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Sleep and performance across the lifespan. What is known about athlete requirements from children to adults and future direction: a narrative review

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ABSTRACT
Sleep is fundamental for health and wellbeing. Throughout our lifespan sleep requirements change due to alterations in our endogenous circadian rhythm and exogenous environment factors. Athletes demand for sleep is greater compared to general population and it is important to consider age specific guidelines for children, adolescents, adult and older adult athletes. However, sleep requirements in children and adolescent athletes is sparce. Further, adolescent athletes have additional stressors such as school and biological demands for sleep such as growth and maturation. Daily sleep demand and quality can be influenced by individual factors as well as the environment. Therefore, we aim to discuss the importance of sleep, the differences in sleep needs across the lifespan. We will then consider how this may be influenced by activity level and the impact of sleep on health and performance. Lastly, we provide possible interventions and future directions for research across the three age groups.

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Introduction

Poor and insufficient sleep is becoming a global concern, despite the known importance of sleep as a key component for overall health and wellbeing (Windred et al. 2024). Guidelines by the American Academy of Sleep Medicine and Sleep Research Society outline the recommended amount of sleep needed for optimal health across age groups, with children (6–12 years) requiring 9–11 hours (h), adolescents (13–17 years) requiring 8–11 h per night, adults (>18 years) 7–9 h and older adults (>65 years)

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7–8 h (Watson et al. 2015). We know that adolescents require more sleep due to development and maturation at both a physical and mental level. Despite greater sleep demand, the association between poor sleep and negative health outcomes is becoming increasingly relevant in adolescents, likely attributed to 24-hour connectivity to electronics and greater caffeine use (Owens et al. 2014). It has also been reported that adolescents have a delay in their biological clock in the timing of sleep onset, further contributing to reduced sleep as they typically stay awake later despite early rising times for school (Kokka et al. 2021). Sleep complaints are also common in adult and older adult populations with reports suggesting 1/3 of the population have "insufficient sleep" (referred to as <6 h per night). When poor quality and duration of sleep become a regular occurrence the risk of cardiometabolic disease, daytime dysfunction and other adverse health outcomes rapidly increases (Grandner and Fernandez 2021). Sleep debt is also prevalent in athletes and hinders performance due to the impact on immunological changes (Everson 1993; Zager et al. 2007) and increased risk of musculoskeletal injuries (Freitas et al. 2020; Silva et al. 2020); as reported in Olympic, Paralympic and young athletes (Silva et al. 2024). Other reported effects of inadequate sleep such as impacts on hormone production, specifically reductions in testosterone, have been reported previously in adult populations. These effects have not yet been evaluated in adolescent populations and therefore it is unknown if the consequences of sleep loss are the same across age groups (Leproult and Van Cauter 2011).

Given the importance of recovery in athletic preparation, in addition to adequate nutrition, sleep is considered a key strategy for success in sport (Nédélec et al. 2015; Watson 2017). Due to multiple factors such as travel to competition, training demands and pre-competition anxiety, the duration and quality of sleep can dramatically decrease prior to competition (Figure 1, Fullagar et al. 2015). When considering age, managing the stressors associated with sport participation become more complex for adolescent athletes as they have additional pressures such as schooling and maturation that must be considered (Figure 1). It is suggested that children and adolescent athletes should be closely monitored to assist and support the long-term development of the athlete and reduce the risk of injury and burnout (Gustafsson et al. 2016). Currently there is no age restriction for competitors in the Olympic Games other than as prescribed in the competition rules of an International Federation, as approved by the International Olympic Committee Board (IOC 2023). Age regulations sometimes differ within these federations, depending on the sport, discipline, or biological sex. The youngest Olympic athlete at Tokyo Summer Olympics 2020 was Hend Zaza a Syrian table tennis player, who was 12 years and 204 days old. In 2018, the International Skating Union proposed to move the minimum age to 17 in figure skating, but this proposal was rejected, suggesting young athletes competing is not set to change. Historically countries take the pragmatic approach and invest in talent identification programs to find potential athletes at an early age to create the correct stress–strain interactions allowing cellular, structural and systemic modifications to develop elite athletes.

Recent reviews investigating sleep in athletic populations have stated future research should broaden the current scope of literature on the prevalence and severity of sleep problems of athletes at all sport levels, particularly in adolescent athletes (Gradisar et al. 2011). A study that evaluated sleep duration of adolescent gymnasts (mean age 12.8

