MATTHEW CRAWLEY, MS, CSCS,*D, RSCC, AND BRIDGET MELTON, EDD, CSCS, TSAC-F

SLEEP HEALTH IN HIGH PERFORMANCE POPULATIONS—CONSIDERATIONS TO OPTIMIZE ATHLETIC POTENTIAL

INTRODUCTION OF SLEEP HEALTH IN ELITE SPORTS

Sleep is an essential component to perform optimally in elite sport, and there is an abundance of research supporting the importance of sleep to achieve maximal athletic potential (3,16,21,24). In addition to physical training and nutritional influences on performance, sleep is often overlooked, but critical in support for recovery (4). Since sleep is a complex physiological process to summarize with numbers, discussing basic facts and quantitative data in high performance populations can provide more insight with the importance of sleep. In fact, about 70 million Americans experience sleep problems that can lead to performance decrements, decreased quality of life, and reduced overall well-being (5). Moreover, 35.2% of adults in the United States average less than seven hours of sleep per night (25). Additionally, a recent article by Nahban et al. performing health screening for 940 Olympic and Paralympic athletes found that over 20% of the athletes screened positive for poor sleep quality. A similar article from Ritland et al. identified that tactical athletes were found to have an average sleep quality rating in between poor and fair by 22% in subjects, and an average sleep time of 6.17 ± 3.24. Such results are concerning for a tactical athlete's marksmanship accuracy due to the risk of short sleep durations that can be associated with cognitive impairments, such as alertness, attention span, and memory (19). In addition, people who suffer from severe insomnia due to insufficient sleep are seven times more prone to experience an accident at work compared to those with sufficient sleep (25). Furthermore, the consequences of insufficient sleep pose risks for performances in the physical and cognitive domains.

The contextual challenges of sport, such as training schedules, competition schedules, travel, work and media obligations, social, personal, and environmental factors, can lead to insufficient sleep quality and sport performance (3). Specifically, sleep deprivation can negatively affect physical health factors, posing a risk for injuries, illnesses, metabolic dysfunction, and motor function, thus affecting sport performance (3,6,15). For example, insufficient sleep can lead to metabolic dysfunction and inflammatory processes, such as changes in the hormonal biomarkers of leptin, ghrelin, testosterone, and cortisol (6). In addition, sleep deprivation can negatively influence mental health factors, such as stress, anxiety, and depression, and may lead to alterations in cognitive performance (3,6,15). These effects pose serious implications for athletes that train at a high level daily with decrements in sport-specific performance if not properly addressed (1). The application of the most current evidence and anecdotal-based practices can drive realistic interventions to positively influence sleep health and sport performance (1). Furthermore, sleep hygiene strategies can combat poor sleep health to improve health, well-being, and athletic potential (27).

The training schedule for high performance populations is highly influential, since accumulated load affects planning sessions for technical and tactical skills, physical training, nutrition, recovery, and sleep practices (21). According to the American Academy of Sleep Medicine and Sleep Research Society, general population adults should attain 7 – 9 hr of sleep to physiologically and psychologically recover from daily activities (6). However, it is recommended that elite athletes attain 9 – 10 hr of sleep for preparation in high-level sports (4). Most recently, Sargent et al. measured habitual sleep duration in 175 elite athletes from team and individual sports reporting 6.7 ± 0.8 hours compared to their 8.3 ± 0.8 hours self-assessed need to feel rested (20). In a similar study, Sargent et al. identified that 70 elite athletes averaged 6.5 hr of sleep while Lastella et al. found that elite athletes average 6.8 hr of sleep due to varied bed and bedtime routines (13,21). It can be seen in the literature that total sleep duration can have serious implications for cognitive and physiological health (14). Therefore, a good understanding of required sleep need on an individual basis can shed light on requirements for high performance populations (21).

THE NEED FOR A SLEEP TOOLKIT FOR PERFORMANCE PRACTITIONERS

The prevalence of insufficient sleep with athletes calls for proper adherence to guidelines and recommendations to optimize health, well-being, sport performance, and tactical performance (26). Identifying trends with average sleep duration, in addition to observing bed and wake time behaviors, can provide an opportunity to self-monitor habits for an individualized, effective and quality sleep health program (26). The contextual challenges of high performance populations with their daily workload requirements (e.g., training schedule, travel, personal obligations) can benefit from direct feedback with sleep data tracking to influence decision making with prioritized efforts to maximize readiness and performance (26). Therefore, a sleep toolkit can provide resources to improve sleep health to optimize health and human performance.

