

Sleep, Nutrition, and Injury Risk in Adolescent Athletes

Subjects: Sport Sciences

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Sleep is viewed as essential to the recuperation process and is distinguished as an active participant in recovery through its involvement in growth, repair, regeneration, and immunity. Furthermore, the literature has shown that the sleep of athletes impacts elements of athletic performance including both physical and cognitive performance, recovery, injury risk, and mental well-being. For sleep to have a restorative effect on the body, it must meet an individual's sleep needs whilst also lasting for an adequate duration and being of adequate quality, which is age-dependent.

Keywords: adolescent ; athletes ; sleep ; nutrition

1. Introduction

Sleep can be defined as a reversible behavioural state of impaired consciousness through a reduction in sensory and motor activity ^{[1][2][3][4][5]}. Sleep is regarded as an active regulatory process ^[6] and facilitates the proper functioning of the brain and cognitive performance while also regulating physiological functions including substrate and energy metabolism ^{[7][8][9]}, cardiovascular function ^{[10][11]}, appetite ^[12], endocrine function ^{[13][14]}, and immune function ^[15]. Several facilitating theories for sleep have been hypothesised ^{[5][16]}, including the regeneration of immune and endocrine function, the nervous system, and metabolic cost of living, and aids in cognitive development and synaptic plasticity ^[17]. As such, sleep is viewed as essential to the recuperation process ^{[3][18]} and is distinguished as an active participant in recovery through its involvement in growth, repair, regeneration, and immunity ^[5]. Furthermore, the literature has shown that the sleep of athletes impacts elements of athletic performance including both physical and cognitive performance, recovery, injury risk, and mental well-being ^{[4][19][20][21][22][23]}.

The architecture of sleep is organised into multiple 90-min series of one rapid-eye-movement (REM) and three non-REM sleep phases (N1, N2, and N3) ^{[24][25][26]}. Non-REM and REM sleep are distinct in nature and are characterised by brainwave activity, eye movement, cardiac rhythm, muscle tone, breath rate, and arousal thresholds ^{[27][28]}. REM sleep facilitates neurological regeneration, learning, memory, and emotional regulation ^{[27][29][30]}. Non-REM sleep is a three-phased process whereby the propensity to wake (the arousal threshold) is lowest during the first phase and progressively increases through to the highest point in the final phase (N3) ^{[27][28]} and can be characterised by the wave activity of the brain ^{[27][31]}. Non-REM sleep functions to support the regeneration of the nervous system, conserve energy, release anabolic hormones that augment protein synthesis to facilitate muscle recovery ^{[32][33]}, and mobilise free fatty acids for ATP production ^[34]. For a detailed breakdown of the brainwave characteristics of the sleep cycle, readers should refer to the AASM manual for the scoring of sleep and associated events ^[25], and the principles and practices of sleep medicine ^[27].

2. Importance of Sleep Health

Sleep health is defined as an individualised and context-specific multidimensional pattern of sleep and wakefulness that supports physical and mental well-being ^[35] and is an integral component of not only living a healthy lifestyle ^{[36][37]} but also of adaptation and recovery ^{[3][27][32][38][39]}. The relationship between sleep and recovery in athletes can be viewed in terms of three key factors that affect restoration processes: 1. sleep duration (total sleep requirements including napping); 2. sleep quality (total sleep absent of sleep disorders, environmental disturbances, or sleep fragmentation); 3. sleep phase (circadian timing of sleep during the light–dark cycle) ^{[39][40]}. During adolescence, the psychosocial and societal pressures experienced may result in adverse sleep health and reduced recovery capacity ^{[41][42]}. This is due to sleep deficiencies, which have a negative impact on health and are linked to increases in all-cause mortality and disease risk ^[43]. Sleep deprivation (an insufficient sleep duration compared to the basal level) and disturbances (the inability to initiate and/or maintain the sleep–cycle) are also risk factors for adverse health, recovery, and injury risk in athletic populations ^{[39][40][44][45][46][47][48]}.

For sleep to have a restorative effect on the body, it must meet an individual's sleep needs whilst also lasting for an adequate duration and being of adequate quality, which is age-dependent [46]. Sleep needs can be defined as the optimum quantity of sleep required to maintain alertness and function throughout daily living [5]. Sleep duration can be influenced by exogenous and endogenous environmental characteristics, which adds complexity to defining an “optimal” sleep pattern due to high inter-individual differences [49][50][51]. Peripheral tissues contain molecular clocks within each cell that dictate the expression of clock-controlled genes in a period (the required time for a cortical neuron oscillation) or phase (waking time in relation to the light cycle) [49][52]. Processes controlled by circadian rhythms also influence sleep duration; thus, the time at which sleep occurs in the light cycle also has an integral role in sleep duration [50][53][54]. The difference between sleep needs and actual sleep duration is known as sleep debt [5].

