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FUELING PERFORMANCE STARTS WITH SLEEP: HOW SLEEP LOSS UNDERMINES NUTRITIONAL GOALS

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KEY POINTS

- Sleep modulates key appetite-regulating hormones (ghrelin, leptin) that influence food intake.
- Sleep deprivation impairs glucose metabolism and raises cortisol, increasing fat storage and metabolic risk.
- Sleep loss shifts brain reward circuitry, intensifying cravings for high-calorie foods.
- Student athletes are especially vulnerable to chronic sleep restriction due to academic responsibilities, social pressures and training or practice schedules, including early school start times particularly for high school students.
- Integrating sleep hygiene into nutrition planning enhances performance, recovery and body composition goals.

INTRODUCTION

Nutritional strategies are essential for athletic performance. Yet sleep remains an often-overlooked factor that profoundly influences dietary regulation, metabolic function and body composition. While its role in enhancing speed, strength, endurance and reaction time is widely recognized, sleep's equally critical influence on nutritional outcomes is frequently underestimated (Craven et al., 2022; MSSE, 2019). Insufficient sleep disrupts key appetite hormones, alters neural reward pathways, impairs glucose metabolism and elevates cortisol levels (Halson, 2014; Rogers et al., 2024; St-Onge et al., 2016b). These physiological shifts can sabotage even the most carefully planned nutrition strategy.

Athletes at all levels, including recreational, collegiate and professional, are susceptible to sleep deprivation due to demanding training schedules, frequent travel, psychological stress and daily obligations. These pressures are well documented to reduce sleep quality and duration, with known consequences for performance and injury risk (Gupta et al., 2017; MSSE, 2019; Roberts et al., 2019). Student athletes face additional challenges. Academic pressures and early school start times further constrain sleep opportunity. Adolescents, in particular, are biologically wired for later sleep timing, but rarely meet the recommended sleep duration (Carskadon, 2014). This compromises both recovery and resilience (Mason et al., 2023). Nearly three-quarters of high school students report inadequate sleep on school nights (CDC, 2021). Among collegiate athletes, short sleep and poor sleep quality are also widespread and are linked to diminished physical and mental performance (Brauer et al., 2019). When sleep is insufficient, hormonal and metabolic systems shift in ways that increase hunger, promote fat storage and impair recovery. Therefore, optimizing sleep should be considered a foundational pillar, alongside nutrition and training, for achieving peak performance and long-term athletic success. This Sports Science Exchange (SSE) article examines issues surrounding sleep and athletic performance. While much of the foundational research on sleep and metabolism comes from non-athletic populations, the physiological mechanisms are highly relevant to athletes. Nevertheless, more athlete-specific studies are needed to better quantify these effects and guide tailored strategies.

RESEARCH REVIEW

Appetite Hormone Dysregulation

Sleep plays a critical role in maintaining hormonal balance, particularly in the regulation of appetite. Sleep restriction consistently leads to an increase in ghrelin, a hunger-stimulating hormone produced by the stomach, and a decrease in leptin, a satiety hormone released from adipose tissue (Spiegel et al., 2004, Taheri et al., 2004). This hormonal shift promotes increased appetite and reduces post-meal satisfaction (Schmid et al., 2008).

Experimental studies in healthy adults show that even short-term sleep restriction, such as one or two nights of insufficient sleep, can significantly raise ghrelin levels and lower leptin concentrations. This hormonal imbalance increases hunger and drives a stronger preference for calorie-dense foods (Schmid et al., 2008; Spiegel et al., 2004; Taheri et al., 2004). These endocrine changes often emerge after just one night of restricted sleep and tend to worsen with ongoing sleep debt (Taheri et al., 2004).

Population-based laboratory studies confirm that short sleep duration is associated with elevated ghrelin and reduced leptin levels, independent of body mass index (Lin et al., 2020). These hormonal alterations are likely to drive increased energy intake and contribute to weight gain. Meta-analyses and recent laboratory findings further support the rapid onset of these effects, with changes in hormone levels occurring by the following morning after sleep deprivation (Lin et al., 2020; van Egmond et al., 2023). The American Heart Association has identified this disruption in appetite-regulating hormones as a key mechanism linking short sleep duration to increased energy intake and obesity risk (St-Onge et al., 2016a).