Sleep interventions promoting sleep hygiene strategies can elicit cognitive and physical performance improvements in high performance sport (3,7,18). The scope of this article is to provide the framework for a "sleep toolkit" for use in high performance populations. The toolkit includes access to education materials,

guidelines for sleep screening, and wearable product information for consumers to drive interventions to improve sleep health, training, and recovery for elite sport. The recommendations will allow tactical facilitators to interpret evidence and practically-based sleep health information advice to improve sleep health in high performance athletes.

SLEEP MEASUREMENT TOOLS

The availability of sleep measurement tools continues to rapidly increase, due to the growth in scope and depth of sleep research for optimal health, well-being, and sport performance (27). There are objective (wearables) and subjective (questionnaires and diaries) ways to monitor sleep. Objective tools, such as smart watches, rings, and wrist straps, can provide short- and long-term data monitoring on routines to improve sleep health awareness, increase coach-athlete interactions, and provide direct feedback (27). Such wearables can measure sleep duration, sleep efficiency, and sleep latency (time to fall asleep). For example, the Oura® ring (finger wearable) and the FitBit Ionic® (wrist wearable) are among some of the most validated devices for sleep health (8,9,12,26). Stone et al. assessed the accuracy of the Oura ring and FitBit Ionic reporting lower percent error values compared to seven other commercial devices in regard to total sleep time, sleep efficiency, and total wake time (26). These data provided evidence to support those two wearables while the others tested overestimated or underestimated such sleep metrics (26).

While wearables can provide direct feedback via smartphones, with the exponential growth of technology advancements to measure sleep duration, it is critical to acknowledge the need for a quality and effective personalized program to influence daily readiness and recovery (26). While there are highly accurate sleep measurements performed in clinical settings, there are limitations to measuring sleep stage subcategories (e.g., awake, light, rapid eye movement [REM], deep sleep) from wearables (10,22,23,26). This can be caused by the ever-improving advancements in technology and science and the varying validation methods in laboratory and third-party settings (10,22,23,26). Consequently, wearable sensors designed for sleep staging require further validation due to varying evaluation methods and risk of biases. Thus, it is recommended that products undergo a rigorous system and method design to measure overall accuracy in sensing, modalities, signals, and sleep stage categorization (10). While refining the sleep staging measurement process is continually changing with advances in technology, quantifying total duration remains a focal point of sleep health programs because of the prevalence of sleep deprivation. Therefore, it becomes vital for athletes, practitioners, and researchers to accurately measure sleep with valid and reliable devices to prompt the experience for the most optimal and consistent improvements in optimal functioning for performance (22).

Subjective tools, such as questionnaires and sleep diaries, can provide simple and cost-effective assessments to track bed and wake times, napping, and sleepiness (27). The most common and validated questionnaires include the Pittsburgh Sleep Quality Index (PSQI), Athlete Sleep Screening Questionnaire (ASSQ), and Athlete Sleep Behavior Questionnaire (ASBQ), because of their ease of use for practical applications (26). However, it is important to acknowledge that while personal perceptions can provide valuable information, emotions may lead to response biases; therefore, the availability of options to measure sleep for tactical facilitators must consider the limitation of subjective measures that fit the needs of their populations. Furthermore, the information provided by sleep measurement tools can provide in-depth details about sleep to drive interaction for an individualized performance program (26).

APPLICATION OF FINDINGS

There is no one-size-fits-all approach when it comes to sleep recommendations for athletes. Recommendations should be athlete-centered and specific to the contextual setting (tactical, sport or fitness-related) with consideration of sleep requirements, adjustments to work hours, training times, and the influence of sleep on eliciting behavior change through buy-in (27). Below are the top three components for sleep health considerations:

1. **Sleep Education**: Sleep education is a critical aspect of increasing awareness of the perceived barriers from a lack of sleep knowledge. Tactical facilitators can seek out information from organizations like the Centers for Disease Control and Prevention (CDC), American Academy of Sleep Medicine (AASM), and National Sleep Foundation (NSF) to develop intervention protocols that cater to the needs and wants for their desired population (Table 1). Resources such as presentations, educational videos, statistics, and scheduled check-ins can bridge the gap between sleep and performance.

2. **Sleep Screening**: Sleep screening can allow tactical facilitators to identify sleep disturbances, implement strategies for an action plan, and refer to specialists when needed. It can help manage athlete health and well-being and is critical in addressing sleep disturbances that may be preventing sleep hygiene strategies from being effective.

