South African Journal for Research in Sport, Physical Education and Recreation, 2012, 34(1) 167-184.
Suid-Afrikaanse Tydskrif vir Navorsing in Sport, Liggaamlike Opvoedkunde en Ontspanning, 2012, 34(1) 167-184.
ISBN 0379-9069

ROLE OF SLEEP IN PERFORMANCE AND RECOVERY OF ATHLETES: A REVIEW ARTICLE

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ABSTRACT

An increasing body of evidence indicates that sleep plays a major role in the performance and recovery of athletes, yet all the complex processes of sleep are still unknown. Understanding the effects of sleep, disturbed sleep and sleep deprivation, promotes a deeper appreciation of its impact on athletes. This review provides insights into the role of sleep in physiological growth and repair, neuro-muscular performance, cognitive functioning and memory, emotional well-being, and immune function. Issues regarding the amount of sleep needed, as well as factors affecting quality sleep, are discussed.

Key words: Sleep; Sport performance; Recovery; Athletes.

INTRODUCTION

Sleep is a basic human need and a healthy adult will spend about one-third of his/her life sleeping (Lee, 1997). Although all the functions of sleep are still unknown (Madje & Krueger, 2005), it has been reported through the years that sleep is closely related to physical and mental health, cognitive processes and metabolic function (Samuels, 2008). Complete rest or sleep is still seen as the main means of restoring physical working capacity, as well as mental restoration (Dale, 2004; Bompa & Haff, 2009). Although many regard sleep as the most significant aspect of recovery, Walters (2002) maintains that athletes often neglect this fact. Research findings indicate that athletes generally sleep less than non-athletes and often have difficulty sleeping (Walters, 2002). It is important for athletes to understand how sleep affects performance and recovery, know which factors could affect sleep quality and be able to develop optimal sleeping habits.

DEFINING SLEEP

Sleep is defined as "…the natural and regular state of inactivity in which consciousness ceases and the bodily functions slow down or cease" (Watson, 1976:1042). Lee (1997) described sleep as a period of diminished responsiveness to external stimuli, while Hobson (1995:1) referred to sleep as "… a dynamic behaviour. Not simply the absence of waking, sleep is a special activity of the brain, controlled by elaborate and precise mechanisms. Not simply a state of rest, sleep has its own specific, positive functions." The state of sleeping is physiologically very different from other states of relative inactivity such as unconsciousness, coma, or hibernation (Stores, 2001). Athletes should be aware of the fact that, although sleep is a state of diminished consciousness and slower bodily functions, it plays a key role in the rest-activity cycle with very specific functions occurring during quality sleep (Davenne, 2009).

STAGES OF SLEEP

There are two types of sleep, namely Non Rapid Eye Movement-sleep (NREM), divided into four stages, and Rapid Eye Movement-sleep (REM). The onset of sleep under normal circumstances in adult humans is through NREM-sleep. This is a fundamental principle of normal human sleep and abnormal entry into sleep via REM can indicate pathological conditions (Carskadon & Dement, 1989). The four NREM stages roughly parallel a continuum of sleep depth. Stage-one sleep is light sleep, and generally persists for only a few (one to seven) minutes. Stage two usually lasts from 10 to 20 minutes. The sleeper then moves to stage three and finally into stage four sleep, the stage of deepest sleep. Normal functions such as blood pressure, respiration and heart rate diminish. Stage-four NREM-sleep generally lasts for about 20 to 40 minutes in the first cycle. Researchers often refer to the combined stages three and four sleep as slow-wave sleep, or deep sleep (Carskadon & Dement, 1989; Gunning, 2001; Stores, 2001).

After 30 to 40 minutes, REM-sleep begins. The brain reactivates into a fast-activity state. Blood flow, heart rate, respiration, body temperature and blood pressure of the person rise, and the eyes, underneath closed eyelids, dart back and forth as if scanning the environment, which may be accompanied by intermittent small muscle twitching (Brassington, 2002; Walters, 2002). REM-sleep episodes become longer as sleep progresses, with the longest REM-sleep episodes occurring in early morning. In normal adults, 20-25% of total sleep time is spent in REM-sleep (Stiller & Postolache, 2005). Dreams are often experienced during REM-sleep and REM-sleep has also been called "dream sleep" (Siegel, 1989; Reisser, 2006). It has been proposed that memory consolidation occurs during this time (Davenne, 2009). REM-sleep is thus essential when complex techniques or tactics are being learnt or explored (Meier-Koll *et al*., 1999; Gunning, 2001), and new motor skills are acquired (Buchegger *et al*., 1991).

