Kölling S[1], Ferrauti A[1], Pfeiffer M[2], Meyer T[3], Kellmann M[1,4]

Sleep in Sports: A Short Summary of Alterations in Sleep/Wake Patterns and the Effects of Sleep Loss and Jet-Lag

Schlaf im Sport: Eine kurze Zusammenfassung über Veränderungen im Schlafverhalten und den Einfluss von Schlafmangel und Jet-Lag

REVIEW

ACCEPTED: January 2016

PUBLISHED ONLINE: February 2016

DOI: 10.5960/dzsm.2016.215

Kölling S, Ferrauti A, Pfeiffer M, Meyer T, Kellmann M. Sleep in Sports: A Short Summary of Alterations in Sleep/Wake Patterns and the Effects of Sleep Loss and Jet-Lag. Dtsch Z Sportmed. 2016; 67: 35-38.

1. RUHR UNIVERSITY BOCHUM, *Faculty of Sport Science, Bochum, Germany*
2. JOHANNES GUTENBERG UNIVERSITY MAINZ, *Institute for Sports und Sciences, Mainz, Germany*
3. UNIVERSITY OF SAARLAND, *Institute for Sports and Preventive Medicine, Saarbrücken, Germany*
4. THE UNIVERSITY OF QUEENSLAND, *School of Human Movement and Nutrition Sciences, Brisbane, Australia*

Summary

- **This review article** aims to summarise general aspects regarding sleep and sports. It is generally assumed that sleep is a basic requirement for physiological and psychological recovery, whereas it appears that sleep of elite athletes is highly influenced by training stimuli and external as well as internal factors.
- **Studies about sleep deprivation** and restricted sleep indicate the importance for cognitive functions as well as mood and behavioural aspects. Effects on performance parameters are not reported as consistently. In contrast to sleep restriction, extending sleep for several nights might lead to improvements in performance, mood, and alertness.
- **In terms of** intercontinental travel, jet-lag might be an issue for elite athletes. Although a few studies indicate that effects on athletic performance might not be present, sleep, mood and some physiological measures are affected due to shift in time zones.
- **Simple strategies** can be applied to enhance adaptation to the destination and diminish jet-lag symptoms.

KEY WORDS:
Recovery, Sleep Loss, Jet-Lag, Performance

Zusammenfassung

- **Dieser Übersichtsartikel** fasst einige allgemeine Aspekte hinsichtlich Schlaf und Sport zusammen. Generell wird davon ausgegangen, dass Schlaf eine grundlegende Voraussetzung für physiologische und psychologische Erholung darstellt, wobei der Schlaf von Leistungssportlern stark von Trainingsstimuli sowie von anderen externen und internen Faktoren beeinflussbar zu sein scheint.
- **Studien über Schlafentzug** und verkürzten Schlaf verdeutlichen die Bedeutung für kognitive Funktionen sowie stimmungs- und verhaltensbezogene Aspekte. Effekte auf Leistungsparameter liefern allerdings kein einheitliches Bild. Im Gegensatz zu Schlafrestriktion kann eine verlängerte Schlafdauer über einige Nächte zu Verbesserungen der Leistung, Stimmung und Aufmerksamkeit beitragen.
- **In Bezug auf** Interkontinentalreisen kann Jet-Lag ein Thema für Leistungssportler sein. Obwohl eine geringe Zahl an Studien darauf hindeutet, dass die sportliche Leistung nicht direkt betroffen ist, werden Schlaf, Stimmung und weitere physiologische Parameter durchaus durch den Zeitzonenwechsel beeinflusst.
- **Einige einfache Strategien** können eingesetzt werden, um die Anpassung an den Zielort zu fördern und Jet-Lag-Symptome zu verringern.

