



Managing Travel Fatigue and Jet Lag in Athletes: A Review and Consensus Statement

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Abstract

Athletes are increasingly required to travel domestically and internationally, often resulting in travel fatigue and jet lag. Despite considerable agreement that travel fatigue and jet lag can be a real and impactful issue for athletes regarding performance and risk of illness and injury, evidence on optimal assessment and management is lacking. Therefore 26 researchers and/or clinicians with knowledge in travel fatigue, jet lag and sleep in the sports setting, formed an expert panel to formalise a review and consensus document. This manuscript includes definitions of terminology commonly used in the field of circadian physiology, outlines basic information on the human circadian system and how it is affected by time-givers, discusses the causes and consequences of travel fatigue and jet lag, and provides consensus on recommendations for managing travel fatigue and jet lag in athletes. The lack of evidence restricts the strength of recommendations that are possible but the consensus group identified the fundamental principles and interventions to consider for both the assessment and management of travel fatigue and jet lag. These are summarised in travel toolboxes including strategies for pre-flight, during flight and post-flight. The consensus group also outlined specific steps to advance theory and practice in these areas.

1 Introduction

The modern-day athlete is often required to travel domestically and internationally including high-frequency short distances (<3 h) and low-frequency long distances (>3 h) that may involve the crossing of numerous time zones. The subsequent travel fatigue and jet lag experienced result in a myriad of shared symptoms, such as daytime fatigue, decreased concentration and alertness, sleep disruption and gastrointestinal disturbances [1, 2]. These can lead to increased illness and injury risk as well as adverse effects on athletic performance [2–9].

Travel fatigue and jet lag are two distinct entities that may co-occur when travelling east or west across three or more time zones [2, 4, 10–12]. Travel fatigue occurs in all travelling athletes and can be acute following any individual long journey, or chronic (cumulative) as a consequence of

repetitive travel within a season [4, 10]. It is a multi-domain disturbance that generally occurs with any travel regardless of the direction of travel or the number of time-zones crossed [2, 4, 10, 13]. It is caused by the demands of travel itself, such as cramped conditions, prolonged mild hypoxia, changes in the external environment (trans-latitudinal travel i.e. winter–summer/summer–winter) and reduced physical activity [10]. Jet lag is episodic with similar but more severe and prolonged symptoms compared to travel fatigue and follows rapid travel across 3 or more time-zones (transmeridian travel i.e. east–west/west–east) [4, 10]. It is typically characterised by the desynchronisation between the internal human circadian system and the time at the new destination [2, 4, 10, 11, 14]. As a result, the circadian rhythm of several psychological, physiological and behavioural variables with a typical early morning nadir and late-afternoon peak is misaligned with the new local time. Depending on the training or competition time, this could directly affect athletic performance [2, 4, 5].

Although the circadian system is well understood and described in the circadian physiology literature [5, 15–19], it remains difficult to translate and to apply this knowledge

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Key Points

Travelling athletes experience travel fatigue and jet lag that intensify their subjective burden and may influence performance and increase illness and injury risk.

Literature on management of travel fatigue and jet lag in athletes is limited. Based on physiological principles and laboratory-based studies, this review and consensus identified the most important interventions to counter.

Travel fatigue: maximise the amount of sleep obtained during travel.

Jet lag: maximise the rate at which the body clock adapts to the new time-zone, by following a guide that specifies 3h periods of light exposure and avoidance.

Other useful interventions include:

Travel fatigue: plan meticulously, prevent illness, formulate hydration and food strategies.

Jet lag: preserve sleep, coincide exercise training with light exposure, adjust meal timing and composition, and sensible use of melatonin at the new destination.

Manipulating exposure to time-givers, e.g. light and exogenous melatonin, may aid in successful circadian re-alignment following travel in athletes. Conversely, inappropriate exposure may be counterproductive and cause detrimental side effects.

Reliable and repeatable multi-centre field studies, over longer durations and involving randomised allocation of potential therapeutic interventions are needed to advance theory and practice in these areas.

to travel management practice within sport. Research in this area is complex due to factors, such as inter-individual differences and the challenge of measuring the circadian phase in field studies, using markers, such as core body temperature (CBT) and melatonin. A recent systematic review on the management of travel fatigue and jet lag in athletes concluded that no evidence exists for specific travel fatigue interventions and that evidence for interventions targeting jet lag is of low quality [20].

Since evidence-based data underpinning travel fatigue and jet lag management are under-developed [3, 21], an expert panel was formed to define criteria from existing recommendations [22, 23], and to inform sport science and medicine practitioners and sport programme managers on current consensus-based recommendations from a practice-led perspective [24]. This paper aims to define the

terminology commonly used in the field of circadian physiology; provide basic information on the human circadian system and how it is affected by time-givers (*zeitgebers*); discuss the causes and consequences of travel fatigue and jet lag; and provide consensus recommendations on managing travel fatigue and jet lag in athletes.

2 Methods

Our methodology is based on a recent publication, recommending specific criteria to reach consensus [23]. A *lead group* of three authors (CJvR, AJvR, PF) initially discussed the writing of a consensus document. A further 23 experienced researchers and clinical practitioners in the fields of travel fatigue, jet lag and sleep in the sports setting were invited to participate on the expert panel to formalise a consensus document and recommendations. The average experience of the authors in this field ranged from 4 to 25 years. The group consisted of 14 males and 12 females and embodied global representation from 11 different countries. Their expertise included 18 scientists (including sleep and circadian physiologists, sport scientists, a nutritionist and a statistician) and 8 medical team practitioners (medical doctors and physical therapists). The authors conducted comprehensive literature searches in PubMed, MEDLINE, CINAHL, Google Scholar, and SPORTDiscus to obtain relevant peer-reviewed publications regarding the human circadian system and the management of travel fatigue and/or jet lag. Two authors (CJvR, AJvR) compiled the first draft and sent it for initial comments by the full author group. The reviewed draft consisted of sections on terminology, the circadian system, travel fatigue and jet lag. According to preference, the authors chose primary working clusters from the four sections. Eight total Qualtrics surveys were sent for those sections where recommendations are provided, i.e. list of terminology (3), management options for travel fatigue (2) and management options for jet lag (3). A statistician (TC) analysed all feedback collected in the 8 surveys. To govern the threshold of agreement, only the statistician had access to the feedback provided by the authors.