In adults, cycles of NREM-sleep and REM-sleep recur within a period of 90 to 100 minutes. NREM- or slow-wave-sleep makes up approximately 75-80% of this time and REM-sleep the remaining 20-25%, occurring in four to six episodes (Carskadon & Dement, 1989; Hobson, 1995; Gunning, 2001). If sleep loss was experienced for one or more nights, slow-wave sleep will be prominent. REM-sleep will recover only after the recuperation of slow-wave sleep. Chronic deprivation of nocturnal sleep, an irregular sleep schedule or frequent disturbance of nocturnal sleep can result in changed distribution of sleep stages. It is most frequently characterised by premature REM-sleep: sleep onset with REM-sleep (Carskadon & Dement, 1989).

BODY RHYTHMS AND SLEEP

Circadian rhythm

Internal clocks that control biological rhythms with periods of about the length of a day (24-hour intervals) are called circadian rhythms. It is derived from the Latin *circa*, which means about, and *dies*, meaning day (Hobson, 1995:31). Mistlberger and Rusak (1989) noted that most human behavioural and physiological processes are characterised by a temporal structure that matches about a 24-hour day-night cycle, with daily patterns of sleep and wakefulness as the most familiar aspect. These daily rhythms are internally generated due to bio-chemical processes and not just reactions to alarm clocks, sunsets or external temperature changes, and persist under constant environmental conditions (Davenne, 2009).

It is proposed that there is a relationship between circadian rhythms and athletic performance with peak athletic performances at a specific time of day. Disturbance of circadian rhythm can influence the athlete's performance negatively; therefore, the timing of athletic performance is important. Most sport performances peak in the afternoon or early evening and the time period between 12:00 and 21:00 is seen as a window for optimal performance (Drust *et al.*, 2005; Davenne, 2009). Aerobic capacity peaks during the evening. Research findings reported that performance in swimming trials and competitions (Reilly, 2009), running, shot putting and rowing was significantly better during the evening than in the morning (Winget *et al.*, 1985). The ability to perform mental tasks, as well as skills depending on reaction time and sustained attention, is reduced during the early morning (Davenne, 2009). Monk (1989) reported a well-defined peak in subjective alertness in the late morning or early afternoon. This has implications for scheduling coaching instructions.

Drust *et al.* (2005) presented a review on circadian rhythms in sport performance. They concluded that world record-breaking performances in sport indicated a circadian variation, with world records broken by athletes competing in the early evening, when body temperature is highest. Performances in competitive cycling time trials were better in the afternoon and evening compared to those in the morning. Sport events that require throwing, 100m and 400m running performances improved in the afternoon and early evening. Muscle strength peaked in the early evening, while tasks demanding fine motor control, mental arithmetic and short-term memory peaked in the morning. The performance of skill-based sport and those requiring complex competitive strategies, decisions and recall of coaching instructions peaked earlier in the day, while those requiring gross motor skills and substantial physical effort should be completed later in the day. The highest values in body temperature, strength, reaction time, pattern recognition and heart rate occur during the afternoon, as well as reduced levels of perceived exertion (Brooks *et al.*, 2005; Reilly & Edwards, 2007). Reilly (2009) suggested that sport practitioners should take these circadian rhythms into account when they plan their training programmes.

Sleep and light

Circadian rhythm is acutely sensitive to environmental photic cues (Mistlberger & Rusak, 1989). Light is one of the universal environmental time cues, or *zeitgebers.* The suprachiasmatic nucleus (SCN) within the hypothalamus regulates the body's circadian system and has been established as the master circadian pacemaker or master clock (Arendt, 2009). The retinohypothalamic tract is a direct neural pathway from the retina to the SCN. The visual receptors involved are independent of the classical rod and cones, and act to assess the time of dusk and dawn according to the quantity and quality of light. The SCN-cells have receptors for melatonin. As darkness falls, melatonin is secreted by the pineal gland, and its vasodilatory effect causes body temperature to drop and other physiological functions to slow down to prepare for sleep. Exposure to light inhibits the release of melatonin (Reilly *et al.*, 2005; Stiller & Postolache, 2005; Waterhouse, 2007). The alteration of light and darkness is seen as the most important factor that can be used to reset the body clock (Arendt, 2009).

Sleep and body temperature

The circadian rhythm of sleeping and waking is also closely related to the daily rhythm of body temperature (Mistlberger & Rusak, 1989). Oral temperature follows a daily rhythm with body temperature at its lowest in the early hours of the morning (04:00), then rising throughout the day to peak between 17:00 and 21:00 (Kräuchi *et al*., 2005). Sleep onset normally occurs as distal-blood skin flow begins to increase and the body temperature starts to drop. When participants are isolated from time cues, they can only fall into long periods of sleep when they are near their minimal body temperature (Gunning, 2001). Results from physiological and neuro-anatomical studies showed that changes in body temperature trigger brain areas to initiate sleep (Kräuchi *et al*., 2005). REM-sleep occurs with a circadian distribution that coincides with the lowest point of body temperature, in the early morning hours. If sleep is delayed until the early morning, REM-sleep will dominate and even occur at the onset of sleep (Carskadon & Dement, 1989).