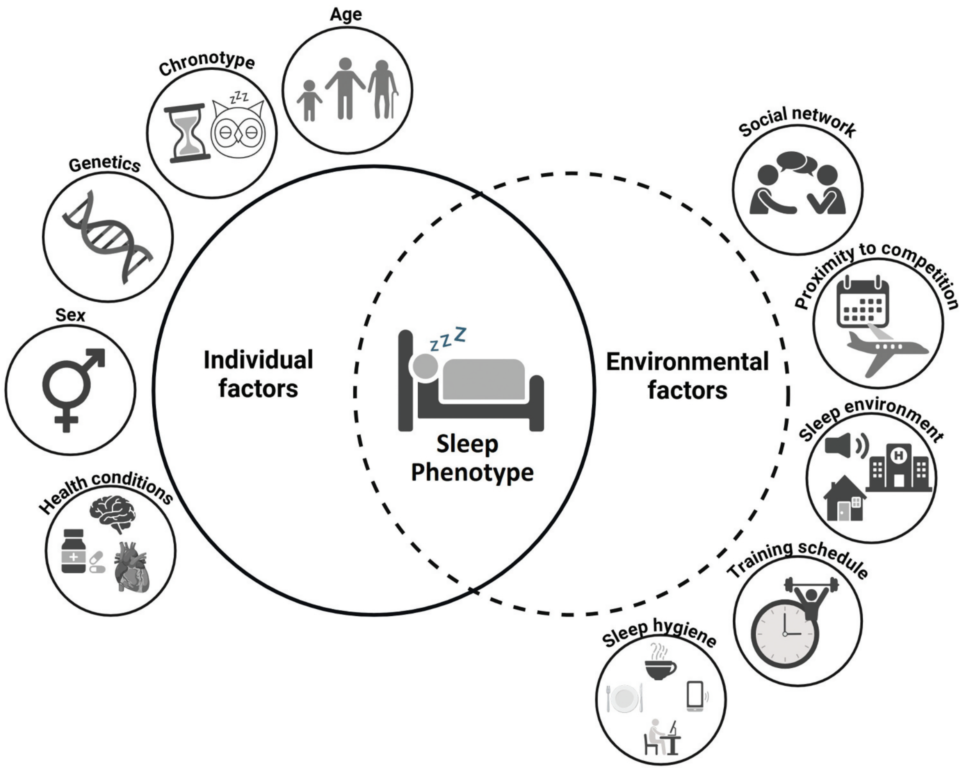

Figure 1. Individual and environmental factors that influence the quantity and quality of athlete's sleep phenotype.

years) reported that 91.5% of the gymnasts slept less than 8 h per night, with females having significantly less sleep on weekdays due to early training sessions when compared to non-athletic females (Silva et al. 2019). Other studies that evaluated adolescent athletic populations reported that inadequate sleep duration was independently associated with increased fatigue, training load, stress and muscle soreness (Coel et al. 2023). Participation in sport for goal-orientated reasons as opposed to enjoyment is at greater risk of not meeting sleep recommendations (Stracciolini et al. 2021). Therefore, the consensus of current research states that there needs to be a shift in focus towards prioritising overall health and performance. Developing a greater understanding of athlete sleep needs as they age will support recovery strategies and educate those supporting the athletes such as coaches, physicians, and parents. Age specific requirements are crucial, particularly for adolescents who are navigating through a period of development/puberty with added pressure of attaining academic achievements, that puts these individuals at risk of burn-out and dropping out of their sport (Gustafsson et al. 2016).

The aims of this review are to 1) discuss the importance of sleep, differences in sleep demands from across the lifespan and how this may be influenced by activity level (sedentary individuals to world class athletes) and the impact of sleep on health and performance, 2) provide possible interventions and suggest future directions for research across the three age groups.

What is sleep, why do we need it?

Sleep is a behavioral state characterized by relative immobility and reduced response to external stimuli. This is all regulated by homeostatic and circadian factors (Edwards et al. 2023). It is also considered a primitive human behavior experienced in the dark period of the day (either for protection or to save energy), which continues to be fundamental to the proper functioning of the human organism (Krueger et al. 2016). Human movement occurs predominant during the light period (solar exposure) of the day, it was necessary to hunt/gather and avoid predators for human survival and continues to be necessary today but for different reasons (Deslandes et al. 2009). Sleep is a non-negotiable biological state and the need for sleep is analogous to that of air and water, for the maintenance of human life (Grandner and Fernandez 2021).

Evolution has provided humans with an internal mechanism (body clock) to take advantage of the daylight hours for activity, rest and sleep during nighttime. This body clock is situated in the suprachiasmatic nuclei in the hypothalamus and becomes synchronized and in-tune with the environment and solar day (~24 h "circadian rhythm"). This is done by the coupling of cyclic changes in the external environment ("zeitgebers"-time cues), with rhythmic signals from melatonin originating from the pineal gland, an "internal zeitgeber" (Reppert and Weaver 2002; Hastings et al. 2018). The body clock is connected to networks of peripheral clocks, has roles in increasing alertness, mental and physical activity in the daytime and preparing the body for sleep. In the absence of external time cues (such as light/dark cycle), this master clock tends to run for about 24.3 h (Chadwick and Ackrill 2008). The "circadian rhythm" enables consolidated sleep to take place at night and prepares the body for waking to face the new day. The body clock does this via the rhythmic changes it produces in the autonomic nervous system, blood-borne hormones, core body temperature and the sleep-wake cycle (Chadwick and Ackrill 2008). Generally, the timing of the body clock is stable where transient changes to a regular routine – for instance taking a nap in the daytime – results in no change in the phase of the body clock (Edwards et al. 2023). Consideration for sleep timing is important as sleeping during the day does not provide the same benefits as sleeping at night, as the circadian system regulates aspects of sleep in the "biological night" such as cellular restitution and memory consolidation (Walsh et al. 2021).