The *terminology group* (AB, ID, TC) listed terms included in this consensus document that are commonly used to describe the human circadian system. The group provided three definitions for each term and administered a Qualtrics survey to systematically combine expert opinions and arrive at an informed group consensus on the selected terms. After the first round, a threshold of 80% agreement [23] was reached on the definitions of the following terms: biological night, chronobiotic, chronotype, circadian rhythm, jet lag, phase shift, phase response curve, re-entrainment, and suprachiasmatic nucleus. For the next round, the rest of the terms were included: body clock, core body temperature

minimum (CBTmin), dim light melatonin onset (DLMO), internal desynchrony, melatonin, nadir, phase, process C, process S, retino-hypothalamic pathway, sedative (hypnotic), and *zeitgebers* (time-givers). For these terms, definitions with the least votes were excluded and the remaining two definitions were adapted according to comments suggested by the authors. In the 3rd round, the senior author group (CJvR, AJvR, PF) based consensus on the majority vote since authors could not agree on phrasing the definition of terms. Further comments from all authors were applied to reach the final definition for each term.

The *circadian system group* (DS, MD) summarised and documented relevant literature on the physiological, psychological and behavioural variables of the human circadian system. They focussed on the relevance to translate theory into practice.

The *travel fatigue group* (KoS, ACS, JV, KM, MB, ML, MN, SH) summarised current literature regarding the causes and consequences of travel fatigue. This group also listed potential management options based on available literature including current opinions, expert recommendations and research-based studies (laboratory and field) on the management of travel fatigue. All authors voted on the inclusion or exclusion of each management option. Consensus was reached after the 2nd Qualtrics survey. A threshold of 80% agreement [23] was used to indicate a consensus among the authors. The average response rate by the author group to reach consensus was 96.2%.

The *jet lag group* (HF, ACS, CS, GV, GR, JMA, LG, MS, MDo, RC, TP) summarised current literature regarding the causes and consequences of jet lag. This group listed potential management options based on available literature including current opinions, expert recommendations as well as research-based studies (laboratory and field) on the management of jet lag. All authors voted on the inclusion or exclusion of each management option using a Qualtrics survey. After three rounds of Qualtrics surveys, consensus was reached. A threshold of 75% agreement [23] to each survey was used to indicate consensus among the authors. The average response rate by the author group to reach consensus was 92.3%.

Each sub-group within the consensus group provided sections on their relevant topics to form a second draft. The *lead group* (CJvR, AJvR, PF) reviewed and collated the different sections into a third draft. The author group collectively revised this third draft. Extensive discussions by all members of the consensus group followed, and all authors provided comments and suggestions. The *lead group* accepted or declined all responses within reason and sent the 4th draft for another round of input from the author group. Subsequently, all authors of the consensus group reviewed and approved the final manuscript.

3 Terminology

Terminology in the field of circadian physiology is complex. The following detailed explanations in Table 1 were developed by consensus and is an overview of specific terms and phrases commonly used when (a) referring to the human circadian system, or (b) when practitioners are contributing to travel planning and intervention design.

Although well described in the literature of circadian physiology, the information on the human circadian system is very detailed and beyond the scope of time-poor practitioners. The section below provides relevant information to aid practitioners to translate and apply circadian physiology into practical travel management.

4 Circadian System

The circadian system regulates the diurnal cyclical rhythms exhibited by physiological, psychological, and behavioural processes of the body over approximately 24 h [35, 36]. This system is regulated by a central “master clock”, the suprachiasmatic nucleus (SCN), as well as peripheral clocks located in almost every cell of the body [16–18]. These are synchronised by a sophisticated system of neuronal, hormonal and autonomous signalling [13]. Output signals from the clocks are subsequently generated, influencing physiological, psychological and behavioural processes [15]. The master and peripheral clocks of the circadian system synchronise through *zeitgebers* or time-givers [37].

4.1 Time-Givers/Zeitgebers

Common time-givers are light, sleep–wake transition, physical activity, social cues and meals [38, 39]. Light is arguably the most critical time-giver, as photic stimuli, via the retino-hypothalamic pathway, stimulates or inhibits the SCN [13, 15, 16, 18]. The timing, intensity, duration and spectral composition of light appear to be the most critical factors in altering the timing of the circadian system [13, 27] (Fig. 1).

4.2 Phase Markers

Key players in successful circadian re-alignment are the phase markers melatonin and CBTmin. *Melatonin* is a hormone secreted by the pineal gland that aids in the process to consolidate sleep. The onset of secretion under dim light conditions, termed dim light melatonin onset (DLMO), occurs ~2 h before habitual bedtime and aligns with the start of the biological night [15–18]. The circadian rhythm of CBT oscillates ~0.8–1.0 °C between a night-time minimum and a daytime maximum in a rhythmic 24-h pattern [42, 43], with CBTmin typically occurring between 03:00 and 07:00 [44, 45].

