mental skills training in the discipline of sport psychology is intended to enhance the neurocognitive function of the central and peripheral nervous system to improve outcomes in sport performance.[58] Specifically, the mental skills trained are intended to directly impact functions like decision-making, perceptual awareness, response and reaction times, attention and focus, coping with pressure, and better situational awareness.[59,60] Although one can infer the potential benefits of neurocognitive training as a prophylactic for injury, limited research exists to support this hypothesis. However, a preponderance of the literature does indicate these neurocognitive abilities play a role in being able to effectively cope with the dynamic movements required in sport in efficient and effective ways; likewise, it is these dynamic, fast-paced, and unpredictable factors that often

lead to sport injury.[58,61] Thus, one can assume if an athlete has better neurocognitive abilities to support responsiveness to dynamic and unpredictable sport situations, they are more likely to be able to protect their bodies from injury.[61] Herein, we will outline the key mental skills that directly impact decision making under pressure, perceptual-awareness, and neurologic responsiveness to incoming stimuli (see Table 1 for a comprehensive summary). Addressing cognitive abilities and mental skills are most critical to injury prevention

Perceptual-Cognitive Skills

Perceptual cognitive abilities are intended to enhance an athlete's ability to read the environment, recognize patterns, and decode and respond to incoming stimuli more rapidly and accurately.[58,60] Perceptual cognitive skills are trained with mental skills such as visualization and imagery, virtual reality, dual-task training, and increased variability in practice conditions and scenarios. Visualization and imagery is the practice of creating internal experiences that mimic real-life competition scenarios. The psychoneuromuscular theory underpins the practice of visualization and imagery, which suggests that neurologic pathways for movements and responses can be relatively charged during the practice of visualization and imagery to increase pathway efficiency. Similarly, virtual reality training also allows the brain to increase repetition under variable conditions to initiate motor learning without the wear and tear of physical activity. Also, introducing unusual variables into the practice environment allows an athlete to build better mental maps, improving reaction times and response times, as research shows these psychomotor abilities in sport are a function of improved visual scanning and pattern recognition rather than the actual speed of neural communication.[58,62] This is pertinent, as mental mapping through mental imagery enables athletes to visualize and rehearse movements without physical practice, significantly enhancing their performance by simulating real-life actions.[63,64] This technique is effective for athletes of all ages and skill levels, aiding in the development of functional representativeness and better performance outcomes.[65]

Furthermore, during dual-task training athletes are asked to perform a cognitive task at the same time they complete a physical task, which has been demonstrated to improve focus and decision making under pressure. For example, a study by Faubert and Sidebottom[66] found that athletes who engaged in dual-task training had better performance and were less prone to injuries during high-pressure situations.

Attentional Focus Skills

The ability to attend to critical information, sustain attention over a lengthy and taxing competition or practice period, and drive out irrelevant distractions has been shown to impact injury-related risks in sport.[59,60] Specifically, several studies have found that athletes with greater cognitive function scores had a lower incidence of sports-related concussions.[60,67-69] The mechanism of action believed to mediate the relationship between attentional control and sports-related injury is enhanced situational awareness and better cognitive recognition.

Skills used to train attention and focus include concentration exercises, such as concentration grids, in which a large box contains a grid with the numbers 1-50 or 1-100 randomly scattered in each small box across the grid. To complete the exercise, a participant must cross off each number in order until they finish timing themselves and competing for better times with each trial. Memorization, trying to attend closely to small

Table 1. Summary of the Various Cognitive and Arousal Regulation Skills Involved in Sports Injury Prevention and Performance Improvement, Along With Their Related Training Methods and Key Supporting Studies

Skill Type	Description	Training Methods
Perceptual-cognitive skills	Enhances an athlete's ability to read the environment, recognize patterns, decode, and respond to stimuli rapidly and accurately.	Visualization and imagery, virtual reality, dual-task training, increased variability in practice.
Attentional focus skills	Ability to focus on critical information and sustain attention while ignoring distractions, impacting injury risk.	Concentration exercises (grids, memorization), mindfulness training shifting focus (internal vs external).
Decision-making skills	Reduces sport injury risk by improving decisiveness, reducing hesitancy, and enhancing motor coordination.	Timed decision-making drills under conditions, arousal regulation technique (breathing control), self-talk, observation of success, and visualization.
Arousal regulation skill	Managing nervous system arousal to balance the effects of autonomic nervous system responses on central nervous system functions, improving cognitive performance and injury prevention.	Breath control techniques (diaphragmatic breathing, box breathing, 4:6 breathing), autogenic training (progressive muscle relaxation, guided relaxation), mindfulness meditation, biofeedback training (heart rate variability, heart rate, skin conductance, etc.).