Extreme temperatures in the sleeping environment will disrupt sleep (Carskadon & Dement, 1989; Glotzbach & Heller, 1989). Often this is why individuals find it difficult to sleep in hot weather or after a very hot bath or shower. The body temperature may not fall due to high external temperatures. Sleeping under very thick bedding, in lots of clothes or with a heater on high may also maintain an individual’s body temperature and affect the quality of sleep (Gunning, 2001).

Napping

When sleep-wake cycles were studied in isolation chambers where participants were allowed to sleep whenever they wanted, it was found that they spontaneously took naps. Dinges (1989) monitored nocturnal sleep episodes and daytime naps of healthy young adults over a five-week period. Naps occurred relative to body temperature cycles. Longer sleep began prior to the minimum temperature, while shorter sleep or naps (*siestas*) occurred near the maximum temperature. If the 24-hour day was divided into four six-hour zones, the probability of sleep onset and wakefulness could be projected relative to the phase of the circadian temperature cycle. A high probability of nocturnal sleep was between 24:00 and 07:00. Morning wakefulness occurred between 07:00 and 13:00. A high probability of a short sleep or siesta was found between 13:00 and 18:00. Evening wakefulness occurred from 19:00.

Zarcone (1989) confirmed the biphasic tendency of sleep and refers to a second peak of sleepiness approximately eight hours after termination of the long consolidated nocturnal sleep. Napping at any time other than 10 to 15 minutes during this peak may have negative effects on sleep in the next consolidated sleep period of the 24-hour day. He stated that naps 10 to 12 hours after the major sleep period are particularly likely to disturb subsequent nocturnal sleep. Postolache *et al*. (2005:435) referred to the two “sleep gates” as two distinct periods when it is easy to fall asleep, which usually occurs between 13:00 and 16:00, and then in the late evening. A 20-minute nap about eight hours after nocturnal sleep should have, according to the authors, positive effects on performance. Loehr and Schwartz (2005:60) used the term “breaking point” which refers to the time around 15:00 when individuals usually experience a high level of fatigue. This greater sleepiness in the early afternoon is also referred to as the “post-lunch dip” (Stores, 2001; Reilly & Edwards, 2007).

A relative short daytime nap (20 minutes) can be beneficial to the learning of visual and motor skills (Walker & Stickgold, 2005), alertness (Reissner, 2006), as well as improved performance levels, self-confidence and daytime vigilance levels (Hayashi *et al*., 1999). Waterhouse *et al*., (2007) also reported that a post-lunch nap positively affected mental and physical performance in partially sleep-deprived individuals. Alertness, short-term memory, accuracy at a choice-reaction time test and sprint times improved. These results have implications for athletes with restricted sleep during or before competitions. Athletes could implement a napping-strategy to manage periods of restricted nocturnal sleep. Because motor-skill learning is also dependent on sleep, naps may be used as a prophylactic strategy against learning deficits if the athlete expects some overnight sleep loss (Reilly & Edwards, 2007). Although many regard a well-timed nap as an essential strategy for athletes in relation to performance and recovery, research by Venter (2008) revealed that team athletes (n=890) from field hockey, netball, rugby union and soccer in South Africa did not regard napping as an important recovery modality.

ROLE OF SLEEP IN WELL-BEING AND PERFORMANCE

Sleep serves multiple purposes. It has been emphasised that sleep helps, for example, with physical and psychological restoration and recovery, conservation of energy, memory consolidation, discharge of emotions, brain growth and maintenance of the immune system, although the complexities of sleep are not yet fully understood (Samuels, 2008). Nadler *et al*. (2003) maintain that sleep is essential for physical and emotional health and it plays a significant role in recovery from illness and injury. Sleep loss, on the other hand, leads to a general decline in performance (Davenne, 2009).

Physiological growth and repair

Although the body is continually in a process of revitalization, this process peaks during stage-three and stage-four sleep. Physiological processes that cause this effect during slow-wave sleep are facilitated by metabolic activity being at its lowest at this point, as well as an increased secretion of growth hormone by the endocrine system (Walters, 2002; Loehr & Schwartz, 2005). Significant neuro-endocrine activity is present with the release of growth- and sexual-maturation hormones.