Table 1 Terminology of specific terms and phrases of the human circadian system [2, 5, 13, 15–18, 25–34]

Biological night	The internal circadian time of diurnal species when melatonin is secreted, core body temperature drops, and sleep propensity increases
Body clock	The body's internal rhythms last approximately 24 h and are controlled by the suprachiasmatic nucleus (master clock) which helps to regulate daily cycles of sleeping, wakefulness, and eating, etc.
Chronobiotic	A substance that adjusts the phase and period of the internal biological rhythms (circadian rhythm) of an individual
Chronotype	The tendency for someone to be a morning-type, an intermediate-type or an evening-type person with a preference to sleep at a specific time as determined by genetics (e.g. Per3 allele), environmental, and age-related factors
Circadian rhythm	An internally generated biological cycle or rhythm of physiological processes recurring naturally in the absence of time-givers lasting approximately 24 h, that can be modulated by external time-givers. The term is derived from "circa diem" meaning "approximately a day"
Core body temperature minimum (CBT-min)	Daily low point (i.e. trough or nadir) of the circadian rhythm of core body temperature that correlates with the lowest levels of alertness
Desynchronisation	A misalignment (desynchronisation) between the body's endogenous circadian system and the light–dark cycle (external environment)
Dim light melatonin onset (DLMO)	The time of the daily onset of melatonin production by the pineal gland located in the base of the brain. Typically, DLMO occurs ~2 h before habitual sleep onset under dim light conditions. Dim light refers to the requirement to assess melatonin levels in low light (< 10 lx) as its production is suppressed by light (i.e. ~ > 10 lx)
Jet lag	Temporary impairment of sleep and wakefulness, as well as other biological functions, associated with rapid eastward or westward travel across 3 or more time-zones
Melatonin	<i>Endogenous melatonin:</i> The darkness hormone which consolidates sleep and is produced predominantly by the pineal gland (melatonin synthesis and secretion is controlled by the suprachiasmatic nucleus) <i>Exogenous melatonin:</i> A synthetic substance that can induce sleepiness and/or shift the timing of the circadian system to help alleviate the symptoms of jet lag and support synchronisation of sleep and wake patterns to a new time-zone
Nadir	Minimum or trough of a rhythm or time series; often the minimum of a fitted curve (rather than the absolute minimum) of a physiological or behavioural rhythm
Phase	A specific time or point within a circadian rhythm
Phase-shift	A shift in a circadian rhythm (phase-advance or phase-delay) - Phase delay: After a <i>westward</i> flight, the body clock is ahead of time (i.e. at a later time of day) compared to the destination time zone and has to delay or move backward (to an earlier time of day) to become synchronised - Phase advance: After an <i>eastward</i> flight, the body clock is behind (i.e. at an earlier time of day) compared to the destination time zone and must advance or move forward (to a later time of day) to become synchronised
Process C	The circadian process coordinating with the light–dark cycle and involved in regulating sleep–wake cycles
Process S	The homeostatic sleep pressure system that is regulated by adenosine, which accumulates with wakefulness and dissipates with sleep
Phase response curve (PRC)	A curve or wave illustrating the magnitude of phase shift of the circadian clock between a stimulus and a response (advance or delay) induced by exposure to a time-giver (e.g. bright light) at various times of day or night
Re-entrainment	Re-alignment of the endogenous circadian system with the timing of the external environment—resulting in both oscillations having the same frequency
Retino-hypothalamic pathway	A photic reception pathway between the retina and master clock in the suprachiasmatic nucleus, activated by light, to coordinate circadian rhythms with the solar day
Sedative (hypnotic)	A drug that suppresses the central nervous system function. It is often referred to as a sleeping pill or a tranquiliser. Its effects range from promoting sleep to reducing anxiety. Adverse effects include lethargy, impaired alertness, etc. Prescription and consumption only on doctor's orders
Sleep banking	To extend sleep beyond normal amounts in order to have a surplus of sleep during sleep deprivation periods (e.g. travel) or when optimal performance is needed
Sleep window	The interval of time when someone is able to sleep and is partly driven by both homeostatic and circadian processes

Table 1 (continued)

Suprachiasmatic nucleus (SCN)	The master clock of the human circadian system which helps synchronise rhythms of physiology and behaviour. It consists of small nuclei in the hypothalamus of the brain, above the optic chiasm and receives external phase information via specialised light-sensitive cells in the retina
Zeitgebers (Time-givers)	The cues (physiological, psychological, behavioural, pharmacological and environmental) that entrain the phase of a biological rhythm, also known as time-givers or timing cues or synchronisers

4.3 Sleep Regulation

When CBT is at its lowest or is falling rapidly, it is easier to initiate sleep, whereas it is difficult to sleep when CBT is high or rising rapidly [2, 46]. Internal physiological changes that occur due to the circadian system also play an important role in initiating sleep. As sleep homeostasis/sleep pressure commonly referred to as Process S, accumulates with increasing waking hours of sleep, circadian-induced secretion of melatonin along with reductions in CBT and blood pressure, known as Process C allows a person to sleep [32]. Misalignment between these processes often leads to sleep disruption, including difficulty initiating and/or maintaining sleep [32].

4.4 Phase-Shift

Exposure to a time-giver induces a wave response and can shift the circadian system (phase-advance or phase-delay). The strength of the shift is often described using a phase response curve (PRC). Light exposure during the 0–6 h period on either side of the CBT_{min} is effective but 0–3 h results in maximum phase shifts [47–49]. Although the dose–response relationship is non-linear, the wavelength (shorter blue light, 400–495 nm) and intensity of bright light (≥ 2500 lx) [50, 51], and the duration of exposure (longer) will determine the degree to which the timing of the circadian system can be shifted [52–54]. The pattern of endogenous melatonin secretion is inversely related to body temperature—peak melatonin secretion occurs at the nadir of CBT (Fig. 2) [55]. Manipulating exposure to time-givers (Fig. 1) may aid in successful circadian re-alignment mitigating the effects of jet lag. Conversely, inappropriate exposure may be counter-productive and cause detrimental side effects. An example of this is evidenced by the impact of irregular exposure to bright light leading to cognitive deficits and mood alterations [56].