SCHLÜSSELWÖRTER:
Erholung, Schlafmangel, Jet-Lag, Leistung

Introduction

Sleep is attributed an important role in recovering from daytime events, saving energy, functioning of the immune system and memory consolidation (3, 29). The alteration of sleep and wakefulness is organised by homeostatic control and the endogenous circadian rhythm which interact with each other (38). The circadian rhythm is driven by the biological clock which operates about 24h. It is keeping track of the time of day (i.e., according to the light-dark cycle) and determines the optimal time for sleep (7). The sleep homeostatic control aims to balance the time spent awake and time spent asleep by building up sleep pressure during periods of wakefulness and dissipating this pressure during sleep periods. Thus, the structure of sleep and the amount of sleepiness depend on the duration of the wake period as well as on the biological time of day (7). Sleep length, quality, and the circadian timing are considered key factors in terms of the overall recuperative outcome of sleep (35).

Typical instruments for the assessment of sleep are polysomnography (PSG), actigraphy and questionnaires which are briefly summarised in Table 1. PSG requires the attendance in a sleep laboratory and as recordings are expensive, it does not allow for long-term monitoring. Therefore, actigraphy has been widely accepted in sleep research because of its invasiveness and unobtrusiveness, as well as its reasonable validity and reliability compared to PSG (34). Wrist activity monitors and armbands can easily be applied in natural settings which offer the opportunity to monitor certain training cycles among athletes without disturbing sleep patterns (21, 22). Furthermore, it is important to obtain subjective perceptions and sleep habits. Still, it should be considered that personality characteristics and mood as well as memory biases might affect self-reported sleep ratings (20). The combination of both methods appears useful in athletic contexts. They can be implemented to examine changes in sleep parameters, and the perception thereof which can be affected by training stimuli and other external factors (22). ›

QR-Code scannen und Artikel online lesen.

CORRESPONDING ADDRESS:
Sarah Kölling, M.Sc. Sport Science
Ruhr University Bochum, Faculty of Sport Science, Unit of Sport Psychology
Gesundheitscampus Nord 10
44801 Bochum, Germany
✉: Sarah.Koelling@rub.de

Table 1

General aspects and issues regarding sleep in sports.

CATEGORY		AIMS/POSSIBLE INTERVENTIONS
Sleep assessment	Polysomnography	Medical examinations Recording sleep stages & cycles Clinical research questions
	Actigraphy	Long-term monitoring of sleep habits Application in home environment Analysing changes in sleep patterns in response to external and internal variances
	Sleep log	Subjective perception & appraisal Subjective changes in sleep patterns
Sleep problems	Difficulty initiating sleep	Implementing bedtime routines or rituals Avoiding activating or stimulating activities before bedtime (e.g., watching exciting movies) Keeping a regular sleep schedule Refraining from caffeinated beverages and alcohol in the evening Implementing relaxation techniques (e.g., controlled breathing, autogenous training)

As a matter of course, sleep/wake patterns do not emerge identically every night. Especially athletes have to deal with changing conditions (e.g., due to training and competition schedules or non-sport related obligations). While there are already some theoretical publications and review articles, studies about sleep in sport settings have not been reviewed and summarised yet. Therefore, the following section briefly summarises findings about changes in sleep in different contexts among athletes. As the absence of sleep or relative sleep restriction underline the role of sleep, relevant effects for athletic settings are reviewed afterwards. Since travel to international competitions may result in a shift in time zone, one section deals with the impact of jet-lag on athletes. Previous publications mainly deal with mechanisms of jet-lag and management strategies, but an overview of empirical findings among (elite) athletes is still lacking. Considering the nature of overview articles in this journal, this review aims to provide a brief summary of the most important aspects regarding sleep in front of a sport scientific background.

Sleep of Athletes in Different Settings

Practitioners and scientists assume a mutual relationship between exercise and the nightly sleep (5, 35). Recent reviews provide expedient details about physiological aspects of the function of sleep (11), as well as nutritional interventions to enhance sleep (18). In addition to these publications, this section focusses on findings that refer to changes of sleep in athletes. In general, sleep patterns and requirements for sleep seem to be highly vulnerable among elite athletes in response to external factors such as training modalities (19, 37), timetable (36), as well as internal factors such as concerns before competitions (10, 23).