details of an object for a set amount of time, and/or trying to shift attention from an internal focus on your inner thoughts and feelings or to an external focus on things in your surroundings both broadly or more narrowly are all concentration exercises that can be practiced to improve attentional control.[70,71]

Perhaps the most widely supported evidence-based training method for improving attention and focus is mindfulness training.[72] Through various mindfulness training exercises, a participant works to draw attention to something specific like his or her breathing, tracking all of the sensations in the moment, noticing when attention has drifted and gently without self-judgment returning attention to the object of focus the breath.[70,71] Repetitive deliberate mindfulness practice has been shown to improve concentration, sustained attention, mental flexibility, and the ability to re-focus quickly.[72]

Decision-Making Skills

Important to reducing sport injury risk attributable to neurocognitive factors is improved decisiveness. Often, injuries are a result of hesitancy, which places the body in odd positions, increases muscle tension, slows reaction times, and decreases confidence, which in turn impairs motor coordination during dynamic sport situations.[59-61,68-70,73,74] Similar to other cognitive skills, decisiveness can be improved with targeted mental skills training.[75] For example, mental training drills in practice that require timed decision making under increasingly stressful conditions and variable levels of distraction are an excellent way to improve decisiveness while balancing accuracy. Importantly, to aid the athlete in coping with these conditions effectively arousal regulation and concentration skills, like breath control and verbal cueing, are a necessary foundation for these drills to improve skills rather than undermine confidence. Likewise, confidence itself can be addressed with mental skills training strategies like self-talk, observation of vicarious success, and visualization, which in turn also supports increased decisiveness and motor control/coordination.[73,76]

Arousal Regulation Skills

Attentional control, decision making, and perceptual cognition rely on managing nervous system arousal to balance the effects of ANS responses on central nervous system functions.[61] Effective regulation of arousal ensures that ANS influences, such as stress or relaxation, are appropriately integrated, enabling optimal cognitive performance and decision-making. This interplay between the ANS and central nervous system is crucial for athletes seeking to maintain focus, process information accurately, and make well-informed decisions on and off the fields of play. Yerkes and Dodson[77] demonstrated the Kuznets curve, often referred to as the inverted-U, relationship between ANS arousal and performance. Specifically, this seminal study explained that as the sympathetic nervous system (SNS) is activated we see an enhancement in neurocognitive and neurophysiological performance, specifically, with increasing doses of norepinephrine and epinephrine the brain and body are mobilized for fast and efficient action, attention narrows, we become increasingly alert, and our body delivers more blood and oxygen to our muscles. It is easy to see why this activation of our SNS can be very beneficial to sport performance and reduction in injury risk; however, as we become increasingly stressed and/or anxious, we receive larger doses of norepinephrine and epinephrine, which results in more intense SNS responses triggering our instinct to run, fight, or freeze, which is not helpful to performance and actively detrimental to the key cognitive and physiological tasks necessary to protect oneself from injury. Specifically, our digestive system shuts down, causing nausea and reducing the body's ability to distribute nutrients needed to the body, our pupils dilate, and attention narrows to a point where we can no longer perceive and track visual stimuli in our periphery; similarly, our ability to perceive sounds is blunted, we receive so much oxygen to our muscles in such a short time we deplete our energy stores very quickly, preventing us from having needed energy late in performance.[60,61,70] Intuitively, we can infer these impairments to one's perceptual-cognitive abilities, situational awareness, and decision-making will negatively impact an athlete's ability to protect oneself from injury.

Although the ANS is generally functioning outside of conscious awareness, the field of sport and performance psychology has developed mental strategies and skills that have been found to directly impact an athlete's ability to up-regulate and down-regulate the ANS to achieve optimal neurocognitive and neurophysiological conditions for performance.[78] The most efficient and effective way to consciously regulate the ANS is via breath control, specifically balancing inhales and exhales to either increase or decrease arousal.[78] Breath strategies for activating the PNS and down-regulating the SNS specifically include (1) diaphragmatic breathing, which emphasizes breathing deep into the belly/diaphragm and equalizing the inhale with a long slow and complete exhale; (2) low and slow breathing, which also emphasizes breath pacing focused exclusively on elongating each breath and attempting to reduce the total number of breaths per minute; (3) 4:6 breathing, which emphasizes the importance of the exhale for activating the PNS effectively by inhaling for 4 seconds and exhaling for slightly longer 6 seconds; and (4) box breathing, also a paced breathing technique in which the athlete uses breath holds along with inhales and exhales of in for 4, hold for 4, out for 4, and

again hold for 4. Zaccaro et al.[78] communicate the advantage of breath techniques is that they can be performed for brief periods of time or longer periods in a dose-response fashion to down-regulate a little, or a lot.