In summary, restricted sleep leads to increased ghrelin and decreased leptin, resulting in greater appetite, reduced satiety and a higher risk of overeating. These effects can occur rapidly and are amplified by ongoing sleep insufficiency. While these hormonal responses are well established in non-athletic populations, few studies have specifically examined these effects in athletes. Given their higher energy expenditure and metabolic flexibility, the magnitude and consequences of these hormonal shifts may differ. More athlete-focused research is needed to determine the relevance of these findings in sports nutrition planning.

Altered Neural Reward Processing

Beyond hormonal disruptions, sleep deprivation also alters brain function in ways that increase vulnerability to poor dietary decisions. Neuroimaging research shows that sleep loss significantly impacts brain regions involved in both reward processing and self-regulation. Specifically, it heightens activation in the amygdala and nucleus accumbens, centers that process hedonic and motivational responses to food, while dampening activity in the prefrontal cortex, which is responsible for impulse control and decision-making (Greer et al., 2013; Gujar et al., 2011; Rihm et al., 2019; St-Onge et al., 2012; Zhang et al., 2021).

Following sleep restriction, individuals exhibit greater responsiveness to high-calorie food cues and a reduced ability to resist them. In research studies, participants rated high-calorie foods as more desirable after sleep deprivation, regardless of hunger, due to amplified reward center activity and diminished prefrontal inhibition (Greer et al., 2013; Rihm et al., 2019). These neural shifts make energy-dense foods more tempting and harder to resist. This increases the likelihood of overeating even without physiological hunger.

Additional evidence confirms that these changes can occur after just one night of restricted sleep (Rihm et al., 2019). Partial sleep deprivation has been associated with increased activation in both the nucleus accumbens and prefrontal cortex in response to food stimuli, reinforcing the link between sleep loss and heightened food cue reactivity (St-Onge et al., 2012). Over time, chronic sleep restriction appears to intensify these effects, boosting the motivational value of calorie-dense foods and weakening the brain's cognitive control systems.

Collectively, these alterations in neural processing bias athletes toward immediate gratification. As a result, it becomes more difficult to follow structured nutrition plans or achieve optimal body composition.

Most neuroimaging studies in this area have been conducted in healthy, non-athletic adults. Although the same brain systems are involved in athletes, further research is needed to understand how these changes interact with training goals, discipline-specific nutrition strategies and performance mindset.

Impaired Glucose Metabolism

Short sleep duration has a well-documented negative impact on glucose metabolism and insulin sensitivity. Even brief periods of sleep restriction, such as 4–5 hours per night, can impair the body's ability to regulate blood sugar. Controlled laboratory studies have shown that insufficient sleep reduces whole-body glucose uptake and slows glucose clearance, leading to elevated blood glucose levels and increased fat storage.

Most of this evidence comes from healthy non-athletic populations, where sleep loss has consistently been linked to reduced insulin sensitivity, impaired glucose tolerance and increased cardiometabolic risk (Rogers et al., 2024; Sondrup et al., 2022; St-Onge et al., 2023; Tsereteli et al., 2022; Wilms et al., 2019). While data specific to athletes are more limited, emerging research suggests that athletes are not immune to these disruptions. For example, the EROS-PREDICTORS study in elite male athletes demonstrated that both sleep quality and duration independently predicted metabolic and hormonal function, reinforcing the importance of sleep for maintaining metabolic health in this population (Cadegiani & Kater, 2020). However, the magnitude and clinical impact of these disruptions in athletes, who often possess greater insulin sensitivity and metabolic flexibility, remain less well characterized and warrant further study.

Experimental evidence in healthy adults illustrates the rapid onset of these effects. A single night of sleep loss has been shown to reduce glucose disposal by ~25% and increase hepatic insulin resistance (Donga et al., 2010). After one week of sleep restriction, insulin sensitivity declined by 11–20%, with no compensatory increase in insulin secretion (Buxton et al., 2010). These findings reflect both peripheral and hepatic impairments in insulin action.

In the athletic population, such impairments could have important performance consequences. Disrupted glucose metabolism may reduce carbohydrate availability for contracting muscles, delay post-exercise recovery and hinder training adaptations. As a result, ensuring adequate and high-quality sleep should be considered a foundational strategy for metabolic health and performance.