Sleep is a complex and dynamic process that affects how you function in terms of cellular restitution, memory consolidation and removal of toxins from the brain. If we accept that the full purpose of sleep is still not completely understood, we can at least agree that normal human sleep comprises two main types – non-rapid eye movement sleep (non-REM) and REM (rapid eye movement) sleep (Walsh et al. 2021). Classically non-REM sleep is divided into three stages, representing a continuum from "light" sleep (stages N1 and N2), through to "deep" sleep (stage N3, also known as slow wave sleep). The composition and duration of normal sleep changes across the life cycle. For a young adult (aged 30 years), a sleep period of 7–9 h contains approximately 61% light sleep, 16% deep sleep and 23% REM sleep. These two "demands" for sleep have been considered previously (Walsh et al. 2021). For adolescents (aged 13–17 years), a sleep duration of 8–10 h contains approximately 57% light sleep, 22% deep sleep and 21% REM sleep. Another study that compared sleep stages in adolescent rugby players compared to a non-athlete adolescents reported the athletic population had less N2 sleep (36 ± 8%

compared to 42 ± 7%), and more N3 sleep (31 ± 8% compared to 25 ± 5%), with no differences observed in REM or N1 sleep (19 ± 4% and 20 ± 6%; 3 ± 3% and 4 ± 3%, respectively; Saidi et al. 2022). Information on REM and non-REM sleep in young athletes aged 6–12 years old does not exist. However, a study in badminton players aged 6–9 years old using actigraphy for 7 days reported total sleep time (TST; duration of time spent sleeping) of 6.9 h and sleep onset latency (SOL; time it takes to fall asleep) of 13–18 minutes (min) with sleep efficiency (SE; ratio between time asleep and total time dedicated to sleep) of 67–80% and wake after sleep onset (WASO; time spent awake after initially falling asleep) of 77–142 min (Choi et al. 2018).

Daily sleep demand can be influenced by individual factors such as age (Hirshkowitz et al. 2015), genetics (Bringmann 2019), sex, chronotype as well as the routine and activities carried out throughout the day. The term chronotype refers to an individual's natural preference or inclination regarding the time of day they prefer to sleep or when they feel most alert (Watson 2017). Therefore, when the routine is aligned with the chronotype, the athlete is expected to present better performance and greater quality, quantity, and regularity of sleep (Figure 1). The considerations for factors that influence daily sleep demand for adolescents, adults and older adults are provided in Table 1.

Sleep quality and health in an athlete can also be influenced by social factors, in addition to global impacts because of living in a modern society (Grandner and Fernandez 2021). We will now consider sleep health and the dimensions of measure in athletes with consideration of demands for sleep due to age. Sleep health is defined as a multidimensional pattern of sleep-wakefulness, adapted to individual, social, and environmental demands, that promote physical and mental well-being. Good sleep health is

Table 1. Considerations of factors that influence daily sleep demand for child, adolescent and adult populations. E and M-types = outright evening and morning chronotypes, respectively.

		Child	Adolescent	Adult
Individual factors	Genetic	Chronic insomnia affects 20 to 30% of children associated with circadian clock genes, pathways that regulate sleep-wake mechanisms and psychiatric and cardio-metabolic conditions.		Genes can increase an individual's risk of experiencing insomnia, with women being at higher risk of experiencing insomnia when compared to males.
	Sex	Evidence for sleep need in addition to training due to growth and maturation.		Additional needs including pregnancy and menopause.
	Chronotype	More E-type due to maturation effects.		Shift towards M-type due to aging.
	Routine	Influenced by school schedule, social and training.	Influenced by school, social and training (demand increased).	Influenced by work, social, family and training (hours and demand increased).
Environment	Sport	Sport requiring a larger skill based component or multi-modal sport such as triathlon which require greater time of practice.		
	Chronotype training	E-types and morning training.	E-types and morning training.	E-types and morning training.
	Athlete level	As the caliber of athlete increases the requirements in terms of training, competition, and resultant level increase.		
	Competition	Closer to competition greater resultant anxiety and sleep loss.		
	Prior-sleep debt	School/training.	School/training/social life.	Work/training/social life/parental role
	Seasons	May require getting up to cold, dark mornings in winter and warm light mornings in summer.		
	Home	Sleep regulated by parents.	Regulated by parents and self.	Self but may have partner sleeping in the same bed etc.

characterized by subjective satisfaction, appropriate timing, adequate duration, high efficiency and sustained alertness during waking hours (Walsh et al. 2021). Dimensions of sleep health include sleep duration (total amount of sleep obtained in 24-h period), sleep regularity (day-to-day variability and consistency of an individual's sleep pattern), sleep efficiency, sleep timing, vigilance-drowsiness and satisfaction/quality of sleep (Edwards et al. 2023). Vigilance/alertness and drowsiness can be affected by acute or accumulated sleep debt, impairing attention and concentration which can lead to worsened coordination and increased errors (Mah et al. 2019).

Irregular sleep patterns are associated with poor physical, mental health and performance outcomes (Murray et al. 2019) hence are stronger predictors of mortality risk (Windred et al. 2024). Athletes at lower levels of competitiveness, males and team sports report to have worse sleep regularity rates (Facundo et al. 2022). The TST decreases with age and daytime nap length is similar between ages but more frequently taken in adults than younger individuals (Li et al. 2018; Vlahoyiannis et al. 2021). Although effects of age (from child to adolescent to adult) on sleep regularity in athletes have not been considered, maintaining a consistent bedtime and sleep retiring time are important factors associated with sleep efficiency in athletes. Where possible training schedules should allow for both regularity and sufficiency of time-in-bed (Halson, Johnston, Appaneal et al. 2022).