In addition to breath techniques, autogenic training such as progressive muscle relaxation or guided relaxation as well as meditation techniques like mindfulness-based training can have a direct impact on global ANS function via increasing overall balance between the SNS and PNS.[79] In progressive muscle relaxation, an athlete is guided verbally through a process of systematically contracting and releasing muscle groups to reduce neuromuscular messages that impact SNS activation. In guided relaxation, the athlete is guided through various imagery or visualization practices that also reduce neuromuscular tension. During mindfulness meditation, athletes are guided through a meditation practice focused on the ability to stay present in the moment, which reduces cognitive anxiety regarding future fears that trigger an SNS response. Although breathwork can be used actively during performance, these types of trainings are typically done pre- or postcompetition or practice.

Finally, aiding athletes in improving their interoceptive awareness of ANS activity can also allow for creative self-guided interventions and skills to improve ANS regulation. The means of doing so are via biofeedback training modalities during which an athlete's biological ANS responses are measured and made visible to the athlete for them to play with different strategies and determine which strategies are most effective for consciously influencing their ANS. Biofeedback uses biological measurement technology to assess things like heart rate variability, skin conductance, breaths per minute, heart rate, skin temperature, and blood pressure. Given the critical role of the ANS for optimizing or undermining the neurocognitive functions critical to self-protection from injury, similar to sleep, almost any mental skills program designed for injury prevention should include ANS management skills.

Conclusions

A broad body of literature supports the importance of neurocognitive abilities in protecting an athlete from injury.[2,19,21,58,60,68,80] Similarly, a preponderance of evidence indicates sleep is the bedrock for the effective functioning of one's neurobiology and neurophysiology and sleep disturbances create direct limitations on these abilities.[3,10,14,37] Likewise, research strongly supports the negative impact of sleep deprivation on both athletic performance and injury risk directly.[2,3,8,9,13-15,41] In contrast, there is a limited amount of research exploring the direct effects of mental skills training on reducing injury risk in sport.[73,79] However, given the evidentiary support that mental skills training does improve neurocognitive and neurophysiological functions directly tied to perceptual acuity in sport and that these functions have been proven to directly influence injury risk, it is safe to infer mental skills training is likely to be an aid in addition to other physiological strategies in preventing injury.[66] Noting that mechanisms to reduce injury include improved sleep and optimal neurocognitive skills and numerous evidence-based interventions exist to improve and optimize sleep and neurocognitive abilities offering sleep and/or mental skills training interventions prophylactically to athletes may be an effective way to reduce the risk of injury.[13-15,59,69,70,81] Specific interventions could include CBTi, visualization and imagery, mindfulness training, autogenic training, autogenic training, and modification of sport drill to improve perceptual-cognitive skills.[14,41,61,66,71-74]

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) used ChatGPT in order to improve readability. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

Disclosures

All authors (B.H., A.E., H.E.) declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. Vorster APA, Erlacher D, Birrer D, Röthlin P. Sleep difficulties in Swiss elite athletes. *Life* 2024;14:779.
2. Bahdur K, Pruna R, Erasmus H, Pedret C. Does cognition play a role in injury prevention and return to play in the elite football player? A perspective from the field. *Apunts Med Esport* 2018;53:125-128.
3. Fullagar HH, Skorski S, Duffield R, Hammes D, Coutts AJ, Meyer T. Sleep and athletic performance: The effects of sleep loss on exercise performance, and physiological and cognitive responses to exercise. *Sports Med* 2015;45:161-186.
4. Cunha LA, Costa JA, Marques EA, Brito J, Lastella M, Figueiredo P. The impact of sleep interventions on athletic performance: A systematic review. *Sports Med Open* 2023;9:58.
5. NCAA. NCAA Health and Wellness Study. 2022-2023. Indianapolis, IN: NCAA. https://ncaaorg.s3.amazonaws.com/research/wellness/Dec2023RES_HW-MentalHealthRelease.pdf. Accessed October 2, 2024.
6. NCAA. NCAA GOALS Study. Indianapolis, IN: NCAA; 2020. https://ncaaorg.s3.amazonaws.com/research/goals/2020AWRES_GOALS2020con.pdf 2019. Accessed October 2, 2024.