Some have suggested reducing carbohydrate intake during periods of sleep deprivation to blunt glycemic excursions. However, this recommendation is largely based on studies in sedentary or general populations. For athletes, carbohydrates remain the primary fuel source, particularly during moderate- to high-intensity training. The American College of Sports Medicine emphasizes that carbohydrate intake should be individualized and periodized according to training demands—even in the context of sleep loss (Thomas et al., 2016; Rodriguez et al., 2009). There is no evidence supporting routine carbohydrate restriction in sleep-deprived athletes. Instead, practitioners should focus on optimizing sleep quality while maintaining carbohydrate timing, quality and quantity to support performance and recovery.

Elevated Cortisol and Fat Accumulation

Sleep deprivation is closely linked to elevated secretion of cortisol, and controlled laboratory studies have demonstrated that both partial and total sleep restriction in healthy adults leads to increased evening and overall cortisol levels (Balbo et al., 2010; Guyon et al., 2014). Leproult and Van Cauter (2010) specifically observed that sleep loss raised

evening cortisol concentrations, reflecting a significant disruption in hypothalamic-pituitary-adrenal (HPA) axis activity. In one study, just two nights of restricted sleep resulted in a 21% increase in total cortisol output (Guyon et al., 2014).

Elevated cortisol has multiple metabolic consequences. It promotes fat storage, particularly in the abdominal region, and interferes with muscle protein synthesis and energy regulation (Leproult & Van Cauter, 2010). In a randomized controlled trial, sleep-restricted participants experienced greater increases in abdominal and visceral fat compared to those who were well rested (Covassin et al., 2022). Chronically elevated cortisol contributes to visceral fat accumulation and reduced insulin sensitivity. Supporting this, recent reviews and Mendelian randomization studies have shown a causal relationship between higher cortisol levels and reduced muscle strength and lean body mass, reinforcing its role in catabolic processes and muscle protein breakdown (Katsuhara et al., 2022; Morrison et al., 2022).

Among athletes, persistently high cortisol levels can hinder recovery, slow lean mass development and increase the risk of injury. The American College of Sports Medicine and the American Medical Society for Sports Medicine have reported that chronic cortisol elevation, particularly in the context of overtraining, is associated with lower testosterone-to-cortisol ratios, diminished anabolic signaling and impaired musculoskeletal repair (MSSE, 2019). Sleep debt may further exacerbate injury risk by increasing catabolic activity and weakening tissue integrity (de Sousa Nogueira Freitas et al., 2020). Long-term cortisol elevation has also been observed in endurance athletes and is linked to adverse outcomes such as muscle loss and impaired recovery (Skoluda et al., 2012).

Taken together, current evidence strongly supports the relationship between sleep deprivation, increased cortisol production and downstream disruptions in fat distribution, muscle metabolism and athletic recovery.

STUDENT ATHLETES: A HIGH-RISK GROUP

Student athletes face a heightened risk of sleep deprivation and the related wide-ranging consequences. According to the Centers for Disease Control and Prevention (2021), nearly 73% of U.S. high school students report sleeping fewer than eight hours on school nights. Among adolescent athletes, sleep duration is even shorter, averaging just 6.3 hours per night. This falls well below the recommended 8-10 hours needed for optimal health and athletic performance (Fox et al., 2020).

Multiple factors contribute to chronic sleep restriction in this population, including early school start times, evening practices, academic pressures and nighttime screen use (Afolabi-Brown et al., 2022; Fox et al., 2020; Owens, 2014). The American Academy of Pediatrics (2014) has identified early start times as a modifiable barrier to adequate sleep and strongly supports delaying school start times to improve sleep duration, health and academic outcomes. Meta-analyses support this approach, showing that later start times are associated with increased sleep, better mood and improved developmental markers (Yip et al., 2022).

For student-athletes, the impact of inadequate sleep extends beyond academics. The physical demands of training and competition intensify the consequences of sleep loss. Research links chronic sleep deprivation in this group to increased hunger, disrupted appetite regulation, poor food choices, impaired glucose control, delayed recovery and greater injury risk (Mason et al., 2023; MSSE, 2019). Adolescence is also a crucial period for growth and musculoskeletal development. Persistent sleep debt during this stage may blunt anabolic signaling, hinder physical development and weaken emotional resilience (Mason et al., 2023).