Another item considered is sleep efficiency, which refers to the relationship between the time slept and the time spent sleeping (time-in-bed) and is influenced by SOL and WASO. This can be described as the ease of falling asleep and going back to sleep. This variable is associated with the risk of injury in the athlete's preparation (Von Rosen et al. 2018), where lower SE is associated with greater risk of injury. One factor that may explain this association is pain, as pain can interrupt sleep by increasing WASO and thus worsening SE. In addition, sleep deprivation can further alter tissue sensitivity and ability to tolerate a given load, thereby increasing the risk of injury and pain (Hainline et al. 2017). Sleep efficiency remains largely unchanged from childhood to adolescence with significant decreases with age in adulthood (Li et al. 2018).

Finally, sleep satisfaction/quality defined as the self-declared perception of sleep as "good" or "bad", is considered one of the indicators of sleep health. For this variable, the most used assessment method has been the Pittsburgh Sleep Quality Index (PSQI; Buysse et al. 1989) and is also among the most used methods in evaluating athletes (Claudino et al. 2019). Self-reported sleep quality is poor in athletes (Walsh et al. 2021), with information on the changes from adolescent to adulthood being more complex and rarely documented (Li et al. 2018). However, recent studies have shown that self-reported anxiety and/or depressive disorders are becoming more prevalent in adolescent populations and are linked to poor sleep quality (Orchard et al. 2020; Stracciolini et al. 2021).

Sleep behavior may be different between athletes from individual and team sports. In athletics, sleep behavior varies according to the stage of the season, with the pre-existing injury and lack of experience in each championship (indicating that age may also be a factor) – explaining the difficulty in sleeping during competition (Mason et al. 2022). A recent study carried out with Olympic athletes from 20 different sports identified that 52% of elite athletes were categorized as "poor sleepers" (Halson, Johnston, Piromalli et al. 2022). Team sport athletes reported significantly longer SOL, longer sleep durations, later waking times and spent significantly more time in bed than individual sport athletes. This is regardless of whether the athletes are in competition or training. Biggins et al. (2021) investigated sleep problems in elite athletes (football, swimming and track and field), competing in international competitions and how this relates to their general health and well-being. They found that 23% of elite athletes were identified as having a moderate or severe clinically significant sleep problem during competition, with 82% reporting less than 8 h of sleep per night. Similarly, in football when players sleep is measured post competition, total sleep time is reduced (Fullagar et al. 2016). Further, athletes have less sleep and poorer quality of sleep on the nights before training days when compared to nights before non-training days. There are also cultural differences in training times for some sports such as swimming, where morning training begins between 05:00 and 06:00 h (Sargent et al. 2014). Therefore, on the nights before training days, bedtime and wake-up times were significantly earlier, time spent in bed was significantly shorter and TST was significantly lower compared to rest days. Hence, early morning training sessions severely restrict the quantity and quality of sleep obtained by swimmers, whereas later training start times result in greater TST (Sargent et al. 2014).

One factor that affects athletes' sleep is sporting events, with "mega" sporting events such as Olympic and Paralympic Games reporting to have a greater impact on athletes sleep when compared to other competitions (Erlacher et al. 2011; Esteves et al. 2015; Silva et al. 2019; Biggins et al. 2021). In a study with football players, it was observed that TST is lower after night competition when compared to training days (−01:32 hs; Nédélec et al. 2019). The reduction in TST may be due to the possible delay in sleep start time due to high exposure to light. This may lead to a block in secretion of melatonin, increased arousal or stress after the game, and an increase in core body temperature (Figure 2). The change in athletes sleep patterns before competition has been attributed to the associated travel fatigue, difficulty initiating sleep due to nervousness about the competition, unusual sleeping environment (hotel room) and nearby noises in the room (Erlacher et al. 2011; Biggins et al. 2021; Halson, Johnston, Piromalli et al. 2022). These factors together contribute to poor quality sleep on the eve of competition and may be associated with the level of competition. The experience and age of the athlete can attenuate or increase these pre-competition effects (Mason et al. 2022).

In addition to these factors, facing a higher ranked opponent can increase stress and impact mood, with the location and result of the competition reducing well-being after a sporting event; together these variables may negatively affect sleep (Abbott et al. 2018). Some habits can also harm the sleep of athletes such as: Activities that require high levels of concentration or the consumption of products containing caffeine or alcohol shortly before bedtime. These habits may lead to irregular wake and sleep times and additional stress (Nédélec et al. 2015). For most behaviors, therapeutic actions are proposed that improve sleep in each of these situations (Walsh et al. 2021). For younger athletes and those with less experience, they may have less ability to cope due to greater fear of failure, which may lower self-confidence and have short-term impacts on academic performance and motivation to perform. Despite research being limited in younger populations, studies report that if coaches teach and employ effective coping strategies (visualisation, planning, seeking support), it can help young elite athletes attain a balanced emotional state (Sagar et al. 2009).