4.5 Individual Differences

Re-entrainment following a time-zone change is believed to also depend on an individual's chronotype [13, 19, 58]. Hypothetically, the population consists of 3 chronotypes: morning-type- (18–30%), intermediate-type- (50–60%)

and evening-type individuals (18–20%) [19, 59]. Currently, evidence to support links between chronotype and jet lag symptoms is based on social jet lag and shift worker studies [60–63]. To assist practitioners in understanding their travelling athlete, and help individualise scheduled intervention (e.g. light therapy), please refer to the advice presented online in Electronic Supplementary Material Table S1: morning-type subjects vs. evening-type subjects [2, 13, 19, 58–69]. Additionally, genetic differences regarding re-entrainment are of potential interest. Specifically, within the Period (*PER*) gene family, the *PER3*⁴ allele is associated with extreme evening-type, whereas the *PER3*⁵ allele is associated with extreme morning-type [69].

5 The Concept and Relationship Between Travel Fatigue and Jet Lag

Travel fatigue is a multi-domain disturbance that can be either acute or cumulative due to repetitive travel over a season, regardless of the mode of transport (road, rail, plane), the travel direction or the number of time zones crossed [2, 4, 10, 13]. Jet lag follows any journey rapidly crossing three or more time-zones, is episodic and implies full recovery after resynchronisation [2, 4, 10–12]. The relationship between travel fatigue and jet lag is conceptualised in (Fig. 3) and further discussed in Sects. 6 and 7.

6 Travel Fatigue

6.1 Causes and Consequences

Travel fatigue refers to exhaustion and tiredness associated with any long journey [4, 70, 71] following trans-latitude travel (north–south/south–north) or transmeridian travel. It is a complex summation of physical, physiological and psychological factors that accrue during an individual trip [4, 9], and could accumulate over a competition season. At present, there is substantial anecdotal evidence of its prevalence [4, 9, 61, 72–74]. There is however a lack of empirical evidence of the mechanisms underpinning travel fatigue, and how it might be prevented or its impact lessened [20]. Some

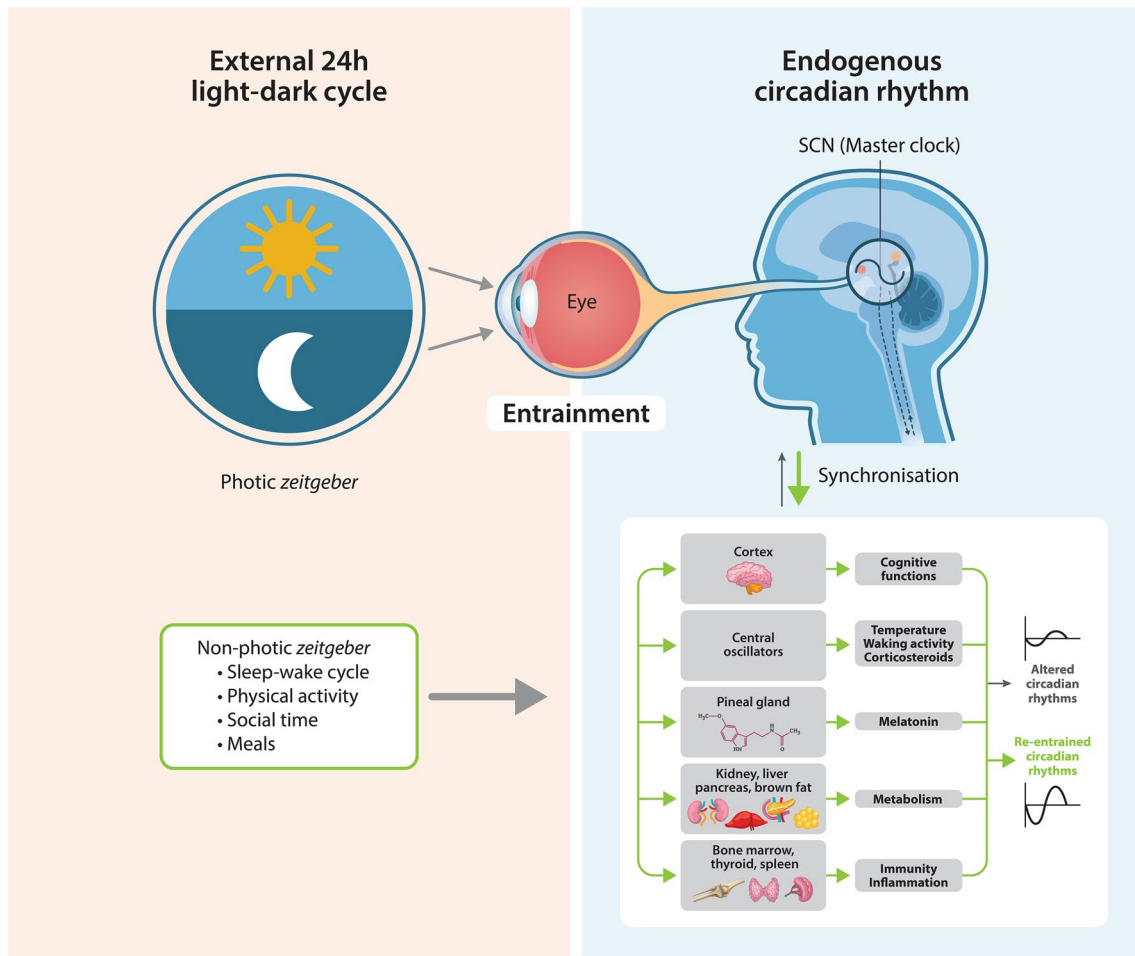


Fig. 1 Schematic diagram of the circadian clock entrainment pathways. Light directly entrains the suprachiasmatic nucleus (SCN), whereas other non-photic zeitgebers exhibit rhythmic changes and

entrain the SCN and peripheral clocks throughout 24 h—adapted with permission from Buttgerit et al. [40] and Hood and Amir [41]

commonly perceived contributors to travel fatigue are highlighted in Fig. 3 and Table 2.