Recently, it has been shown that an overload training protocol in triathlon can induce disturbed sleep (19). Similar results were found for female swimmers during a peak training period (37). Even short microcycles of few days might have an effect on sleep, whereas subjective mood ratings seem to be more affected than objective sleep parameters (21). Moreover, extended work periods over three months without regular weekends resulted in impaired sleep among ballet dancers in preparation of a premiere (12). In many sports, early morning trainings are very common. However, lately it has been shown that these schedules lead to reduced nightly sleep periods (36). Recent survey data (10, 23) as well as a sleep study with wrist activity monitors (24) examined athletes' precompetitive sleep behaviour. The outcomes indicate that sleep quality appears to be poor among a large number of athletes.

Regarding typical sleep durations of athletes, relatively little is known. Preliminary findings indicate that athletes obtain about seven hours of sleep per night in regular training situations (25, 27). It seems that athletes of individual sports often have even shorter sleep durations than team sport athletes (25). Assuming that seven hours of sleep probably is not the optimal amount for sufficient recovery due to the heavy training loads in elite sports, more research appears necessary to identify the individual optimum. Analysing the effects of sleep debt might be an expedient approach. Therefore, the following section discusses the consequences of the lack of sleep.

Effects of Sleep Loss and Restricted Sleep

Imposing participants to a complete sleep deprivation or partial sleep restriction is a common approach to investigate the role of sleep on recovery and performance. Over the past decades numerous studies have been executed with partially contradictory findings, which have been extensively reviewed recently (17). Consistently negative effects of sleep deprivation, however, seem to be present for cognitive and mood parameters, while only some athletic performance measures are affected, especially during endurance tests lasting longer than thirty minutes (17).

Nevertheless, it seems unrealistic and somewhat imprudent among (elite) athletes to induce entire nights without sleep during training or competition phases. Since it is expectable for athletes to suffer from disturbed sleep due to internal or external changes, partial sleep deprivation and sleep restriction studies are probably more relevant considering real life contexts. The authors of a recent review concluded that maximal strength parameters and aerobic endurance capacity might not be affected during single testing, when maximal effort is required, while the execution of sport-specific tasks, submaximal strength and anaerobic endurance capacity might be impaired by sleep restriction (17). Having analysed 205 studies about sleep deprivation and sleep restriction, the authors, furthermore, supposed that differences in study design, recruiting criteria of participants, and small sample sizes impede general conclusions and the extrapolation to high-performance sports (17). Considering more than one night of reduced sleep, results of chronic sleep restriction show negative effects as well. Following a nightly ration of 3h of sleep for three successive nights, performance of weight-lifting tasks (bench press, leg press, and dead lift) significantly decreased on the second day (31). The more pronounced deteriorations were reported in mood states (i.e., confusion, vigour, and fatigue) (31). Axelsson and colleagues showed an accumulation of sleepiness during five consecutive restricted nights (4h) (1). Each day resulted in an increase of median reaction times and lapses in a serial reaction time test. Both median reaction times and sleepiness returned to baseline during seven recovery days, while lapses were still increased (1). In another sleep-dose-response study, seven days with 5h and 7h of sleep restriction initially resulted in a declined performance in the psychomotor vigilance task which appeared to stabilise at a lower-than-baseline level after a few days (2). During that same study, following severe sleep restriction (i.e., 3h) performance declined continuously and three days of 8h recovery sleep did not restore performance to baseline levels. It is argued that the brain undergoes adaptive changes that serve to sustain a stable (though reduced) level of performance which persists into the recovery period and prevents rapid return to baseline levels (2). Furthermore, it is assumed that waste products

of neuronal activity accumulate during wakefulness. This process prevents the effective clearance of toxic waste and impedes regular neuronal performance. Consequently, cumulative sleep loss causes an oxidant imbalance and cell death (9). Generally, these findings should be treated with caution, as the studies vary significantly regarding study design and small sample sizes without elite athletes and almost exclusively male participants. Nevertheless, this underlines the importance of sufficient sleep.