More than 95% of the daily production of these hormones occurs during NREM-sleep (Gunning, 2001). In normal young adults, the 24-hour profile of growth hormone secretion takes place at low levels, which is intermittently interrupted by large secretary pulses. Major secretion usually occurs shortly after sleep onset in temporal association with the first episode of slow-wave sleep. A large pulse of growth hormone secretion occurs more than 90% of the time during the first slow-wave period, and there is a quantitative relationship between the duration of the slow-wave stages and the simultaneous amount of growth hormone secreted (Van Cauter *et al*., 1997; Stores, 2001). NREM-sleep is considered to be the time during which the body can repair and restore itself (Gunning, 2001). Sleep deprivation is therefore regarded as a stressor that has a significant detrimental effect on physiological growth and repair.

The pulsatile pattern of human growth-hormone secretion follows a circadian rhythm. The most powerful, non-pharmacological stimuli to initiate the secretion of growth hormone are sleep and exercise (Godfrey *et al*., 2003). If energy expenditure increases during the day, the blood levels of growth hormone rise during the following night, but when an athlete loses slow-wave sleep, these levels fall significantly (Davenne, 2009). The elevated secretion of growth hormone is often given as one of the reasons why athletes are encouraged to sleep during the day to stimulate the release of growth hormone. This could be useful for athletes who are due to perform strength-training sessions after sleep.

Neuromuscular performance

While learning new skills, athletes often believe that practice is the only prerequisite for improvement. Although correctly repeating a new task will result in learning benefits, it has been shown that the human brain continues to learn in the absence of further practice, and this delayed improvement develops during sleep (Walker & Stickgold, 2005). Walker and Stickgold (2005:301) rephrased the old saying "practice makes perfect" to: "it's practice, with sleep, that makes perfect". The authors conducted a series of studies on the effect of sleep on motor-sequence learning. The significant delayed learning without further practice was only observed after a night of sleep, and not over the equivalent period of wake time. It is suggested that optimal skill learning in athletes is dependent on sleep. Walker and Stickgold (2005) also demonstrated that when participants were deprived of sleep on the first night after training, and then took a night of recovery sleep before being retested, normal overnight improvements in learning were blocked. This indicates that quality sleep on the first night following training is critical, and that the sleep-dependent motor sequence learning depends on quality sleep within the first 24 hours after training.

Cognitive functioning and memory

Sleep is not only about resting the body, but it also has important implications for brain functioning (Gillis, 1996). It is believed that sleep influences brain activity patterns. During sleep, newly formed memories are being organised in the brain resulting in better recall and more accurate memory the next day (Andrews, 2005). Stickgold (2005) referred to the familiar concept of "sleeping on a problem" and reported that evidence indicates that memory reprocessing during sleep is an important component of the forming and shaping of memory. Song (2006:83) referred to results from various researchers: "sleep helps consolidate memory, improve judgment, promote learning and concentration, speed of reaction time and sharpen problem solving and accuracy."

Relationships between sleep-wake patterns and academic performance have been found. Higher levels of sleep problems were related to lower academic performance, as well as significantly higher levels of risk-taking behaviour in adolescents. Students with more consistent week and weekend wake times experienced better sleep quality and academic performance (O'Brien & Mindell, 2005). Students who got eight hours of sleep, but shifted their sleep schedules by two hours, reported greater depressive symptoms, lowered sociability and more frequent attention and concentration difficulties (Brown *et al*., 2006). The effects of sleep loss among students are evident on higher cognitive functions, such as attention, memory and problem solving. Learning capacity and academic performance may consequently be negatively affected by sleep deprivation (Curcio *et al*., 2006).

One night's sleep deprivation can affect verbal working memory, storytelling, arithmetic calculations, object naming, and delayed recall. These aspects of executive functioning depend largely on the activity in the prefrontal cortex. The prefrontal cortex is affected negatively by acute sleep deprivation, and cognitive work tasks might therefore be impaired (Nilsson *et al*., 2005). According to Reilly and Edwards (2007), sport performance often incorporates decision-making, and errors as a result of low sleep quality will be reflected in performance outcomes.

Emotional well-being

Emotional well-being has an effect on every aspect of life. It has been shown that being optimistic, sociable, and happy can protect individuals against stroke and cardiovascular disease, accelerate wound healing, increase resistance to infectious illnesses, is associated with lower levels of bodily pain and higher pain tolerance. Haack and Mullington (2005) revealed that sleep restriction (four hours per night over a period of 16 days) leads to a significant decrease in optimism-sociability, with the lowest values at awakening and at the end of the day. Bodily discomfort (ratings of generalised body pain, stomach pain, backache, headache, joint pain and muscular pain) increases. Because optimism and positive mood states are associated with better mental and physical health, it is possible that chronic sleep deprivation could be involved in decreasing psychosocial functioning and optimism. Insufficient sleep might also contribute to a high prevalence of localised and generalised pain (Haack & Mullington, 2005).