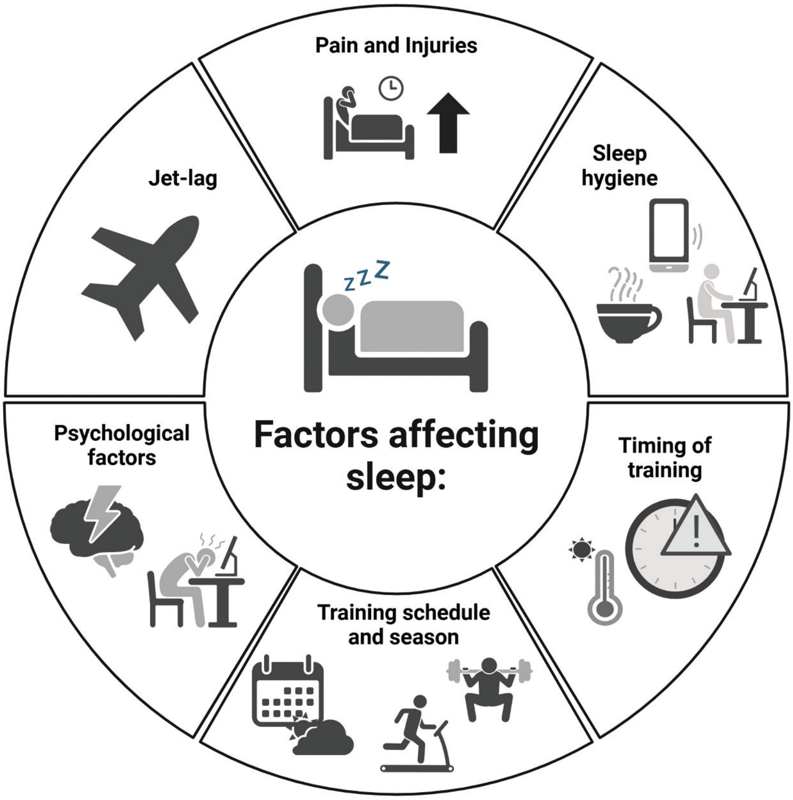

Figure 2. Factors in the routine of athletes that impact the quantity and quality of sleep.

Sleep restriction and performance

Sleep loss, restriction and deprivation are used interchangeably in the literature, to this end we will use the term restriction in the manuscript. The lack of quantification of normal sleep (retiring and wake hours) in athletes in the literature hinders the understanding of effects of sleep loss on performance, as the amount of sleep restriction the athlete is being subjected to is unknown compared to the amount habitually taken. Whether there is a dose response relationship for sleep restriction on performance is dependent on the characteristics of the task (Table 2). When individuals are under conditions of partial sleep deprivation (50% less than that of habitual sleep time) for 2 nights, there is no effect on submaximal weightlifting performance in upper and lower body efforts (Gallagher et al. 2023) but 63% sleep restriction resulted in a decrease in performance at % of one repetition max (1RM), commonly used for training (Brotherton et al. 2019). However, only one night of sleep restriction can result in a decrease in psychomotor functions, while consecutive nights of poor sleep can cause deficits in neurobehavioral aspects and increased daytime sleepiness and fatigue (Walsh et al. 2021). The recent consensus on sleep and the athlete identified that protocols employing one or two nights of total sleep restriction, or 1 or 2 weeks of partial sleep restriction have been used to demonstrate the importance of sleep for both mental and physical health (Walsh et al. 2021). They concluded that sleep loss

Table 2. A taxonomy of sports and recreational activities affected by sleep loss with consideration of daily sleep demand for child, adolescent and adults. Adapted from Reilly and Edwards (2007)..

Characteristics	Sports	General effects	Child	Adolescent	Adult
Low-aerobic, High vigilance	Sailing, road cycling, aiming sports	**Errors ↑**	Unknown	Unknown	Agrees with effects
Moderate-aerobic, High concentration	Field sports, team games, court games	**Decision making ↓ Motor control ↓ Motor memory ↓ Risk for injuries ↑**	Unknown	Agrees with effects	Agrees with effects
High-aerobic, Gross skills	Running 3000 m, swimming 400 m	**Marginal**	Unknown	Agrees with effects	Agrees with effects
Mixed-aerobic-anaerobic	Combat sports, swimming. Middle distance running	**Power↓**	Unknown	Unknown	Agrees with effects
Anaerobic	Sprints, power events	**Marginal**	Unknown	Unknown	Agrees with effects
Multiple anaerobic efforts	Jumping events, weight training	**Fatigue ↑**	Unknown	Unknown	Agrees with effects

was shown in otherwise healthy and "good" sleeping adult populations to impair cognition, learning, memory consolidation and mental well-being, however the level of impairment is dependent on the type of task and components of the performance being measured. A taxonomy of sports and recreational activities with different characteristics such as low to high aerobic components, tasks that require high vigilance and concentration and the effects of sleep loss has been considered (Reilly and Edwards 2007; Table 2). These considerations are largely in adult populations with little concern for child or adolescent athletes.