7. Mah CD, Kezirian EJ, Marcello BM, Dement WC. Poor sleep quality and insufficient sleep of a collegiate student-athlete population. *Sleep Health* 2018;4:251-257.
8. Fox JL, Scanlan AT, Stanton R, Sargent C. Insufficient sleep in young athletes? Causes, consequences, and potential treatments. *Sports Med* 2020;50:461-470.
9. Roberts SSH, Teo WP, Warmington SA. Effects of training and competition on the sleep of elite athletes: A systematic review and meta-analysis. *Br J Sports Med* 2019;53:513-522.
10. Walsh NP, Halson SL, Sargent C, et al. Sleep and the athlete: Narrative review and 2021 expert consensus recommendations. *Br J Sports Med* 2021;55:356-368.
11. Hamlin MJ, Deuchrass RW, Olsen PD, et al. The effect of sleep quality and quantity on athlete's health and perceived training quality. *Front Sports Act Living* 2021;3:705650.
12. Silva A, Narciso FV, Soalheiro I, et al. Poor sleep quality's association with soccer injuries: Preliminary data. *Int J Sports Physiol Perform* 2020;15:671-676.
13. Huang K, Ihm J. Sleep and injury risk. *Curr Sports Med Rep* 2021;20:286-290.
14. Charest J, Grandner MA. Sleep and athletic performance: Impacts on physical performance, mental performance, injury risk and recovery, and mental health: An update. *Sleep Med Clin* 2022;17:263-282.
15. Milewski MD, Skaggs DL, Bishop GA, et al. Chronic lack of sleep is associated with increased sports injuries in adolescent athletes. *J Pediatr Orthop* 2014;34:129-133.
16. Watson NF, Badr MS, Belenky G, et al. Recommended amount of sleep for a healthy adult: A joint consensus statement of the American Academy of Sleep Medicine and Sleep Research Society. *J Clin Sleep Med* 2015;11:591-592.
17. Paruthi S, Brooks LJ, D'Ambrosio C, et al. Consensus statement of the American Academy of Sleep Medicine on the recommended amount of sleep for healthy children: Methodology and discussion. *J Clin Sleep Med* 2016;12:1549-1561.
18. Ochoa-Lácar J, Singh M, Bird SP, Charest J, Huyghe T, Calleja-González J. How sleep affects recovery and performance in basketball: A systematic review. *Brain Sci* 2022;12:1570.
19. Chandrasekaran B, Fernandes S, Davis F. Science of sleep and sports performance—a scoping review. *Sci Sports* 2020;35:3-11.
20. Kjær M, Doessing S, Mjøsund Kp. Endocrine adaptations to training In: *The encyclopaedia of sports medicine: An IOC Medical Commission Publication, The Olympic textbook of medicine in sport*. 1st ed. Vol 14. Oxford, UK: Wiley-Blackwell, 2009;87.
21. Paillard T. Detrimental effects of sleep deprivation on the regulatory mechanisms of postural balance: A comprehensive review. *Front Hum Neurosci* 2023;14:1146550.
22. Doherty R, Madigan SM, Nevill A, Warrington G, Ellis JG. The sleep and recovery practices of athletes. *Nutrients* 2021;13:1330.
23. Siegel JM. The REM sleep-memory consolidation hypothesis. *Science* 2001;294:1058-1063.
24. Smith CT, Aubrey JB, Peters KR. Different roles for REM and stage 2 sleep in motor learning: A proposed model. *Psychol Belg* 2004;44:81-104.