Effects of Jet-Lag

Among elite athletes, travelling around the world is a necessity in order to participate in international competitions. However, it is assumed that travelling over three and more time zones will lead to jet-lag which is classified as a circadian rhythm sleep disorder with external conditions conflicting with the internal pacemaker (13). Common symptoms are difficulties with sleeping at the correct time, transient fatigue during the day, lack of concentration, decreased motivation, gastrointestinal disturbances and loss of appetite, feelings of disorientation as well as an impaired mental and physical performance (33). While jet-lag tends to be similar in men and women, symptoms are usually worse after eastward rather than westward flights (26). Lee and Galvez (26) reported that westward travels (i.e., causing a phase delay) lead to a symptom peak in the first three days, while eastward travels (i.e., leading to a phase advance) cause more severe and persistent symptoms.

Despite these general symptoms, empirical evidence regarding the effects of air travel and jet-lag on athletic performance is somewhat limited up to this point. Only few studies have been conducted with elite athletes (5, 16, 28, 30). After travelling six time zones westwards, as well as travelling eight time zones eastwards, male Olympic gymnastics athletes showed perceptual jet-lag symptoms and effects on the cardiovascular system, whereas reduced training and coordination performances were only present after the westward travel (28). It was concluded that athletes should arrive at least two weeks in advance to overcome jet-lag before commencing competitions after travelling six time zones (28). Among female and male collegiate swimmers, negative physiological, perceptual, and affective changes did not occur during heavy training, neither upon travelling four time zones from east to west nor from west to east (30). Even following a 16h-delayed time shift there was no significant impairment on sprinting performance among elite skeleton athletes (4). On the other hand, these athletes perceived themselves as jet-lagged for up to seven days after travel and salivary cortisol was reported to display a typical time course response to the change in time zone. This points to the estimation of one day needed for each time zone crossed to readjust (4). Additionally, a recent study with elite football players has shown that sleep was impaired upon travelling westward with a 4h-delayed time shift for the first two nights (16). Perceptual measures of jet-lag and recovery did not reveal significant differences between baseline and any time point during the 10-day tour (16). However, following 24h simulated international air travel with simulated time zone shifts, reductions in sleep duration, sprint performances as well as exacerbated mood states were reported for physically active male participants (14, 15).

Generally, this small number of studies seems to indicate that athletic performance is probably not directly affected by jet-lag following travel across several time zones but rather behavioural and perceptual factors. Nevertheless, more research is needed, and in anticipation of the upcoming Olympic Games 2016 in Rio de Janeiro, Brazil, efforts should be undertaken to counteract potential issues regarding the effect of time zone shift and eventual jet-lag symptoms. Regarding European athletes, the Games require westward travelling which might be endured easier due to a phase delay (i.e., -5h from UTC +2 during Central European Summer Time). A typical range for an organised circadian pattern is assumed between 23.5h to 26.5h which enables a 30min phase advance or 2.5h phase delay on any single day (6).

Concluding Remarks

This review highlights the importance of adequate sleep behaviour in athletic settings in order to achieve optimal recovery. Findings of changes in sleep in athletes and recent survey data of athletes' sleep behaviour (10, 23, 27) suggest that sleep habits and sleep times, as well as the awareness about the importance of sleep have some need for improvements among athletes. They should be educated in terms of optimal sleep routines and dealing with sleep problems (before competitions) (10). For instance, it could be shown that sleep hygiene recommendations improved sleep quantity in tennis players (8). Table 1 gives an overview of relevant aspects and possible interventions in sport contexts.