When discussing the burden of travel fatigue on athletes, there are four key factors to consider: the total distance travelled, the time of travel (am or pm), the frequency of travel, and the length of the season. This concept is also referred to as the “recovery window” and indicates the available time for recovery (Fig. 3). The first three factors are well-documented in some professional sports [83, 86, 87]. For example, the National Basketball Association’s (NBA) regular season continues over 6 months consisting of 41 home games and 41 away games often inclusive of back-to-back games [87]. Congested schedules often include large travel distances as experienced by teams within the 4 top professional leagues [i.e. the National Hockey League (NHL),

Major League Baseball (MLB), National Football League (NFL), and the NBA] in the United States entailing travel between 40,000 km (once around the world) and 80,000 km (twice around the world) per season [88].

There is limited evidence on the potential consequences of travel fatigue. Studies have assessed the acute effects of air travel without crossing time zones on performance and perceptual measures among team sports players [6–9]. Overall, under these circumstances, travel has no noticeable effect on indicators of performance (i.e. technical and tactical performance during competition; countermovement jump performance; Yo-Yo intermittent recovery test performance), but negatively influences perceptual measures (e.g. reduced alertness, motivation and mood, increased perceived stress and fatigue) [4, 6–9].

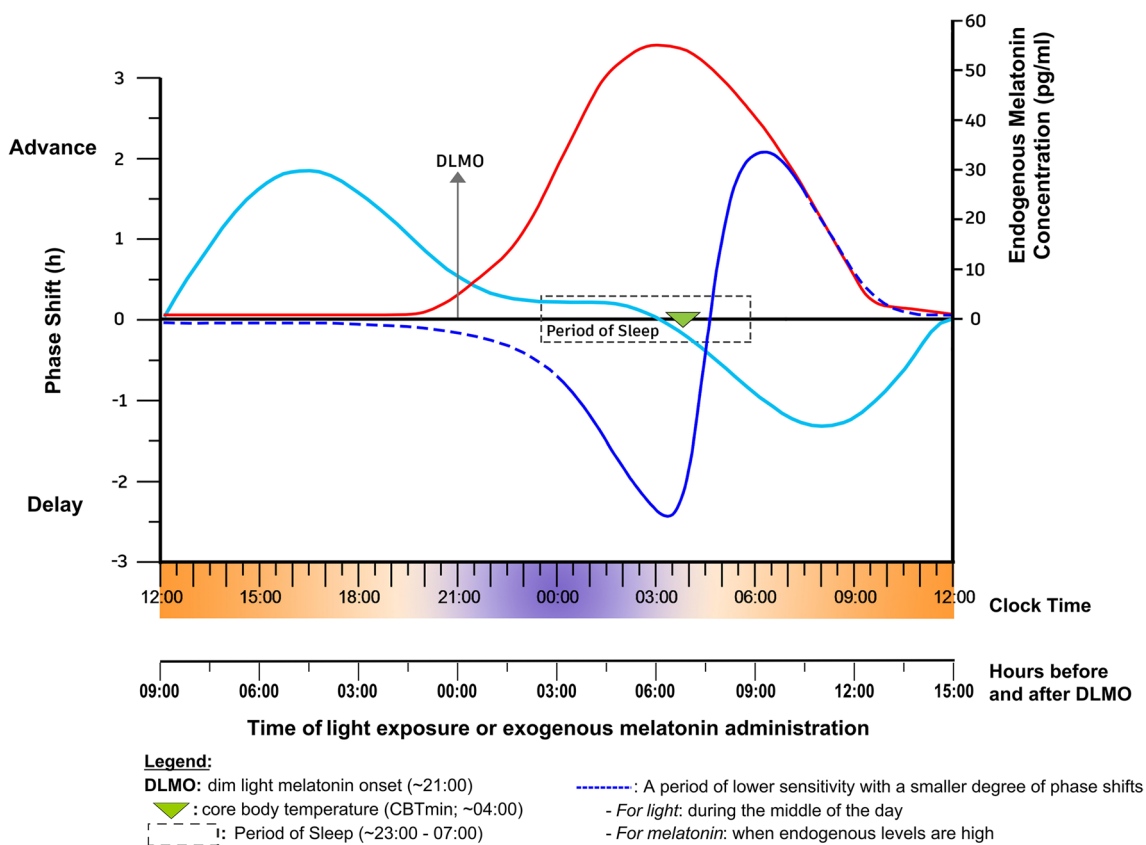


Fig. 2 Normal profile of endogenous melatonin (red line) and schematic human phase response curves to light (dark blue line) and exogenous melatonin (light blue line). The y-axis on the right shows the endogenous melatonin concentration. The y-axis on the left shows the direction and relative magnitude of the phase shift following light

exposure or exogenous melatonin administration at various times as presented on the x-axis. The magnitude of phase shifts will depend on the dosage used and should not be directly compared—adapted with permission from Eastman and Burgess [5] and Burgess et al. [57]