3. Sleep Adaptations during Adolescence

The chronotype that defines the expression of individual circadian rhythmicity [55] may similarly shift during adolescence [56][57][58][59][60] due to the greater robustness to increased sleep pressure [61] and environmental factors that increase evening alertness [42]. An individual's chronotype is mainly dictated by their genetic makeup; however, environmental and societal factors also affect the chronotype [55][62]. Cross-sectional research has evidenced that during adolescence, the distribution of the chronotype shifts toward the evening chronotype, reverting back to the earlier chronotypes post-maturation [56][57][58][59][60]. As sleep needs change over the lifespan, The National Sleep Foundation has published guidelines for age-dependent sleep durations, which includes recommendations for the following: adolescents (8–10 h), adults (7–9 h), and older adults (7–8 h) [46]. The literature has suggested that athletes have increased sleep needs, and thus the general recommendations may not be sufficient for athletic populations [23][63]. Therefore, a more individualised approach accounting for overall sleep health may be more appropriate for addressing sleep needs in individuals including athletes [23][35][63]. To feel rested, the literature has demonstrated that elite athletes need ~8.3 h of sleep [64][65]. Moreover, adolescent athletes achieve, on average, ~6.3 h [47][66][67] of sleep, demonstrating a discrepancy between sleep recommendations and actual sleep achieved [42][68][69]. Sleep–wake cycles also undergo development during adolescence whereby adaptation occurs in sleep regulation during this phase [68]. These adaptations to sleep regulation increase sleep pressure tolerance (reduced adenosine accumulation) [70][71][72] and are driven by the maturation of physiological, psychological, and cognitive functioning along with delays in circadian rhythmicity [73], thus creating an environment for inadequate sleep influenced by external factors associated with adolescence (**Figure 1**) [41][42][73][74]. This results in ever-decreasing time spent asleep during the ages of 15–18 years, with research reporting a decrease of ~1.5–3 h during this period [70][75][76]. Despite this, an adolescents sleep needs (pressure dissipation) under free living conditions does not appear to alter from the recommended ~9.25 h [42], irrespective of maturation status [77][78][79], thus attributing the decline to environmental factors as opposed to biological factors [73][80].

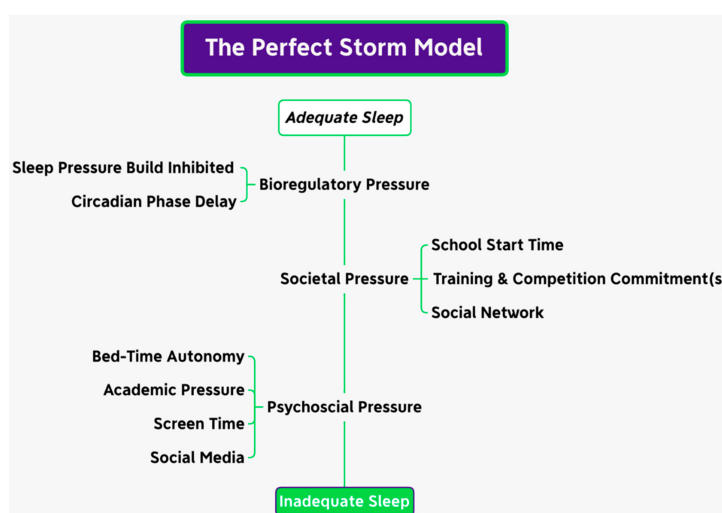


Figure 1. The perfect storm model.

4. Growth, Maturation, and Energy Demands in Adolescent Athletes

Adolescence is the transitional life stage where the process of maturation occurs [81]. Maturation signifies the progressive period toward the adult or mature state [82], and is characterised by status (maturity state at the time of observation), timing (biological age at which specific maturational events occur), and tempo (the rate of maturational progression) [82][83][84][85][86]. During the maturation period, approximately 20% of the final adult height is reached and 50% of the predicted adult body weight is achieved with an increase of up to 40% in bone mass [81][87]. The adolescence period is a significant

life stage that begins in conjunction with the onset of puberty. Puberty is unique to the individual with a vast range of inter-individual differences in maturation status impacting both physical and psycho-social development [82][84][86]. As evidenced, maturation status influences the development of and improvement in locomotive competencies in both a linear (accrual of strength capabilities) and non-linear (accrual of co-ordinative capabilities) fashion [88], influencing training adaptations in adolescent athletes [88][89][90][91]. Puberty onset is the catalyst of the growth period where the body undergoes meaningful physical and psycho-social adaptations such as alterations to body composition, including the accrual of bone, muscle, and fat mass, metabolic and endocrine system development, the development and maturation of the organ system, the establishment of nutrient storage and partitioning, and the establishment of self-esteem and psychological well-being, all of which affect general health and well-being [81][92][93][94]. Maturation results from the outcome of a multitude of complex processes that are governed by genetics, the endocrine system, environmental constraints, and nutrient intake [86][89][95][96].