Several psychological and physiological parameters might be impaired due to the lack of sleep, even when sleep duration is only reduced by some hours. In summary, results of different performance measures in response to sleep loss somehow reveal inconsistent evidence. In contrast, cognitive functions and mood states appear to be negatively affected quite consistently. This implicates that interventions should be primarily directed to mood-related or motivational aspects of athletes.

Time zone shifts following air travel might also lead to disturbed sleep patterns and cause jet-lag symptoms. Therefore, sufficient time should be considered for an optimal adjustment to the destination before starting the competition. Treatment strategies have been recently reviewed: The duration of jet-lag might be shortened when the sleep schedule is adapted one to two hours toward the destination time zone in the days preceding the departure (26). During the flight, caffeinated and alcoholic beverages should be avoided and plenty of fluids should be ingested to decrease the severity of jet-lag (26). Upon arrival, exercise might help to maintain the arousal level, while strategic napping might alleviate symptoms of jet-lag as well (26). In Rio de Janeiro, athletes might consider exposing to light and avoiding light following certain schedules, which depend on the direction of travel and the numbers of time zones crossed (13). Besides, the timing of the meal should be congruent to the destination's time. This factor seems to be more important than the type of meal (26). Regarding drug supplementation, elite athletes should not consider antidotes to fatigue such as modafinil, methylphenidate and pemolane as well as melatonin, which is supposed to promote sleep (32). Therefore, adaptation strategies should be concentrated on behavioural aspects exclusively.

Acknowledgement

The theoretical deliberations of this article have been compiled within the framework of the project "RegMan - Optimization of Training and Competition: Management of Regeneration in Elite Sports [grant number IIA1-081901/12-16]", initiated and funded by the German Federal Institute of Sport Science.

Conflict of Interest

e authors have no con ict of interest.

References

(1) **AXELSSON J, KECKLUND G, ÅKERSTEDT T, DONOFRIO P, LEKANDER M, INGRE M.** Sleepiness and performance in response to repeated sleep restriction and subsequent recovery during semi-laboratory conditions. Chronobiol Int. 2008; 25: 297-308. doi:10.1080/07420520802107031

(2) **BELENKY G, WESENSTEN NJ, THORNE DR, THOMAS ML, SING HC, REDMOND DP, RUSSO MB, BALKIN TJ.** Patterns of performance degradation and restoration during sleep restriction and subsequent recovery: A sleep dose-response study. J Sleep Res. 2003; 12: 1-12. doi:10.1046/j.1365-2869.2003.00337.x

(3) **BRYANT PA, TRINDER J, CURTIS N.** Sick and tired: Does sleep have a vital role in the immune system? Nat Rev Immunol. 2004; 4: 457-467. doi:10.1038/nri1369

(4) **BULLOCK N, MARTIN DT, ROSS A, ROSEMOND D, MARINO FE.** Effect of long haul travel on maximal sprint performance and diurnal variations in elite skeleton athletes. Br J Sports Med. 2007; 41: 569-573. doi:10.1136/bjsm.2006.033233

(5) **CHENNAOUI M, ARNAL PJ, SAUVET F, LÉGER D.** Sleep and exercise: A reciprocal issue? Sleep Med Rev. 2015; 20: 59-72. doi:10.1016/j.smrv.2014.06.008

(6) **DAVIS JO.** Strategies for managing athletes' jet lag. Sport Psychol. 1988; 2: 154-160.

(7) **DIJK D-J, ARCHER SN.** Light, sleep, and circadian rhythms: Together again. PLoS Biol. 2009; 7: e1000145. doi:10.1371/journal.pbio.1000145

(8) **DUFFIELD R, MURPHY A, KELLET A, REID M.** Recovery from repeated on-court tennis sessions; Combining cold water immersion, compression and sleep recovery interventions. Int J Sports Physiol Perform. 2014; 9: 273-282. doi:10.1123/IJSPP.2012-0359

(9) **ENGLE-FRIEDMAN M.** The effects of sleep loss on capacity and effort. Sleep Sci. 2014; 7: 213-224. doi:10.1016/j.slsci.2014.11.001