Delaying school start times is a scientifically supported public health intervention that promotes better sleep, enhances student well-being and supports athletic performance. Schools and athletic programs should align their schedules and policies with current evidence to give student athletes the opportunity to rest, recover and perform at their highest potential (AAP, 2014; Wheaton et al., 2016; Yip et al., 2022).

NUTRITIONAL STRATEGIES FOR SLEEP-DEPRIVED ATHELTES

Adequate sleep is essential for athletes' physical and cognitive performance, making nutritional strategies for sleep promotion a critical skill to develop early. A "food first" approach, emphasizing whole foods over supplements, supports both recovery and sleep quality. Sports dietitians, coaches, healthcare professionals and parents should align dietary choices with workout parameters (type, duration, intensity, frequency, timing, etc.) and periodized training plans. Key focus areas include strategic caffeine use and incorporating sleep-promoting foods into the athlete's diet.

Caffeine

Caffeine is widely used by 75-90% of athletes as an ergogenic aid (Del Coso et al., 2011; Desbrow & Leveritt, 2006; Van Thuyne et al., 2005). As an adenosine receptor antagonist, caffeine enhances endurance, power, resistance exercise performance and provides cognitive benefits (Pickering & Grgic, 2019). The International Society of Sports Nutrition recommends 3-6 mg/kg body mass taken 60 min pre-exercise for optimal performance while avoiding side effects associated with 9 mg/kg doses (Guest et al., 2021).

Habitual caffeine consumers may develop tolerance, requiring higher doses or timing adjustments to maintain ergogenic effects (Khodadadi et al., 2025). However, studies in a healthy adult population suggest that caffeine can negatively impact sleep latency and quality (Drake et al., 2013; Gardiner et al., 2023). Dunican et al. (2018) demonstrated this in rugby players, where elevated post-game caffeine concentrations from evening competition were associated with increased sleep latency. Athletes must carefully consider caffeine timing and dosage to balance performance benefits with sleep quality.

Genetic variations in caffeine metabolism partially explain inter-individual differences in performance responses and why some athletes experience sleep disruption or heightened anxiety post-ingestion (Guest et al., 2021). Since caffeine increases anxiety, athletes prone to pre-competition jitters may experience exacerbated symptoms and impaired performance (Liu et al., 2024; Guest et al., 2021).

Best practices include assessing individual caffeine tolerance, considering competition timing relative to sleep and following recommended dosages. Since side effects correlate directly with dose, athletes should use trial-and-error with lower doses during training sessions to develop an individualized, practical approach that optimizes benefits while minimizing adverse effects.

Sleep Promoting Foods

A functional food is a dietary item that, besides providing nutrients and energy, beneficially controls one or more targeted functions in the body by improving specific physiological responses and/or by reducing the risk of diseases (Nicoletti, 2012). Athletes should have a keen interest in including minimally-processed, functional foods, which could have a positive impact on sleep quality. A few examples of functional foods that may help promote positive sleep adaptations include tart cherries, tryptophan-containing foods and kiwifruit.

Tart Cherries. Tart cherries are well-known for their antioxidant capabilities, particularly anthocyanins (Damar et al., 2012). Beyond their potential for combating oxidative stress and inflammation, tart cherries have garnered attention for their possible role in assisting in sleep due to their melatonin concentration. It is well established that melatonin plays a crucial role in regulating sleep-wake cycles (Cajochen et al., 2003). Howatson et al. (2012) examined the effects of tart cherries on insomnia in 20 older healthy adults who drank one ounce (30 mL) of tart cherry juice concentrate 30 minutes before their evening meal for 10 days. When compared to their baseline, the participants who consumed tart cherry juice had significantly elevated melatonin levels. They also experienced increased sleep time and sleep efficiency compared to the placebo group. A recent meta-analysis by Stretton et al. (2023) suggested that there is evidence to support significant improvements in total sleep time and sleep efficiency. In addition, the objective meta-analysis included a wide age range of participants, suggesting that tart cherry juice may affect sleep regardless of age. When initiating a sleep protocol, 100% juice with no added sugar is advisable. A typical dosage of ~4 ounces (~120 mL), consumed around 30 min prior to sleep is generally recommended as a starting point for those seeking to enhance sleep quality (Stretton et al. (2023)).