25. Klemm WR. Why does rem sleep occur? A wake-up hypothesis. *Front Syst Neurosci* 2011;5:73.
26. Killgore WD, Balkin TJ, Wesensten NJ. Impaired decision making following 49 h of sleep deprivation. *J Sleep Res* 2006;15:7-13.
27. Grewal S, Theijse RT, Dunlop G, et al. Exploring the impact of sleep on emotional and physical well-being in professional cricketers: A cohort study over an in-season training period. *Front Sports Act Living* 2024;6:1389565.
28. Cook JD, Charest J. Sleep and performance in professional athletes. *Curr Sleep Med Rep* 2023;9:56-81.
29. 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;55:287-292.
30. Besedovsky L, Lange T, Born J. Sleep and immune function. *Pflugers Arch* 2012;463:121-137.
31. Cardinali D, Esquifino A. Sleep and the immune system. *Curr Immunol Rev* 2012;8:50-62.
32. Halson SL. Sleep in elite athletes and nutritional interventions to enhance sleep. *Sports Med* 2014;44:13-23.
33. Nobari H, Banihashemi M, Saedmocheshi S, Prieto-González P, Oliveira R. Overview of the impact of sleep monitoring on optimal performance, immune system function and injury risk reduction in athletes: A narrative review. *Sci Prog* 2023;106:368504231206265.
34. Samuels CH. Jet lag and travel fatigue: A comprehensive management plan for sport medicine physicians and high-performance support teams. *Clin J Sport Med* 2012;22:268-273.
35. Charest J, Grandner MA. Sleep and athletic performance: Impacts on physical performance, mental performance, injury risk and recovery, and mental health. *Sleep Med Clin* 2020;15:41-57.
36. Monti E, Carroll LM. Psychology of performance. *Curr Otorhinolaryngol Rep* 2023;11:381-386.
37. Grandner M. *Sleep and health*. London: Elsevier Science, 2019.
38. Morin CM, Espie CA. *Insomnia: A clinical guide to assessment and treatment*. New York, NY: Springer, 2003.
39. Bootzin RR, Epstein DR. Understanding and treating insomnia. *Annu Rev Clin Psychol* 2011;7:435-458.
40. Bonnet MH, Arand DL. Hyperarousal and insomnia: State of the science. *Sleep Med Rev* 2010;14:9-15.
41. Grandner M, Athey AB. *Sleep and sport: physical performance, mental performance, injury prevention, and competitive advantage for athletes, coaches, and trainers*. London: Academic Press, 2024.
42. Miglis MG. Autonomic dysfunction in primary sleep disorders. *Sleep Med* 2016;19:40-49.
43. Fink AM, Bronas UG, Calik MW. Autonomic regulation during sleep and wakefulness: A review with implications for defining the pathophysiology of neurological disorders. *Clin Auton Res* 2018;28:509.
44. Williams J, Roth A, Vatthauer K, McCrae CS. Cognitive behavioral treatment of insomnia. *Chest* 2013;143:554-565.
45. Morin CM, Bélanger L. Cognitive therapy for dysfunctional beliefs about sleep and insomnia. In: Perlis M, Aloia M, Kuhn B, eds. *Behavioral treatments for sleep disorders*. London: Academic Press, 2011;107-118.
46. Lopes Dos Santos M, Uftring M, Stahl CA, et al. Stress in academic and athletic performance in collegiate athletes:

A narrative review of sources and monitoring strategies. *Front Sports Act Living* 2020;2:42.
47. Baron KG, Abbott S, Jao N, Manalo N, Mullen R. Orthosomnia: Are some patients taking the quantified self too far? *J Clin Sleep Med* 2017;13:351-354.
48. Edinger JD, Arnedt JT, Bertisch SM, et al. Behavioral and psychological treatments for chronic insomnia disorder in adults: An American Academy of Sleep Medicine clinical practice guideline. *J Clin Sleep Med* 2021;17:255-262.
49. Friedrich A, Schlarb AA. Let's talk about sleep: A systematic review of psychological interventions to improve sleep in college students. *J Sleep Res* 2018;27:4-22.
50. 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:S123-S130 (suppl 1).
51. Lee S, Buxton OM, Andel R, Almeida DM. Bidirectional associations of sleep with cognitive interference in employees' work days. *Sleep Health* 2019;5:298-308.
52. Kim H, Jung HR, Kim JB, Kim DJ. Autonomic dysfunction in sleep disorders: From neurobiological basis to potential therapeutic approaches. *J Clin Neurol* 2022;18:140-151.
53. Sharma MP, Andrade C. Behavioral interventions for insomnia: Theory and practice. *Indian J Psychiatry* 2012;54:359-366.
54. Walker J, Muench A, Perlis ML, Vargas I. Cognitive Behavioral Therapy for Insomnia (CBT-I): A primer. *Klin Spec Psihol* 2022;11:123-137.
55. Peter L, Reindl R, Zauter S, Hillemacher T, Richter K. Effectiveness of an Online CBT-I Intervention and a face-to-face treatment for shift work sleep disorder: A comparison of sleep diary data. *Int J Environ Res Public Health* 2019;16:3081.
56. Simpson NS, Gibbs EL, Matheson GO. Optimizing sleep to maximize performance: Implications and recommendations for elite athletes. *Scand J Med Sci Sports* 2017;27:266-274.
57. Mann DT, Williams AM, Ward P, Janelle CM. Perceptual-cognitive expertise in sport: A meta-analysis. *J Sport Exerc Psychol* 2007;29:457-478.
58. Williams M, Wigmore T. *The best: How elite athletes are made*. London: Nicholas Brealey, 2021.
59. van de Wouw A. Advocating a holistic approach for sport injury prevention and rehabilitation. *Br J Sports Med* 2023;57:895-896.
60. Grooms DR, Onate JA. Neuroscience application to noncontact anterior cruciate ligament injury prevention. *Sports Health* 2016;8:149-152.
61. Ericksen S, Dover G, DeMont R. Psychological interventions can reduce injury risk in athletes: A critically appraised topic. *J Sport Rehabil* 2022;31:224-229.
62. Williams AM, Ford PR, Eccles DW, Ward P. Perceptual-cognitive expertise in sport and its acquisition: Implications for applied cognitive psychology. *Appl Cogn Psychol* 2011;25:432-442.
63. Di Corrado D, Guarnera M, Guerrera CS, et al. Mental imagery skills in competitive young athletes and non-athletes. *Front Psychol* 2020;11:633.
64. Cumming J, Williams SE. *The role of imagery in performance*. Oxford, England: University of Oxford, 2012.
65. Frank C, Land WM, Popp C, Schack T. Mental representation and mental practice: experimental investigation on the functional links between motor memory and motor imagery. *PLoS One* 2014;9:e95175.
66. Faubert J, Sidebottom L. Perceptual-cognitive training of athletes. *J Clin Sport Psychol* 2012;6:85-102.
67. Swanik CB, Covassin T, Stearne DJ, Schatz P. The relationship between neurocognitive function and noncontact anterior cruciate ligament injuries. *Am J Sports Med* 2007;35:943-948.
68. Wilke J, Groneberg DA. Neurocognitive function and musculoskeletal injury risk in sports: A systematic review. *J Sci Med Sport* 2022;25:41-45.
69. Johnson U, Ivarsson A. Psychosocial factors and sport injuries: Prediction, prevention and future research directions. *Curr Opin Psychol* 2017;16:89-92.
70. Ivarsson A, Johnson U, Andersen MB, Tranaeus U, Stenling A, Lindwall M. Psychosocial factors and sport injuries: Meta-analyses for prediction and prevention. *Sports Med* 2017;47:353-365.
71. Reiche E, Lam K, Genoese F, Baez S. Integrating mindfulness to reduce injury rates in athletes: A critically appraised topic. *Int J Athl Ther Training* 2023;28:291-298.
72. Jha A. *Peak mind: Find your focus, own your attention, invest 12 minutes a day*. London: Hachette UK, 2021.
73. Feltz DL, Ewing ME. Psychological characteristics of elite young athletes. *Med Sci Sports Exerc* 1987;19:S98 (5 suppl).
74. Williams AM, Reilly T. Talent identification and development in soccer. *J Sports Sci* 2000;18:657-667.
75. Gabbett TJ, Carius J, Mulvey M. Does improved decision-making ability reduce the physiological demands of game-based activities in field sport athletes? *J Strength Cond Res* 2008;22:2027-2035.
76. Vealey RS. Conceptualization of sport-confidence and competitive orientation: preliminary investigation and instrument development. *J Sport Exerc Psychol* 1986;8:221-246.
77. Yerkes RM, Dodson JD. The relation of strength of stimulus to rapidity of habit-formation. *J Comp Neurol Psychol* 1908;18:459-482.
78. Zaccaro A, Piarulli A, Laurino M, et al. How breath-control can change your life: A systematic review on psycho-physiological correlates of slow breathing. *Front Hum Neurosci* 2018;12:353.
79. Ganguly A, Hulke SM, Bharshanakar R, Parashar R, Wakode S. Effect of meditation on autonomic function in healthy individuals: A longitudinal study. *J Family Med Prim Care* 2020;9:3944-3948.
80. Walker MP. The role of sleep in cognition and emotion. *Ann N Y Acad Sci* 2009;1156:168-197.
81. Gabbett TJ, Jenkins DG. Relationship between training load and injury in professional rugby league players. *J Sci Med Sport* 2011;14:204-209.