(10) **ERLACHER D, EHRLENSPIEL F, ADEGBESAN OA, EL-DIN HG.** Sleep habits in German athletes before important competitions or games. J Sports Sci. 2011; 29: 859-866. doi:10.1080/02640414.2011.565782

(11) **ERLACHER D, GEBHART C, EHRLENSPIEL F, BLISCHKE K, SCHREDL M.** Schlaf und Sport. Motorisches Gedächtnis, Wettkampfleistung und Schlafqualität [Sleep and sports: Motoric memory, competition performance and sleep quality]. Z Sportpsychol. 2012; 19: 4-15. doi:10.1026/1612-5010/a000063

(12) **FIETZE I, STRAUCH J, HOLZHAUSEN M, GLOS M, THEOBALD C, LEHNKERING H, PENZEL T.** Sleep quality in professional ballet dancers. Chronobiol Int. 2009; 26: 1249-1262. doi:10.3109/07420520903221319

(13) **FORBES-ROBERTSON S, DUDLEY E, VADGAMA P, COOK C, DRAWER S.** Circadian disruption and remedial interventions. Effects and interventions for jet lag for athletic peak peformance. Sports Med. 2012; 42: 185-208. doi:10.2165/11596850-000000000-00000

(14) **FOWLER PM, DUFFIELD R, MORROW I, ROACH G, VAILE J.** Effects of sleep hygiene and artificial bright light interventions on recovery from simulated international air travel. Eur J Appl Physiol. 2015; 115: 541-553. doi:10.1007/s00421-014-3043-2

(15) **FOWLER PM, DUFFIELD R, VAILE J.** Effects of simulated domestic and international air travel on sleep, performance, and recovery for team sports. Scand J Med Sci Sports. 2015; 25: 441-451. doi:10.1111/sms.12227

(16) **FULLAGAR HHK, DUFFIELD R, SKORSKI S, WHITE D, BLOOMFIELD J, KÖLLING S, MEYER T.** Sleep, travel and recovery responses of national footballers during and following long-haul international air travel. Int J Sports Physiol Perform. 2015; 11: 86-95. doi:10.1123/ijspp.2015-0012

(17) **FULLAGAR HHK, SKORSKI S, DUFFIELD R, HAMMES D, COUTTS AJ, MEYER T.** Sleep and athletic performance: The effects of sleep loss on exercise performance, and physiological and cognitive responses to exercise. Sports Med. 2015; 45: 161-186. doi:10.1007/s40279-014-0260-0

(18) **HALSON SL.** Sleep in elite athletes and nutritional interventions to enhance sleep. Sports Med. 2014; 44: 13-23. doi:10.1007/s40279-014-0147-0

(19) **HAUSSWIRTH C, LOUIS J, AUBRY A, BONNET G, DUFFIELD R, LE MEUR Y.** Evidence of disturbed sleep and increased illness in overreached endurance athletes. Med Sci Sports Exerc. 2014; 46: 1036-1045. doi:10.1249/MSS.0000000000000177

(20) **JACKOWSKA M, DOCKRAY S, HENDRICKX H, STEPTOE A.** Psychosocial factors and sleep efficiency: Discrepancies between subjective and objective evaluations of sleep. Psychosom Med. 2011; 73: 810-816. doi:10.1097/PSY.0b013e3182359e77

(21) **KÖLLING S, WIEWELHOVE T, RAEDER C, ENDLER S, FERRAUTI A, MEYER T, KELLMANN M.** Sleep monitoring of a six-day microcycle in strength and high-intensity training. Eur J Sport Sci. 2015; 11: 1-9. doi:10.1080/17461391.2015.1041062

(22) **KÖLLING S, ENDLER S, FERRAUTI A, MEYER T, KELLMANN M.** Comparing subjective with objective sleep parameters via multi-sensory actigraphy in German Physical Education students. Behav Sleep Med. 2015; 15: 1-17 doi:10.1080/15402002.2015.1017096