Mood was strongly affected by sleep deprivation, and poor sleep quality was associated with significantly higher self-reported negative moods in a sample of 1125 male and female students (Lund *et al*., 2010). A reduced ability to deal with emotions is one of the first symptoms associated with sleep deprivation. Sleep-deprived individuals consistently show increased levels of depression, stress, anxiety, worry, frustration, irritability, diminished vigour, lower confidence and difficulty in coping with new environmental stressors (Brassington, 2002; Walters, 2002). It seems that REM-sleep specifically is necessary for hypothalamic functioning, because these are hypothalamic-related symptoms (Lee, 1997). For example, with even minimal sleep loss, perceived exertion is increased and the threshold for containing anger is lowered.

The potential health impact of insomnia has received increased attention and insomnia is regarded as a serious risk factor for depression, anxiety disorders, the development of alcohol and substance abuse problems and suicide (Taylor *et al*., 2003). When healthy, young adults had their sleep restricted by 33% to 4.9 hours per night for seven consecutive nights, this sleep restriction resulted in significant effects on fatigue, confusion, tension, as well as total mood disturbance (Dinges *et al*., 1997).

The sleep-wake patterns of college students and its effects on their lives have received considerable attention. A reduction in total sleep time, delayed bedtime and increased nap episodes were found in this population. Sleep deprivation or fragmented sleep leads to a disturbance in mood states in healthy persons, with an increase in negative mood states, tension, confusion and depression. Students who fell asleep in classes experienced greater negative mood states than those who did not, and also reported greater use of alcohol and smoked more than those who did not fall asleep (Jean-Louis *et al*., 1998). Students who reported earlier bedtimes were in a healthier psychological state, which strengthens the notion that earlier onset of sleep is associated with a better mood (Asaoka *et al*., 2004).

Immune functioning

It is suggested that there is a link between the recovery effects of sleep and the immune system. Interference with immune functioning through impaired cellular and hormonal influences has been noted in sleep-deprived individuals. It is believed that melatonin and growth hormone, released during the sleep cycle, stimulate and enhance the immune system. Sleep deprivation may thus have a negative effect on tissue healing and recovery (Nadler *et al*., 2003). Chronic low-quality sleep, or successive nights of disrupted or shortened sleep increases vulnerability to infections, emphasising the negative effects of sleep loss on neuro-endocrine and immune functioning (Basta *et al*., 2007). Samuels (2008) also reported impaired immunological functioning in athletes with non-restorative sleep.

In a review on the role of sleep in the immune system by Bryant *et al*. (2004:457,465), the authors concluded: "an increasing body of evidence indicates that even minor sleep loss, accumulated over time, … has a considerable impact on the immune response". Sleep loss and sleep disruption are seen as occupational hazards. It is suggested that the ever increasing pressures to train for longer hours and perform well, combined with other non-training stressors, could affect the quality of the athlete's sleep and compromise immunity.

AMOUNT OF SLEEP NEEDED

"For a lot of people, the body's need to sleep is treated as a waste of time. In our 24-hour society, we often steal night time hours for daytime activities, depriving ourselves of precious sleep" (Ferrara & De Gennaro, 2001:155). The question can be asked: Is there a specific optimal amount of sleep?

The average length of sleep for people in the developed world has reduced quite dramatically over the years. Hicks and Pellegrini (1991) reported that the average hours of sleep among college students dropped by one hour from 7.75 hours per night in 1969 to 6.75 hours in 1989. According to Ferrara and De Gennaro (2001), the number of nocturnal hours of sleep for healthy adults has fallen from 8-8.9 hours per night in 1959 to 7-7.9 hours per night in 1980. About 27% of people had 6-6.9 hours of sleep per night.

The 2005 *Sleep in America Poll* (National Sleep Foundation, 2005), indicated that individuals older than 18 years tend to sleep an average of six hours 40 minutes during the week and seven hours 15 minutes over weekends. Fifty per cent of the respondents reported that they felt tired and not up to par during wake time. Seventy-five per cent reported sleep problems, with 27% of respondents using alcohol, over-the-counter sleep aids or prescription medicine to help with their sleeping problems.