Partial or total sleep deprivation reduces anaerobic performance, the effects of sleep loss on muscular performance are dependent on the time-of-day (Craven et al. 2022). Sleep restriction negatively affects the postural control of judo athletes, which directly interferes with balance and sports performance in this modality. Further, Judo athletes perform 3 to 4 matches in the morning (eliminations) and the afternoon (finals) during competitions. In these athletes, going to bed later rather than waking up earlier for competition, brought greater losses in muscular strength and power (Craven et al. 2022). In addition, decreases in performance requiring maximum efforts taken in the afternoon, when the final fights take place were also observed (Souissi et al. 2013). Hence, waking up early is more harmful than waking up late for the muscular strength and power of athletes, especially in the afternoon (finals matches). Recommending extended sleep in the morning could be an advantage to be investigated in competitive conditions with the characteristics of judo as well as use of naps (Brotherton et al. 2019). There is a consensus that sleep restriction is harmful to performance, however waking up earlier or sleeping later affects sports performance in different ways. It must therefore be monitored appropriately to ensure less damage to the variables that determine performance in each modality.

In a study carried out with 360 adolescent athletes, an association was observed between musculoskeletal injuries and sleep ≤6 h the night before the injury occurred

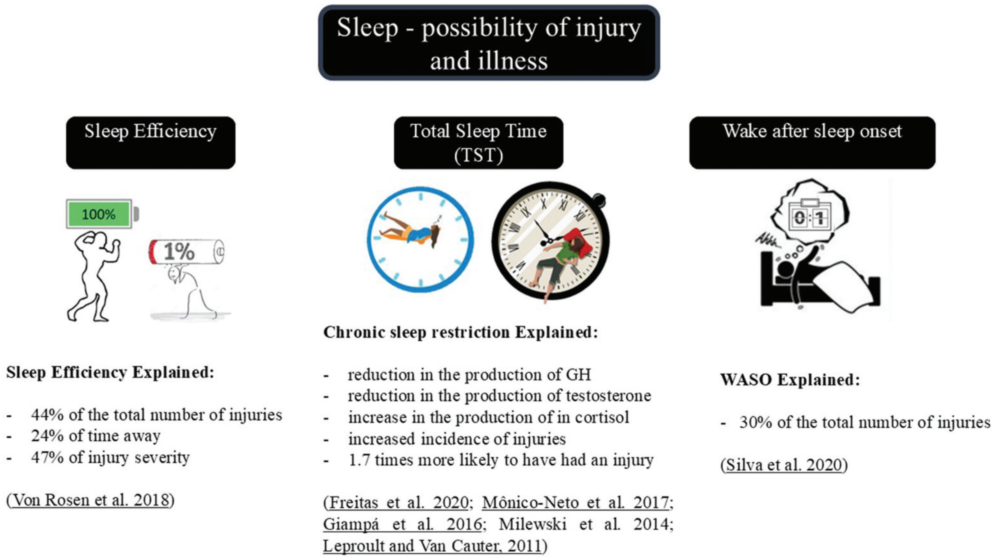

Figure 3. Interrelationship between quantity and quality of sleep, the possibility of injuries and illnesses in athletes.

(Luke et al. 2011). Furthermore, Milewski et al. (2014) reported that adolescent athletes who sleep less than 8 h per night are 1.7 times more likely to suffer a sports injury. Athletes, when subjected to sleep deprivation, present changes in biomechanical patterns and neuromuscular coordination (Mah et al. 2019), which can increase the risk of musculoskeletal injuries. Further, increasing training load and intensity in conjunction with decreased sleep duration leads to an increased risk of injury (Von Rosen et al. 2018). In agreement, Silva et al. (2020) demonstrated that sleep efficiency can explain 44% of the total number of injuries, as well as 24% of the time away from activities and 47% injury severity. Where 30% of the total number of injuries can be explained by WASO, in which it was observed that higher WASO was associated with a higher risk of injury. Burke et al. (2020) evaluated 94 division I football players and identified that 67.4% indicated a risk of sleep disorders, with an average sleep duration of 7:16 ± 1:18 h in the pre-season and 6:04 ± 0:41 h during the season, indicating a reduction in sleep time during the competitive period. In this study, 45 athletes were injured during the study period; however, sleep was not associated with an increased risk of injury for these college football players. In summary, the influence of sleep on the injury process is highlighted in Figure 3. Again, these considerations are largely in adult populations with little concern for child or adolescent athletes.

Possible intervention strategies

Athletes' sleep monitoring

Some athletes are already aware of poor sleep quality and the impact on sports performance (Halson, Johnston, Piromalli et al. 2022). For sleep monitoring, the PSQI has been suggested to be applied at regular intervals over periods of 2 months or more. Likert scales like those used by Hooper with 7 or 5 points (Hooper et al. 1995) can be quickly applied in daily training to assess fatigue, stress, sleep, painful muscles, pleasure in training, irritability, among others. Furthermore, with investment in equipment and trained professionals, the use of validated wearable devices (e.g. actigraphy), especially those that allow remote monitoring, can be a good strategy for monitoring sleep in athletes (Miller et al. 2022). Despite the convenience of wearable devices, it is recommended to use non-invasive and no-contact devices for children and adolescents to avoid greater sleep disturbance. Previous studies that have monitored child and adolescent sleep have tried different methods such as infrared cameras in the home setting, however this method lacks the ability to detect sleep metrics such as sleep stages and this research has typically been explored in children under 10 years (Kamon et al. 2022).