6.2 Assessment of Teams and Athletes

Athlete monitoring tools may help to understand both acute and chronic travel fatigue in athletes. In this respect, the creation and validation of a travel fatigue scale would improve understanding of the travelling effect [72] and should target measurement of the main symptoms of travel fatigue, namely persistent fatigue, recurrent illness, behaviour and mood changes and loss of motivation. An ideal tool should detect a significant part of travel fatigue including travel, sport, personal, social and seasonal factors and also provide scores for both individual trips and accumulative travel fatigue over a season (repeated measures design). Additionally, the coefficient of variation between different assessments of the same athlete should be small in comparison with the difference between athletes. Finally, its levels should not vary significantly in the same athletes under the same conditions at different times. As this is a highly individualised measurement, it should be used primarily to detect intra-individual changes. Travel fatigue is multifactorial and

presently no single marker quantifies all these requirements. Surrogate markers for travel fatigue must include subjective ratings of sleep quality, stress/mood, fatigue, and recovery [89]. Current recommended tools include the Total Quality of Recovery Scale [90] to measure psychophysiological recovery (i.e. mood states and body signals, such as sensations of soreness or heaviness), the Daily Analysis of Life Demands for Athletes Questionnaire and the Acute Recovery Stress Scale [91], which are also practical and intelligible measures that can be used to monitor general changes in fatigue and recovery states [92]. Athletes must be thoroughly familiarised with these perceptual rating scales in order to benefit. Notably, travel fatigue-specific assessments would only be used in a scenario where jet lag is not a problem (e.g. teams competing in the UEFA European Football Championship), as there is shared symptomatology and it is difficult to separate out the fatigue caused by the travel itself. It is also important to take into account that too many different psychometric tools will add to the daily burden on athletes and may lead to superficial feedback.

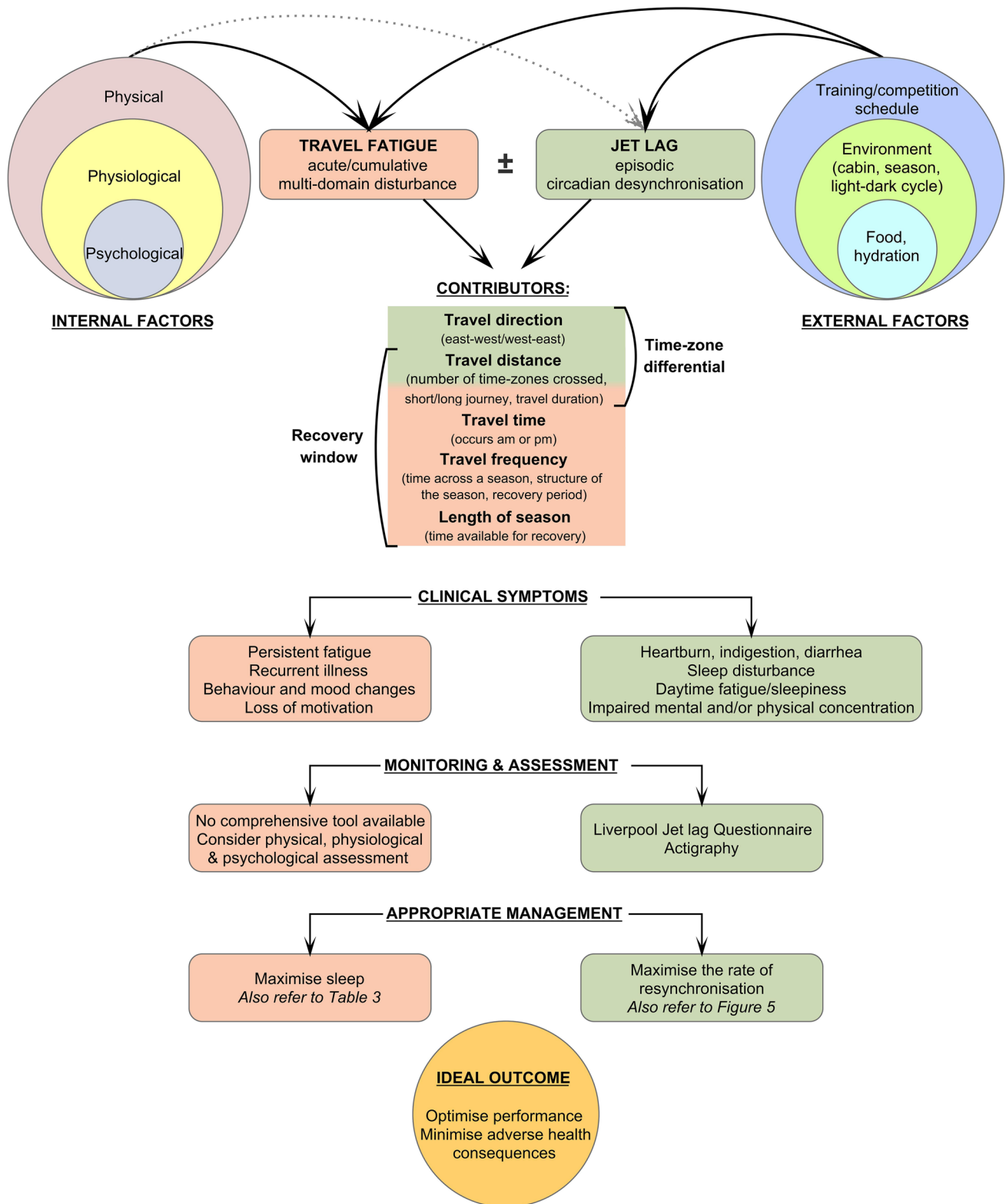


Fig. 3 A proposed multifactorial model of travel fatigue and jet lag—adapted with permission from Samuels [4]. *Travel fatigue* (on the left) is influenced by both internal and external factors. Allowing a recovery window taking into account travel distance, travel time, travel frequency and the length of the season combined with monitoring and appropriate management will lead to the ideal outcome. *Jet*

lag (on the right) is also influenced by external factors and less so by internal factors. Travel direction and travel distance, specifically the number of time zones crossed will affect the severity experienced by the individual. Recovery to achieve the ideal outcome relies on resynchronisation of the body clock