Kamdar *et al*. (2004) stated that every human being needs a specific amount of sleep in order to meet the daily homeostatic sleep requirement. When participants were placed in isolation without exposure to clocks and natural light, they slept seven to eight hours out of every 24 hours (Loehr & Schwartz, 2005). “Sleep research has consistently shown that most adults actually *do* need the proverbial eight hours of sleep a night in order to perform at their best and avoid general tiredness, daytime drowsiness, and even fatigue-related illnesses” (Reisser, 2006:1).

Many young people suffer from a chronic lack of sleep. Many adolescents have “arousing” activities available at all hours in their bedrooms, such as television, play stations, Internet connections and cellular phones. Outside employment, consumption of alcohol and caffeine and lengthy athletic practice can all contribute to short nights and irregular sleep patterns (Carskadon, 2005). Bompa and Haff (2009) believe that athletes require 9 to 10 hours of sleep, 80-90% of it during the night. The balance may be completed by naps during the day. Samuels (2008) assessed the sleep quality of competitive athletes and found a substantial prevalence of poor sleep quality. Because of individual variations with regard to the optimal amount of sleep, Bonnet and Arand (1995) suggested that the best way to achieve sleep requirements is to go to bed when tired and sleepy and get up in the morning feeling refreshed, without any alarm, for a few days.

FACTORS AFFECTING SLEEP PATTERNS

Various factors could make it difficult for athletes to sleep as well as they would like. They might not be totally sleep-deprived, but may feel the consequences of fragmented or disturbed sleep.

Arousal in the sleep setting

Many factors can lead to arousal in the sleep setting. Some are related to psychological stressors, for example, deadlines, examinations, job crises or marital conflict. Tension and stress were the most important factors predicting sleep quality among the college students (N=1125) in the study conducted by Lund *et al.* (2010). Athletes are often under pressure to keep up with the demands of work and/or study, family commitments, training and social life, all of which could affect the quantity and quality of sleep (Bompa & Haff, 2009). Worry is regarded as a major contributor to pre-sleep cognitive arousal, leading to interfered sleep (Carney & Waters, 2006). Other factors might not be related to any particular psychological stressor, but might still be major sources of excitation, for example, someone working on a task related to his/her occupation right up to the moment he/she turns off the lights prior to sleep (Zarcone, 1989). Playing computer games at night can affect sleep patterns and sleep quality negatively. Heart rate was found to be significantly higher after playing games than after the control conditions. Sleep latency was significantly longer, and REM-sleep was significantly shorter after playing the games (Higuchi *et al*., 2005).

Sleep environment

People are sensitive to their sleep environment and might find it difficult to fall asleep in a strange setting. Noise affects sleep by causing awakening or making sleep shallower. A number of studies showed that the noise of traffic has a disturbing effect on sleep, such as a decrease in total sleep time and REM-sleep (Kawada & Suzuki, 1995). It was also found that traffic noise was more disturbing for sleep quality than ventilation noise, giving support to the notion that intermittent and fluctuating noise such as traffic noise disturbs sleep more than an even constant noise (Öhrström & Skånberg, 2004). It is recommended that athletes select a bedroom next to the courtyard (even if there is ventilation equipment), rather than one that is located next to the road. Venter (2010) found that 41% of the 890 elite team-sport players experienced problems falling asleep at night. Noise and light were reported as the two main factors affecting the quality of their sleep.

Travel

Long journeys usually cause tiredness in athletes. This might be due to cramped conditions, dehydration as a result of low humidity on board a plane, air turbulence, reduced barometric pressure, vibration, noise, flight anxiety and whole-body stiffness due to relative inactivity while travelling. The athlete might also feel stressed due to the generally high level of activity surrounding any long trip, transport arrangements at departure and arrival and control checks when crossing national borders. Mood states may also be negatively affected by the above-mentioned factors (Reilly *et al*., 2005; Reilly & Edwards, 2007).

A greater problem becomes evident when athletes cross multiple time zones, rather than covering the same distance in a northerly or southerly direction. Some of the symptoms that the athlete might experience include an inability to sleep at the local time, bowel irregularities, increased incidence of headaches, irritability and moodiness, fatigue, reduced cognitive skills and poor psychomotor co-ordination (Brooks *et al*., 2005). The athlete's circadian rhythms are disturbed by trans-meridian travel, when the time in the new environment no longer matches the body's internal circadian rhythm. This psychophysiological impairment of well-being and performance is known as circadian dysrhythmia or "jet lag" (Dale, 2004; Reilly *et al*., 2005). Reilly and Edwards (2007:278) maintain: "The body's circadian rhythm initially retains the characteristics of the point of departure. The body attempts to adjust to the new context, but core temperature is relatively slow to do so. Athletic performance will be adversely affected until the whole range of biological rhythms has adapted to the new local time." The severity of jet lag is directly related to the direction of flight (worse after flying eastwards compared to westwards), and the number of time zones crossed. The general rate of adjustment was traditionally seen as one day for each time zone crossed, but large inter-individual variations in this rate became evident (Reilly *et al*., 2005).