Sleep can also be monitored through self-reporting using questionnaires such as the PSQI which may be useful to professionals in guiding decision-making regarding sleep interventions, with strategies aimed at improving SOL being particularly important for athletes (Halson, Johnston, Piromalli et al. 2022). The athlete sleep screening questionnaire (ASSQ) provides a method of accurately determining which athletes would benefit from preventative measures and those who suffer from clinically significant sleep problems. The first recommendation is to assess the sleep difficulty score (SDS), which corresponds to clinical sleep problem categories according to the total sum of the responses (None: 0–4; Mild: 5–7; Moderate: 8–10; Severe: 11–17). Based on the SDS, recommendations are provided to the athletes who classify as having a moderate or severe sleep problem, these individuals should be further evaluated. Along with the ASSQ, the athlete sleep behaviour questionnaire (ASBQ) is being widely used to differentiate the sleep practices between athletes and non-athletes. It has been used as a practical tool to identify maladaptive sleep behaviors (Driller et al. 2018; Facundo et al. 2021), with questions asking how often they have engaged in specific behaviors over the last month; the higher the ASBQ global score, the greater indication of poor sleep behaviors.

Sleep hygiene in athletes

Using validated instruments, we can identify if an athlete is having insufficient sleep and use strategies such as sleep hygiene practices that can be adopted and implemented into an athlete's routine. Sleep hygiene is defined as habits and practices that lead to obtaining the right quality and quantity of sleep and includes responding and adapting to environmental factors that can influence sleep (Walsh et al. 2021). It is known if an athlete perceives their SOL or sleep quality as poor it can directly impact their sleep (Halson, Johnston, Piromalli et al. 2022). It has been postulated that an increase in artificial light at night is among the greatest impact factors for longer SOL. Athletes typically have little free time in their routines and therefore commonly use smartphones before bedtime as a means of social connectivity. Dunican et al. (2017) examined effects of nighttime use of electronic devices on sleep quality and next-day athletic and cognitive performance in elite judo athletes. Cognitive performance, physical performance and sleep related measures did not show significant differences between athletes who used or did not use electronic devices. However, when athletes were allowed to use electronic devices before bed they retired to sleep after 22:30 h on average, compared to 22:00 h when devices were prohibited. This strategy of removing devices prior to bed can increase sleep duration and be especially beneficial for beginner athletes who may have less experience, discipline and self-regulation of their behavior, like child and adolescent athletes (Mason et al. 2022). Furthermore, if removing the device worsens psychological aspects such as increasing the athlete's anxiety or stress, this practice should be discouraged. Regarding screen use, it is also important to highlight the impact of social media on sleep as it is widely used and rapidly growing. Investigations into screen use and sleep are predominately in adolescent populations with studies reporting an association between social media use and short sleep duration among students. Despite adults remaining an understudied population, engagement in social media use is also high in adults and reported to increase risk of insomnia, anxiety and shorter sleep on weeknights (Tandon et al. 2020).

Sleep hygiene strategies must be tailored to specific behaviors surrounding each sport modality so that they promote the best quality and quantity of sleep. This involves avoiding behaviors that interfere with sleep patterns and/or engaging in behaviors that promote good sleep. Sleep hygiene strategies are efficient in improving sleep and should be incorporated into the athlete's routine or specific situations (Vitale et al. 2019). In summary, it must be considered that, when applying guidance on sleep hygiene to a group of people, behaviours may be changed. However, behaviours will return to the initial pattern if new reinforcement is not offered (Caia et al. 2018), indicating that if you want to maintain sleep behaviour these actions need to be consistent.

Adjusting the training routine to the athletes' chronotype

The chronotype of an athlete seems to be an important indicator for adherence as well as for choosing the best time to exercise, since outright evening type individuals have greater difficulty exercising in the morning (Siviero et al. 2015). On the other hand, most training begins in the early hours of the day, which can be a limiting factor in the training process for evening type individuals and generally leading athletes to reduced TST (Walsh et al. 2021). In contrast, Eastman et al. (2015) reported that there is a greater number of people in the general population with an endogenous rhythm greater than 24 h a day, which would indicate a natural tendency to sleep later and wake up later as the week progresses. Child to adolescent athletes are typically moderate evening type in terms of sleep and wake habits, with adults becoming more moderate morning type hence waking earlier and going to bed earlier with age.

Considering the information discussed above, it could be beneficial to athletes' training, to adjust the training start time to the athlete's chronotype as well as biological requirements due to maturation and age. Dunican et al. (2017) reported that when training was postponed to a later time, adult athletes slept ~46 min longer than on training days with early start times. Therefore, it was suggested that a better strategy for increasing TST may be to change the start time of training, especially for younger athletes. There is a need for more research to better understand whether this change can improve sports performance. While the delay in starting sports activities can represent an increase in TST, this may conflict with the cultural mindset of sports coaches and may require re-education of the staff. This may reduce young talented athletes leaving the sport due to the demand of morning practice.