3. **Choose Sleep Measurement Tools Wisely**: Monitoring sleep with objective and/or subjective tools can be used to provide feedback for the athlete. Athlete-specific questionnaires, such as the ASSQ and ASBQ, can alert practitioners with sport-specific maladaptive sleep behaviors contexts associated with contact and non-contact sports (2,27). In turn, the practitioner must observe, interpret, and apply the findings of the data, thus understanding the limitations that exist between sleep monitoring tools.

FIGURE 1. TOP THREE SLEEP RECOMMENDATIONS

TOP THREE SLEEP HYGIENE RECOMMENDATIONS	
1. **Attain 8 – 10 hr of sleep per night**	The CDC reports that > 1/3 of adults in the United States receive insufficient sleep (5). Monitor pro-sleep habits such as making time for exercise, attaining natural sunlight to normalize circadian rhythms, adjusting and limiting caffeine intake in the afternoon, being mindful of alcohol effects, and avoiding late-night meals to prevent sleep disruption (17).
2. **Develop and keep a consistent sleep schedule**	Seek to wake up and go to bed at the same time every day, even on the weekends or vacations (5). Budget time for sleep, give extra time to wind down before bed, and adjust schedule gradually over time 1 – 2 hr maximum if needed (17).
3. **Create a personalized bedroom environment**	Use quality bedding, high-performance mattresses, and pillows. Additionally, set the thermostat to ideal temperatures of ~65° F to avoid feeling too hot or cold (17). Discontinue electronic devices 30 min before bedtime to avoid suppression of melatonin production (5,17).

FIGURE 2. SLEEP DISTURBANCE FACTORS (27)

SLEEP DISTURBANCE FACTORS					
Occupation Related	Training load (technical and non-technical responsibilities, training schedules, recovery)	Sleeping environment (temperature, lighting, comfort of bedding/pillows, quiet/white noise)	Work environment (climate, temperature), physiological arousal	Early or late occupation start and ending shifts (schedule times), night before scheduled events (training, competition, missions)	Travel and jet-lag considerations (adjustment to pre-wake routines, time zones, circadian rhythms alterations)
Non-Occupation Related	Individual (age, gender, training status, pre-existing health conditions)	Personality characteristics (attitudes, beliefs, values, morals)	Lifestyle habits (nutrition, caffeine, alcohol, drugs, leisure)	Social life, family and friend relationships (parents, spouse, children, friends)	Personal obligations (social media, sponsorship, personal demands)

(Figure adapted from Walsh et al., 2021)

FIGURE 3. SLEEP MEASUREMENT COMPARISONS (27)

SLEEP MEASUREMENT COMPARISONS			
	Advantages	*Disadvantages*	*Usability*
Sleep Questionnaires	Inexpensive and cost-effective. Feedback can be used to give sleep behavior information.	Can be influenced by response bias and lack of standardization in specific populations.	Require continued research and further validation support in athlete populations.
Wearables	Less invasive and user-friendly than research-grade tools, includes long-term data collection and analysis for increases in sleep awareness.	Sleep stage measurements can vary per tool. Immediate feedback can be detrimental to performance and are context-dependent.	Provide long-term monitoring in applied settings with the ability to be updated regularly through feedback.

(Figure adapted from Walsh et al., 2021)

ADVANTAGES AND DISADVANTAGES OF WEARABLE TYPES

The tradeoffs that exist for sleep wearables include battery life, size, weight, and human factors (e.g., wearable etiquette for training and bedtime), that may cause constraints with compliance (10). Therefore, size and comfort play a larger role with wrist-based devices, such as watches and straps, compared to smaller devices, such as rings. In addition, the cost of devices can range from $80 to over $300, leading to budgetary concerns. However, this is only a fraction of the cost of laboratory-based tests of sleep parameters (26). In all, these less invasive and cost-effective devices can present valuable information for long-term monitoring to create a sleep profile that provides details to positively influence health and human performance.

CHALLENGES AND FUTURE RESEARCH

Increases in sleep health awareness will lead to further advancements in research and development with wearable devices due to more robust evaluations, quality, effectiveness of application, and price. It is important to acknowledge the individual constraints that are linked to the usability, suitability, and limitations associated with wearables for long-term sleep monitoring to influence training and recovery (10). A foundational understanding of sleep physiology to assess sleep duration and efficiency must be considered when seeking to distinguish sleep stages (26). Furthermore, research should continue to evaluate and validate the accuracy of sleep staging, thus creating a new field in sleep research (10,26).