5. Differences between Adolescent and Adult Athletes

During adolescence, there are vast inter-individual differences in nutritional needs dependent on factors including maturation status, body composition, physical activity, chronological age, and gender [92][95][96][97][98]. The implementation of correct and individualised nutrition for adolescent athletes not only supports overall health, adaptation, recovery, and athletic performance, but is also necessary for meeting growth and development demands [92][95][96][97][98]. Compared to their adult counterparts, adolescents possess several differences in substrate storage and metabolism, in conjunction with numerous physiological and metabolic alterations associated with maturation that contribute to an individual's nutrient requirements [96]. Furthermore, nutrient and energy requirements in adolescence are also largely dictated by the interplay between three main factors: (1) current anthropometry, (2) maturation state, rate, and timing, and (3) physical activity and sporting demands [92][96][97]. These energy requirements of an individual are fulfilled by the intake of energy-yielding macro-nutrients, carbohydrates, protein, and fat [96][99][100][101]. The specific energy intake of adolescent athletes should be largely dictated by total daily energy expenditure (TDEE) [96][102][103][104].

Growth and maturation are energy-intensive processes where energy intake influences both the synthesis of new tissue and the deposition of nutrients into the new tissue [92][96][105]. The basal metabolic rate denotes the energy expended to synthesize new tissue during growth; however, energy deposition is difficult to accurately measure [92][96][105][106]. During both peak height velocity (PHV) and peak weight velocity (PWV; weight denotes body mass) periods, energy requirements are in flux and are variable among adolescents of the same chronological age, in particular their basal metabolic rates, which rapidly increases in a stepwise fashion to match their maturation status, timing, and tempo [95][96][107][108]. The thermic effect of activity often makes the largest contribution to energy requirements in adolescent athletes [92][96][107]. The thermic effect of activity is influenced by anthropometry and the duration, intensity, and mode of physical activity, which also contribute to total activity energy expenditure [92][96], resulting in large interindividual variability in energy requirements [92][95][96], creating difficulties in prescribing energy requirement recommendations for adolescent athletes [92][95][96][97]. Persistent low energy availability (LEA) contributes to negative outcomes in growth and development including impaired cellular, organ, and tissue development, reduced bone mineral density, an increased risk of stress fractures, delay and/or regression in sexual maturation, and immune deficiencies [96][109][110]. Thus, it is recommended that if any signs or symptoms of LEA persist in adolescent athletes, energy intake should be increased to prevent detrimental effects on maturation, recovery, and injury risk [96][103][110].

6. Nutrition Knowledge of Adolescents

As established within the literature, adequate nutrition is paramount for performance, recovery, and adaptation to training, along with optimising the maturation process during adolescence [96][103][111]; thus, sufficient nutritional knowledge is required to optimise dietary behaviours to support these processes and inform eating habits [112][113][114][115][116][117]. In the absence of sufficient nutritional knowledge, nutritional intake may be compromised due to poor food selection and decreased dietary quality [118]. This may negatively impact the training–recovery cycle in athletes and adolescent growth and development [112][113][115][116][117][119][120][121][122]. It has been reported that athletic populations fail to meet the recommended nutritional requirements to support training demands [116][118]; however, with regards to the level of nutrition knowledge, a weak positive relationship ($r = >0.26$) exists between the level of one's nutrition knowledge and their energy balance and dietary quality [113][118][121][122]. Due to the multiple assessment tools utilised in nutrition knowledge research including the Abridged-Nutrition for Sport Knowledge Questionnaire (A-NSKQ), General and Sports Nutrition Knowledge Questionnaire (GeSNK), Nutrition Knowledge Questionnaire for Athletes (NKQA), Nutrition for Sport Knowledge Questionnaire (NSKQ), Nutrition Knowledge for Young and Adult Athletes (NUKYA), and Platform to Evaluate Athlete Knowledge of Sports Nutrition Questionnaire (PEAKS-NQ) [116], research is difficult to infer. Despite this, research

suggests that that the mean correct scores for general (GNK) and sport (SNK) nutrition knowledge in adult athletes are between $40.2 \pm 12.4\%$ and $70 \pm 9\%$ [118]. Moreover, research in adolescent athletes suggests that mean nutrition knowledge ranges between $43.8 \pm 11.4\%$ and $48.85 \pm 12.7\%$ [115][123][124], which is lower than that of their elder counterparts (overall NK% = $55.1 \pm 10.7\%$) [118], therefore highlighting the importance of increasing the level of nutritional knowledge in adolescent athletes to support maturation, recovery, and injury risk.

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