Coping with jet lag has been dominated by problems concerning the sleep-wake cycle, with the focus on how to improve nocturnal sleep, how to eliminate sleep disturbances and how to promote adjustments of the body clock. A behavioural approach should focus on optimum flight arrangements and planning the itineraries for athletes to arrive in sufficient time for the body clock to adjust before competitions (Waterhouse *et al*., 2002; Reilly *et al*., 2005). The researchers recommended that flight schedules should be arranged to allow athletes to arrive at their destination as close to their recommended sleep time as possible. Brooks *et al*. (2005) advised athletes to make eastbound flights during daylight hours with an earlier start for the longer flights. Westbound flights should be late in the day to arrive as close to the athlete's sleep time as possible.

In-flight activity should be considered with the planning of activities focusing on the local time at the destination. Watches can be reset and rest-activity cycles can be controlled. Arendt

(2009:252) refers to the "nudging technique" where athletes can even start to adapt to the new time zone before flight by adapting sleep cycles and manipulating exposure to bright light.

Athletes' dietary programme during and after a flight has received some attention in an attempt to apply dietary counter measures to jet lag. The macronutrient content of the diet could be manipulated to promote circadian resynchronisation. Protein is suggested to raise plasma tyrosine levels to activate the body's arousal system, while carbohydrate can raise plasma tryptophan levels, promoting the synthesis and release of serotonin, a precursor of melatonin. Caffeine, as a central nervous stimulant, can also increase alertness (Winget *et al.*, 1985; Reilly *et al.*, 2005). Waterhouse (2007) stated that the effect of such a dietary intervention seems to be small, and that appropriate times of exposure to and avoidance of bright light, might be better alternatives.

It is suggested that natural daylight or bright artificial light, when appropriately timed, is therefore more effective at phase resetting than the use of melatonin (Carskadon, 2005; Reilly & Edwards, 2007). Melatonin is produced at night and suppressed by daylight. Exposure to daylight might enhance the phase adjustment process and lessen the jet lag experience. Graeber (1994) found that a group confined to their hotel room after a transatlantic flight experienced more severe jet lag than a parallel group allowed outdoors. Postolache and Oren (2005) cautioned against indiscriminate exposure to light, because of the alerting properties of light. They advocate appropriately timed light exposure and light avoidance to be effective in the treatment of jet lag symptoms. Dark glasses could be worn during the morning in the new zone as dim light conditions assist with adaptation to the new time zone (Arendt, 2009).

Alcohol, caffeine and drug ingestion

The acute ingestion of ethyl alcohol, even at relatively low doses in normal subjects, leads to changes in sleep patterns. According to Hobson (1995) alcohol has profound short- and long-term effects on the quality and quantity of sleep. Blood alcohol levels below 10mg/dl may be associated with increased total sleep time and reduced awake activity. More than 10mg/dl will cause a decrease in REM-sleep, particularly during the early part of the night. Between three and eight drinks will lead to disturbed sleep. The awakenings are part of the sympathetic arousal that occurs along with catecholamine secretion following even moderate doses of ethanol near bedtime. Ethanol is metabolised at approximately the rate of one drink per hour. Sympathetic arousal can persist for as long as two to three hours after the blood concentration returns to zero. Chronic ingestion of alcohol will cause a loss of slow-wave sleep and disruption of sleep patterns (Hobson, 1995).

Sierra *et al.* (2002) investigated the sleep quality of Spanish university students, as well as the effects of alcohol, caffeine and tobacco consumption on sleep quality. They concluded that students who drank between two and four alcoholic drinks daily, or between two and four cups of coffee, or who daily smoked between 20 and 30 cigarettes, had poor sleep quality, greater sleep latency, a greater number of sleep disturbances and greater daytime dysfunction. Lund *et al.* (2010) also found that students who were poor-quality sleepers drank more alcohol per day than optimal-quality sleepers. The poor-quality sleepers were twice as likely to use alcohol to induce sleep compared to students with better sleep quality and had a more frequent use of over-the-counter drugs to regulate their sleep-wake cycle. Lund *et al.*

(2010:130) described the "stimulation-sedation loop" where students use caffeine and other stimulants during the day and depressants at night to counteract the effects of the stimulants, which increases the risk of developing drug dependence. Research has shown that intercollegiate athletes have significantly higher proportions of risky lifestyle behaviour patterns when compared with non-athletes, with intercollegiate athletes having been identified as an at-risk group for heavy alcohol consumption (O'Brien & Lyons, 2000; Nelson & Wechsler, 2001;Vampley, 2005; Martens *et al*., 2006; Maughan, 2006;), which could negatively affect sleep quality.