PRACTICAL APPLICATIONS

The ability to understand current sleep habits with bed and wake routines, total sleep time, and sleep latency can provide insights into improving health, well-being, and performance (26). Sleep monitoring can help with identifying the health and safety of athletes by managing fatigue and reducing the risk of decreased reaction time, thus reducing a multitude of physical and mental factors linked to poor sport performance (23). Thus, sleep measurement tools that are validated can increase sleep awareness and drive athlete-staff interaction to prompt further discussions regarding optimal performance (9,11,12,26). The monitoring of sleep can provide high performance populations health-related data to adjust their lifestyle and training load with biofeedback to influence decision making on recovery and readiness to perform.

REFERENCES

1. Anderson, M, and Reale, R. Discrepancies between self-reported current and ideal sleep behaviors of adolescent athletes. *Sleep Science* 13(1): 18-24, 2020.

2. Bender, A, Lawson, D, Werthner, P, and Samuels, C. The clinical validation of the athlete sleep screening questionnaire: An instrument to identify athletes that need further sleep assessment. *Sports Medicine* 4(23): 1-8, 2018.

3. Biggins, M, Purtill, H, Fowler, P, Bender, A, Sullivan, K, Samuels, C, and Cahalan, R. Sleep in elite multi-sport athletes: Implications for athletes health and well-being. *Physical Therapy in Sport* 39: 136-142, 2019.

4. Bonnar, D, Bartel, K, Kakoschke, N, and Lang, C. Sleep interventions designed to improve athletic performance and recovery: A systematic review of current approaches. *Sports Medicine*, 48, 683-703, 2018.

5. CDC. Centers for Disease Control and Prevention. June 5, 2017. Retrieved 2021 from Sleep and Sleep Disorders: https://www.cdc.gov/sleep/about_us.html.

6. Grandner, M. The cost of sleep lost: implications for health, performance and the bottom line. *American Journal of Health Promotion* 32(7): 1629-1633, 2018.

7. Dunican, I, Martin, D, Halson, S, Reale, R, Dawson, B, Caldwell, J, et al. The effects of the removal of electronic devices for 48 hours on sleep in elite judo athletes. *Journal of Strength and Conditioning Research* 31(10): 2832-2839, 2017.

8. Haghayegh, S, Khoshnevis, S, Smolensky, M, Driller, K, and Castriotta, R. Accuracy of wristband fitbit models in assessing sleep: systematic review and meta-analysis. *Journal of Medical Internet Research* 21(11): 1-17, 2019.

9. Henriksen, A, Svartdal, F, Grimsgaard, S, Hartvigsen, G, and Hopstock, L. Polar vantage and Oura® physical activity and sleep trackers: A validation and comparison study. *medRxiv* 1-11, 2021.

10. Imtiaz, S. A systematic review of sensing technologies for wearable sleep staging. *Sensors* 21(1562): 1-21, 2021.

11. Kinnunen, H, Rantanen, A, Kentta, T, and Koskimaki, H. Feasible assessment of recovery and cardiovascular health: Accuracy of nocturnal HR and HRV assessed via ring PPG in comparison to medical grade ECG. *Physiological Measurement* 41(4): 1-10, 2020.

12. Koskimaki, H, Kinnunen, H, Kurppa, T, and Roning, J. How do we sleep-a case study of sleep duration and quality using data from Oura® ring. Association for Computing Machinery International Joint Conference, 2018.

TABLE 1. SLEEP RESOURCES

SLEEP RESOURCES	
Centers for Disease Control and Prevention	https://www.cdc.gov/sleep/index.html
Sleep Education | AASM	http://www.sleepeducation.org/
AASM	http://www.aasmnet.org/
National Sleep Foundation	https://www.thensf.org/
Sleep Health | Healthy People 2020	https://www.healthypeople.gov/2020/topics-objectives/topic/sleep-health

13. Lastella, M, Roach, G, Halson, S, and Sargent, C. Sleep/wake behaviours of elite athletes from individual and team sports. *European Journal of Sport Science* 15(2): 1-8, 2015.

14. Marshall, G, and Turner, A. The importance of sleep for athletic performance. *Strength and Conditioning Journal* 38(1): 61-67, 2016.

15. Munafo, D, Loewy, D, Reuben, K, Kavy, G, and Hevener, B. Sleep deprivation and the workplace: Prevalence, impact, and solutions. *American Journal of Health Promotion* 32(7): 1644-1646, 2018.

16. Nabhan, D, Lewis, M, Taylor, D, and Bahr, R. Expanding the screening toolbox to promote athlete health: How the US olympic and paralympic committee screened for health problems in 940 athletes. *British Journal of Sports Medicine* 0: 1-6, 2020.