Scheduled naps

Imbedding naps into athletes' routines can be beneficial, especially for those who have limited time available to sleep at night (such as an athlete who studies at night and trains in the morning). When an individual remains awake for >17 h it is associated with the performance of a person with a 0.05% blood alcohol concentration, causing reduced attention and increased response time (Dawson and Reid 1997). Most, but not all, findings suggest that long-duration (>35–90 min) versus short-duration (20–30 min) naps provide greater benefits to athletes and that lack of benefit or even deterioration in performance after a nap in some studies was likely the result of sleep inertia (Lastella et al. 2021). The use of naps has been used as an attempt to increase the TST of athletes, especially for those who train twice a day. The specific characteristics of sleep that support such practices have not yet been clarified. When possible, the nap should be scheduled between 12:00 and 14:00 h, optimizing the athletes' sleep regularity and in line with the circadian dip of temperature and alertness. Despite this recommendation, younger athletes who are attending school during the week may not have the opportunity to nap on weekdays. Therefore, it is important to consider individuals needs and potentially only implement naps on weekends for those who are unable to be in the week due to school/work commitments (Botonis et al. 2021).

Education interventions

Education on sleep and chronobiology such as time-of-day effects on performance intuitively would benefit both the athlete and support staff (coach, sport scientist and parents/guardian for adolescents). Hershner and O'Brien (2018) assessed the effect of a sleep education website "Sleep to Stay Awake" (sleeptostayawake.org), on sleep behaviors of college students and reported personalized online sleep education interventions improved sleep behaviours, sleep quality and depression scores. However, there is currently no validated sleep educational questionnaire for athletes, or a delivery platform yet to be created. The goal of the intervention is to make a tailored package for the athlete to adjust the sleep balance or provide short-term strategies to overcome sleep restrictions and circadian rhythm disorders, achieving excellence in competition. Educational sessions can also be delivered online which makes the material more accessible and can be distributed on a larger scale.

In summary

We sought to introduce the idea of sleep, why we need it and the relevance of sleep to athletes' health and specifically performance with considerations for sleep requirements across the three ages. We primarily found research investigating sleep and/or performance in adult populations was present and to some extent in adolescents' athletes. This area of research is warranted in the future when considering athlete recommendations and the young age that an Olympic athlete can compete. This would give some insight into this silent generation of athletes to whom we are applying findings of adults yet may have different socio, psychological and physiological demands. Considering a gap in the literature, future studies should investigate the relationships between sleep and performance in children and adolescents, and how acute and chronic sleep restriction may affect the performance of these young athletes. Additionally, it is still a question whether young people who have a morning chronotype can have an advantage in the training process considering the demands and culture of training in the morning.

It is acknowledged that most of the literature is based on adult athlete populations and for some sections evidence for adolescents may be limited. Furthermore, not all studies discuss and describe the athlete's competitive level as well as other details mentioned.

Further considerations

Currently there is no standardisation in quantifying levels of "athleticism" between cohorts using different sporting modalities – such as has been designed for research using the "Participant Classification Framework" (Vlahoyiannis et al. 2021; McKay et al. 2022), a psychological model for classifying the validity for appraisal of expertise for athletes; however, this is not universally used.

The low quality and quantity of sleep among athletes may be due to schedule restrictions, low priority of sleep related to other training demands and the lack of awareness among coaches about the role of sleep optimizing recovery and sports performance (Simpson et al. 2017). Technical interventions can be effective and help improve the quality and quantity of sleep and performance of athletes, in addition to strategies such as sleep hygiene and education aimed at raising awareness about the importance of sleep (Nédélec et al. 2015). In our searches, we did not identify any studies addressing this issue, but it is possible that if training and sleep hygiene for athletes are conducted by their own coach, there may be greater adherence and benefits compared to a member external to the team, such as a sleep researcher. Further, the routine implementation of the ASSQ and ASBQ would help identify sleep problems, followed by interventions and a routine follow-up questionnaire to see if behavioral change occurred. It is noted that implementation of these considerations would have to be tailored for adolescent athletes as well as the educational background of the athletes. This would potentially involve changing the language of the questionnaires to suit the age of the athlete with shorter and more straightforward language for children as it may take them longer to process information compared to adults (Gray et al. 2020).

When possible, adjusting training schedules to the athletes' chronotype can be converted into circadian benefits (best time for training) as well as increased TST. Actions in this sense could be targeted at beginner, male and collective athletes as they are those with the worst sleep regularity rates (Facundo et al. 2022). As well as considering adolescent athletes who have school commitments and therefore have less flexibility regarding schedule changes. Furthermore, monitoring sleep (through wearable devices or questionnaires), fatigue and readiness should be a routine procedure in sport and would help in better adjustment to training and understanding performance fluctuations in the preparatory period.

Sports competitions present great physical demands requiring maximum performance from the athlete, hence why special attention must be paid to preparation and recovery after these events where athletes have greater difficulty sleeping, especially after evening competition (Richard and Koehle 2019). Avoiding travel immediately after competition and promoting an environment for adequate recovery immediately post competition should be a priority in managing sports teams. Being aware of the sleep problems of elite athletes before competitions and potentially delaying training start times to allow extension of sleep prior to major competition could be useful. Such a strategy would allow for an increase in sleep time during a crucial period for preparation.

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