Sexual activity

Studies on the effect of sexual activity on athletic performance tended to indicate that sexual activity did not have a big effect on the athlete's performance (Sztajzel *et al*., 2000). The effect of sexual activity on sleep in humans has been poorly studied. Relaxation, quiescence of the body, reduced tension, a hypnotic effect, sleepiness and sleep are often found to be after-effects of an orgasm (Anshel, 1981; Brissette *et al*., 1985; Thornton, 1990). Refinetti (2005) found that most sexual encounters in a university student population (N=38) occurred at night between 23:00 and 01:00. Coaches therefore may be favouring abstinence because they want to make sure that athletes get enough sleep (Lovgren, 2006).

BEHAVIOURS PROMOTING SLEEP

Sleep is a vital part of the recovery process. A lack of sleep can cause a decrease in work capacity and increased feelings of fatigue. This can decrease performance and reduce the effectiveness of a training programme (Gunning, 2001). It is therefore crucial for athletes to sleep well and be optimally rested and ready to perform on a particular day at a particular time. Athletes must be able to fall asleep as planned, either at night or when taking a nap.

Conditions that may impair sleep are an upright posture, excessively hot or cold temperatures, bright light, noise and stress. This suggests that the opposite conditions might promote sleep: lying down comfortably, appropriately warm or cool temperature, motor relaxation, sensory withdrawal and cognitive relaxation (Cole, 2005). It is recommended that the athlete should identify the amount of sleep that is needed and keep a regular sleep schedule (Walters, 2002). Inconsistent sleep patterns disrupt the internal biological clock and tend to increase the amount of time it takes to fall asleep. Adjustments to earlier or later sleep times than the regular schedule should not exceed 30 minutes. Changing the schedule for more than two days or sleeping one hour longer on weekends disrupts the biological clock. It usually takes four to five days to adjust to a particular bedtime. The athlete should get up in the morning at the same time, even if he or she experienced low quality sleep the previous night, and therefore establish consistent sleep and wake-up times (Nicol, 1988; Reisser, 2006).

Many people are aware that they need a period of relaxation between the concerns and psychological stressors of the day and their major or nocturnal (night) sleep. Athletes should be encouraged to follow a bedtime ritual and develop a "winding-down routine" that serves as a cue to the mind and body to get ready for sleep (Reisser, 2006:9). A period of as little as 10 minutes can be effective. Simple techniques of stress management can include making a list of the psychological stressors that occurred and some plans to deal with them the next day, assuring oneself that the sleep environment is safe and reading entertaining material. An easily visible clock could be an arousing stimulus, which should be dealt with by athletes (Zarcone, 1989).

Postural immobility and muscle relaxation are critical factors in facilitating sleep onset and can be voluntarily controlled. One's posture should be supported to allow complete muscle relaxation and physical stillness. An individual could adopt a posture that he/she finds particularly favourable for sleep onset for him/her, called the "sleep-launch position" (Hobson, 1995:106). Voluntary breathing and relaxation techniques can produce a feeling of calm (Cole, 2005). It has been known that music has psychological effects on humans and can be used to create a relaxing environment. Athletes should choose music with a tempo slower than their heartbeat to induce a calming and relaxing effect (Le Roux, 2005,2006).

CONCLUSION

Many athletes are subjected to intense, high-volume training sessions in combination with many non-training stressors. It is suggested that sleep has a central role to play in aiding the short-term and long-term recovery of the athlete. Acute and chronic sleep disturbances could negatively affect physical performance, emotional well-being, and immune functioning. Athletes should be educated with regard to the role of sleep on performance and recovery, as well as various factors that could negatively affect or promote sleep. There might be a growing need for athletes and coaching staff to focus on the quality and the quantity of sleep among athletes. Pro-active screening could be done to identify athletes with sleep difficulties. Reasons for poor sleep quality could be identified and athletes could be assisted to develop coping strategies.

Internationally, adolescents and young adults (ages:12-25) have been identified as a population at high risk for sleep problems (Wolfson, 2010). While many athletes from the above mentioned age group compete in sport at various levels in South Africa, little sleep research has focused on athletes within the South African context. Although sleep has been identified as an important aspect of the recovery process and critical for optimal performance, most studies on sleep interventions have not focused on athletes. Recently, there has been concern about the effects of concussion on sleep quality in athletes participating in contact sport (Gosselin *et al*., 2009; Schreiber & Pick, 2009), which could be another area for research.

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(Subject Editor: Prof. Ben Steyn)