Tryptophan-Containing Foods. Tryptophan is an essential amino acid that plays an important role in the synthesis of neurotransmitters, including both serotonin and melatonin (Paredes et al., 2009). Tryptophan levels in the blood depend on food consumption, especially protein, because, as an essential amino acid, the body cannot synthesize tryptophan. Considering the central role played by serotonin and melatonin in sleep and mood regulation, tryptophan-containing foods that increase the synthesis of these two neurotransmitters could prove beneficial (Peuhkuri et al., 2012).

Cereal is often a pre-sleep snack choice for athletes. The consumption of a tryptophan-enriched cereal (60 mg) has been shown to increase sleep efficiency, actual sleep time, immobile time and decreased total nocturnal activity, sleep fragmentation index and sleep latency in middle-aged/elderly (aged 55-75 yr) individuals (Bravo et al., 2013). While this study was performed in older adults, cereal sources like wheat germ, oat bran and whole oats can contain significantly more tryptophan and may be a prudent recommendation for young athletes to not only improve whole grain/fiber/nutrient intake but also support healthy sleep habits. Verster et al. (2015) found a moderate but significant impact of tryptophan on both sleep quality and insomnia in Dutch university students, even when controlling for total calorie intake. Nutrient dense foods that contain higher amounts of tryptophan content include 3 ounces (85 g) of turkey, beef, pork, tilapia, tuna, salmon, lobster and crab, 1 cup (240 mL) of 2% milk, ½ cup (170 g) of tofu and 1 cup (340 g) of quinoa (USDA Food Data Central).

Kiwifruit. Kiwifruit offers a host of nutritional benefits, including offering a rich source of vitamin C, potassium, fiber and other essential vitamins and minerals (USDA Food Data Central). Research investigating the impact of consuming two medium-sized kiwifruits by elite athletes (n=25) one hour before bedtime over four weeks produced significant improvements in sleep quality (i.e., improved Pittsburgh Sleep Quality Index global scores and sleep quality component scores) and improvements in recovery stress balance as defined by reduced general stress and sports stress scales (Doherty et al., 2023). This finding aligns with the work by Lin et al. (2011), which employed the same protocol, and reported significant improvements in total sleep time (13.4%) and sleep efficiency (5.4%). While more research is needed, the preliminary results suggest that a simple way to improve aspects of sleep for athletes may be as straightforward as consuming two kiwifruits one hour before bedtime as a practical, whole-food-based intervention.

PRACTICAL APPLICATIONS

- Integrate sleep as a core pillar of athletic nutrition and recovery strategies.
- Encourage 7-9 hours of quality sleep per night for adults and 8-10 hours for adolescents to optimize hormonal balance and metabolic health.
- Educate athletes on how sleep loss affects hunger cues, food cravings, insulin sensitivity and overall energy regulation.
- Modify nutrition plans during periods of sleep restriction by emphasizing protein and fiber intake while reducing added sugars and ultra-processed carbohydrates. However, athletes engaged in high-intensity training still require adequate carbohydrate availability. Instead of restricting carbohydrates outright, focus on timing, quality and portioning to align with training demands.
- Advocate for student athlete wellbeing through smarter scheduling, sleep hygiene education and protected recovery time.

- Consider individual tolerance to caffeine ingestion, the timing of the competition in relation to sleep and the appropriate dosage based on current recommendations.
- Functional, nutrient-dense foods may help promote sleep and/or enhance sleep quality measures, while also contributing to overall diet quality for athletes.

SUMMARY

Sleep is a critical regulator of the hormonal, metabolic and cognitive systems that shape nutritional outcomes and athletic performance. When sleep is insufficient, athletes experience disruptions in appetite-regulating hormones, stronger cravings for high-calorie foods, impaired glucose metabolism and elevated cortisol levels. These changes can undermine nutritional strategies, limit training adaptations and increase the risk of injury.

Student-athletes are especially vulnerable due to early school schedules, academic pressures and athletic demands that reduce sleep opportunity. Addressing sleep as an integral part of performance planning, alongside training and nutrition, is essential.

Prioritizing sleep supports better energy regulation, faster recovery and more consistent decision-making around food. For athletes at every level, sleep is not a luxury, it is a foundational tool for reaching performance, body composition and health goals.

While current evidence provides strong guidance from general population studies, further research focused specifically on athletic populations is needed to refine strategies and ensure optimal outcomes across various sports and training demands.

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