Table 2 Possible physical, physiological, psychological contributors to travel fatigue [4, 9, 14, 20, 61, 70–85]**Physical***Internal factors*

General health

External factors

Confined and uncomfortable space for a prolonged period of time

Restricted movement and muscle inactivity

Vibration effects from the mode of transport

Physiological (external factors causing internal physiological changes)

Exposure to dry cabin air and low hypobaric pressure (causing dehydration)

Prolonged exposure to low air quality (impairing immunity)

Prolonged exposure to mild hypoxia (reducing oxygen saturation)

Experiencing sleep disturbances, due to the cabin environment (i.e. cramped conditions, light and noise) and travel schedule

Impaired nutritional intake (including timing and quality)

Psychological

Mental monotony of a journey

Concerns regarding the journey, logistics, competition and/or the destination

Disruptions to daily routines

Noise stress from the mode of transport and fellow passengers

Home and societal influences

Fulfilment/enjoyment of the craft/trade

6.3 Current Recommendations in the Management of Travel Fatigue

A recent systematic review reported that no research exists on interventions that specifically manage travel fatigue in athletes [20] with available studies limited to opinions and collective experience rather than original research [93]. While travel distance or duration may be the key factor in the magnitude of travel fatigue experienced, having an adequate period to recover from travel (e.g. a recovery window) to prepare for training or competition is critical [4] and should be accounted for in travel arrangements. This may be unfeasible for athletes that travel frequently. Hence, they may need to implement interventions before and during travel to reduce fatigue (e.g. protecting sleep) or to treat fatigue post-travel (e.g. utilising napping and caffeine) [4, 94]. Following consensus, the information discussed in Table 3 was determined valuable for the management of travel fatigue.

7 Jet Lag

7.1 Causes and Consequences

7.1.1 Causes

The concept of “time-zone differential” relies on the function of distance travelled, i.e. travel duration and number of time-zones crossed as well as the travel direction. It is a circadian phenomenon specifically relating to jet lag [4] (Fig. 3). After rapid transmeridian travel (air travel across 3 or more time-zones) or trans-litudinal travel including crossing of three or more time zones, the circadian system

cannot immediately adjust to the light–dark cycle in the new time zone. This causes internal desynchrony, between both the master and peripheral clocks [2], as well as with sleep homeostasis [5, 104]. As a result, the circadian system remains aligned, at least initially, with the timing of the light–dark cycle in the departure time zone rather than the arrival time zone [105]. The circadian system must be re-entrained, whereby the internal clocks resynchronise with external time-givers (Fig. 2) [17, 18], over several days [2]. As a rule of thumb, the duration of natural alignment is 0.5 days per time-zone crossed in a westerly direction, i.e. 2 h per day, and 1 day per time zone crossed in an easterly direction, i.e. 1 h per day [5, 57]. Until re-entrainment is complete, the physiological and psychological systems that are regulated by the circadian system (e.g. digestion, sleep, or mood) will remain misaligned with the new local time, and depending on time of training or competition, this may impact performance [2, 5, 9, 21].

7.1.2 Consequences

The most common symptoms of jet lag are gastrointestinal discomfort, daytime fatigue/sleepiness, impaired mental or physical performance and poor sleep [71, 106]. The intensity and duration of jet lag symptoms worsen with an increasing number of time zones crossed, i.e. crossing 3–4 time zones produces milder symptoms compared to crossing 10–12 time zones [106]. The experience of jet lag is also greatly influenced by the direction of travel [5]. For example, after a westward flight over 8 time zones, athletes will feel sleepy, their performance will be impaired in the evening, and they will wake earlier than usual in the morning [21]. In contrast, after an eastward flight over 8 time zones, athletes will also

Table 3 Important information to consider in the application of travel fatigue management [2, 4, 82, 93–103]**Pre-travel***Sleep*

- Protect sleep as much as possible
- Be well-rested before travel (e.g. sleep banking strategy)
- If sleep deprived avoid aiming to catch up on sleep during travel

Planning

- Start as soon as destinations and dates of sporting events are known
- Identify optimal travel options (flights, rail or bus) in terms of departure and arrival times, the flow-through security, venues for eating, availability of lounges
- Calculate the total travel duration and stopover durations
- Minimise time between last "proper" sleep at the place of departure and first "proper" sleep at the destination
- Provide exact schedules and individual responsibilities to athletes and management in advance of travel
- Ensure all documentation is in order

Training synchronisation

- Plan training load and intensity before travel to allow for expected relative rest associated with travel

Illness prevention

- Ensure vaccinations are up to date
- Treat recurrent illnesses
- Pack prefilled WADA-approved prescription medication
- Replace long duration, high volume training which can be immuno-suppressive with shorter duration, high intensity sessions

Refuel and rehydrate

- Implement an evidence-based nutrition and hydration plan to meet macro- and micro-nutrient needs as well as fluid needs well in advance of travel
- Focus on electrolyte replacement is required for a minority of athletes e.g. "salty sweaters", nutrient deficiencies, etc. as electrolyte needs should be covered for the majority of athletes following recommended nutrition and hydration guidelines
- Check food availability during the trip
- Pack non-perishables (check customs regulations)
- Plan catering, eating-out, and self-catering options at destination ahead of time
- Vet dietary supplements (risk of prohibited substances, illegal substances, ingredient interactions or side effects) that could be counter-productive to travel, sleep or performance goals