(23) **LASTELLA M, LOVELL GP, SARGENT C.** Athletes' precompetitive sleep behaviour and its relationship with subsequent precompetitive mood and performance. Eur J Sport Sci. 2014; 14: S123-S130. doi:10.1080/17461391.2012.660505

(24) **LASTELLA M, ROACH GD, HALSON SL, MARTIN DT, WEST NP, SARGENT C.** Sleep/wake behaviour of endurance cyclists before and during competition. J Sports Sci. 2015; 33: 293-299. doi: 10.1080/02640414.2014.942690

(25) **LASTELLA M, ROACH GD, HALSON SL, SARGENT C.** Sleep/wake behaviours of elite athletes from individual and team sports. Eur J Sport Sci. 2015; 15: 94-100. doi:10.1080/17461391.2014.932016

(26) **LEE A, GALVEZ JC.** Jet lag in athletes. Sports Health. 2012; 4: 211-216. doi:10.1177/1941738112442340

(27) **LEEDER J, GLAISTER M, PIZZOFERRO K, DAWSON J, PEDLAR C.** Sleep duration and quality in elite athletes measured using wristwatch actigraphy. J Sports Sci. 2012; 30: 541-545. doi:10.1080/02640414.2012.660188

(28) **LEMMER B, KERN R-I, NOLD G, LOHRER H.** Jet lag in athletes after eastward and westward time-zone transition. Chronobiol Int. 2002; 19: 743-764. doi:10.1081/CBI-120005391

(29) **MAURER JT, WEESS H-G, SCHREDL M.** Physiologische Grundlagen des normalen und gestörten Schlafes [Physiological principles of normal and disturbed sleep]. In Stuck BA, Maurer JT, Schredl M, Weeß H-G, eds. Praxis der Schlafmedizin [Practice of sleep medcine]. Heidelberg: Springer; 2013: 1-20.

(30) **O'CONNOR PJ, MORGAN WP, KOLTYN KF, RAGLIN JS, TURNER JG, KALIN NH.** Air travel across four time zones in college swimmers. J Appl Physiol. 1991; 70: 756-763.

(31) **REILLY T, PIERCY M.** The effect of partial sleep deprivation on weight-lifting performance. Ergonomics. 1994; 37: 107-115. doi:10.1080/00140139408963628

(32) **REILLY T, ATKINSON G, EDWARDS B, WATERHOUSE J, ÅKERSTEDT T, DAVENNE D, LEMMER B, WIRZ-JUSTICE A.** Coping with jet-lag: A position statement for the European College of Sport Science. Eur J Sport Sci. 2007; 7: 1-7. doi:10.1080/17461390701216823

(33) **REILLY T.** How can travelling athletes deal with jet-lag? Kinesiology. 2009; 41: 128-135.

(34) **SADEH A.** The role and validity of actigraphy in Sleep Med: An update. Sleep Med Rev. 2011; 15: 259-267. doi:10.1016/j.smrv.2010.10.001

(35) **SAMUELS C.** Sleep, recovery, and performance: The new frontier in high-performance athletics. Neurol Clin. 2008; 26: 169-180. doi:10.1016/j.ncl.2007.11.012

(36) **SARGENT C, LASTELLA M, HALSON SL, ROACH GD.** The impact of training schedules on the sleep and fatigue of elite athletes. Chronobiol Int. 2014; 31: 1160-1168. doi:10.3109/07420528.2014.957306

(37) **TAYLOR SR, ROGERS GG, DRIVER HS.** Effects of training volume on sleep, psychological, and selected physiological profiles of elite female swimmers. Med Sci Sports Exerc. 1997; 29: 688-693. doi:10.1097/00005768-199705000-00016

(38) **VAN DONGEN HPA, DINGES DF.** Sleep, circadian rhythms, and psychomotor vigilance. Clin Sports Med. 2005; 24: 237-249. doi:10.1016/j.csm.2004.12.007