17. National Sleep Foundation. Sleep hygiene, healthy sleep tips. 2020. Retrieved 2021 from: https://www.sleepfoundation.org/sleep-hygiene/healthy-sleep-tips.

18. Peacock, C, Mena, M, Sanders, G, Silver, T, Kalman, D, and Antonio, J. Sleep data, physical performance, and injuries in preparation for professional mixed martial arts. *Sports* 1(7): 1-8, 2019.

19. Ritland, B, Simonelli, G, Gentili, R, Smith, J, He, X, Oh, H, et al. Sleep health and its association with performance and motivation in tactical athletes enrolled in the reserve officers' training corps. *Sleep Health* 5(9): 309-314, 2019.

20. Sargent, C, Lastella, M, Halson, S, and Roach, G. How much sleep does an elite athlete need? *International Journal of Sports Physiology and Performance* 16(12): 1-12, 2021.

21. Sargent, C, Lastella, M, Halson, S, and Roach, G. The impact of training schedules on the sleep and fatigue of elite athletes. *Chronobiology International* 31(10): 1160-1168, 2014.

22. Scott, H, Lack, L, and Lovato, N. A systematic review of the accuracy of sleep wearable devices for estimating sleep onset. *Sleep Medicine Reviews* 49(101227): 2020.

23. Seshadri, D, Thom, M, Harlow, E, Gabbett, T, Geltka, B, Hsu, J, et al. Wearable technology and analytics as a complementary toolkit to optimize workload and to reduce injury burden. *Frontiers in Sports and Active Living* 2: 1-17, 2021.

24. Snedden, T, Scerpella, J, Kliethermes, S, Norman, R, Blyholder, L, Sanfilippo, J, et al. Sport and physical activity levels impacts health-related quality of life among collegiate students. *American Journal of Health Promotion* 33(5): 675-682, 2019.

25. Suni, E, and Troung, K. Sleep statistics. February 8, 2021. Retrieved 2021 from: https://www.sleepfoundation.org/how-sleep-works/sleep-facts-statistics.

26. Stone, J, Rentz, L, Forsey, J, Ramadan, J, Markwald, R, Finomore, V, et al. Evaluations of commercial sleep technologies for objective monitoring during routine sleeping conditions. *Nature and Science of Sleep* 12: 821-842, 2020.

27. Walsh, N, Halson, S, Sargent, C, Roach, G, Nedelec, M, Gupta, L, et al. Sleep and the athlete: Narrative review and 2021 expert consensus recommendations. *British Journal of Sports Medicine* 55(7): 1-13, 2020.

ABOUT THE AUTHORS

Matthew Crawley is a Strength and Conditioning Coach at the Ultimate Fighting Championship (UFC) Performance Institute. With over 11 years in the strength and conditioning industry, he brings experience with professional organizations, such as UFC, National Football League (NFL), National Hockey League (NHL), and National Lacrosse League (NLL), as well as Olympic, tactical, collegiate, high school, and youth sectors. Crawley has presented at multiple regional and state conferences for the National Strength and Conditioning Association (NSCA), and published peer-reviewed articles and other scholarly publications. He holds Master's degrees in Human Health and Performance and Applied Nutrition, and is currently working towards a PhD in Leadership Studies: Health and Human Performance. Crawley's mission is to use evidence- and applied-based research to influence the implementation of physical preparation in elite athletes with an interdisciplinary athlete-centered approach to maximize their athletic potential. He is a Certified Strength and Conditioning Specialist® with Distinction (CSCS,*D®) and Registered Strength and Conditioning Coach (RSCC) with the NSCA.

Bridget Melton is a Professor of Exercise Science and Coaching Education, teaching a variety of undergraduate, graduate, and doctoral level courses. Her research incorporates physical activity promotion, worksite wellness, and tactical athletes. She has published 47 peer-reviewed articles, contributed to 13 books, and has given over 90 presentations to national and international audiences. Melton is active with several organizations, included the National Strength and Conditioning Association (NSCA), American Colleges of Sports Medicine (ACSM), National Association of Kinesiology in Higher Education (NAKHE), and the Georgia Association of Health Physical Education Recreation and Dance (GAHPERD).

PUSH YOURSELF TO BE THE BEST

HAMMER STRENGTH®

Introducing the new, self-powered Hammer Strength Performance Trainers. The **HD Tread**, **HD Air Bike** and **HD SPARC** are tough, durable and built to help service members quickly and efficiently push the boundaries of their performance training.

HammerStrength.com