During travel*Sleep*

- Take naps when appropriate
- Utilise eye-masks, earplugs or noise-cancelling headphones and/or pillows
- Do not allow screen time to interfere with napping or sleeping
- Maximise angle of recline

Compression

- Wear medical-grade compression and comfortable clothing

Illness prevention

- Early management of illness and/or motion sickness
- Avoid touching areas commonly infested with micro-organisms (e.g. tray tables, chair headrest, etc.); frequently wipe these areas clean
- Adhere to guidelines to prevent the spread of illness (e.g. coronavirus disease (COVID-19) guidelines)

Refuel and rehydrate

- Follow a hydration plan configured pre-travel; regular sips of non-alcoholic and non-carbonated drinks; water (best), fruit juice, or carbohydrate-containing drinks based on individual energy/caloric needs. Avoid caffeinated beverages and foods at least ± 6 h before bed or sleep time
- Avoid alcohol completely
- Consume regular but smaller meals, nutritious fibre-rich snacks (fresh or dried fruit, high-fibre crackers, energy bars, trail-mix), avoid calorie-overload (stick to the plan, limit "mindless grazing" on calorie-dense snacks (such as potato crisps, chocolates, ice cream, pies, high-fat energy bars, greasy foods))
- Food hygiene is essential (sanitise hands regularly, eat non-perishable, or freshly prepared foods, keep hot foods hot, keep cold foods cold)

Stopovers

- Move frequently
- Stretch
- Walk around
- Get fresh air

Table 3 (continued)**Post-travel***Sleep*

Take naps when appropriate
 Utilise eye-masks, earplugs or noise-cancelling headphones
 Sleep hygiene behaviours i.e. maintain sleep in a cool, dark and quiet environment / do not allow screen time to interfere with napping or sleeping

Refuel and rehydrate

Follow nutrition plan (amount of food or fluid, type and timing optimised for training and competition and "practiced" pre-travel)

Gastrointestinal: (during or after travel)

Constipation: more fluid, fibre-rich foods, natural laxatives (prunes, chia seeds, kiwi fruit, apples, oranges, nuts), soluble fibre (fruit, cooked oats), soluble fibre supplement, improve toilet routine, avoid over-use of laxatives
 Diarrhoea: regular sips of fluid (and food if tolerated), consider liquid meal replacement (with soluble fibre), probiotic supplement for susceptible athletes (strain or dose-specific)

Rest

Strategic brief naps as early in the day as possible, with the aim of not interfering with night-time sleep

Caffeine

Strategic intake during the local morning
 Avoid in the late afternoon or evening

Training on arrival

At low to moderate intensity
 Avoid extended video sessions

Other considerations*Sleep disorders*

There are > 70 recognised sleep disorders with limited knowledge about the prevalence in athletes
 Obstructive sleep apnoea (OSA) is currently regarded as the most common sleep disorder in athletes with a reported prevalence rate of 24%
 A review of the sleep disorder literature is beyond the scope of this consensus paper but the potential prevalence of a sleep disorder may affect the ability of an athlete to overcome the harmful effects of travel fatigue and jet lag
 It is recommended that athletes be screened for sleep disorders in pre-season to identify and treat athletes and more importantly, to improve performance

Effects of altitude on sleep

Athletes travelling to locations of high altitude may experience an increase in sleep disordered breathing events resulting in sleep fragmentation
 This may cause loss of sleep and potentially negatively affects performance

feel sleepy, but their performance will be impaired in the early afternoon, they will have difficulty falling asleep at their regular bedtime, and they will sleep in later than usual [21]. Chronotype may also influence these responses as morning larks adapt better to eastward travel (easier to shift circadian rhythms earlier), whereas night owls adapt better to westward travel (easier to shift circadian rhythms later) [62].

7.2 Assessment of Teams and Athletes

Given the complexity of the disruption to the circadian system, as well as the variety of associated physiological and psychological symptoms, several assessment tools can be used to assess the different aspects of jet lag. These may include questionnaires, sleep diaries in conjunction with actigraphy and circadian-phase markers.

Of the available questionnaires, the Liverpool Jet Lag Questionnaire appears to be the most valid and reliable subjective tool [74, 107]. This questionnaire is a visual analogue scale with 15 subjective ratings about overall perceived jet lag and its symptoms (sleep, fatigue, appetite, mental performance and bowel function), measured at different times

of the day. Other tools such as the Columbian Jet Lag Scale [108] may offer suitable alternatives [109].

Actigraphy typically utilises movement-derived algorithms to provide estimates of sleep timing, duration and quality, and is commonly used in athletic settings in conjunction with sleep diaries [110, 111]. While actigraphy can help with information regarding rest–activity and/or sleep behaviour during travel, there is minimal evidence to support its use in evaluating jet lag per se. Circadian-phase markers perhaps represent the most accurate objective measure to assess jet lag, as they examine a phase response to interventions (e.g. CBT, salivary melatonin, [48, 112] body skin temperature) [13, 113, 114] but are unlikely suitable for sport due to the practicality, cost and invasiveness. If feasible, these circadian-phase markers could give insight into designing optimal jet lag interventions. A technique to indicate if sleep–wake behaviour has adapted is to measure the change in the mid-point of the sleep period between home and destination time zone, i.e. the difference in the median hours between bedtime and get-up time as assessed by actigraphy [60, 115]. The authors suggest this as a possible alternative to measuring CBT and salivary melatonin-phase markers.

There are several online jet lag calculators and mobile applications which provide advice on the timing of

interventions to theoretically help adjust to a new time-zone [116–118]. In the elite sport environment, these calculators and mobile applications still require validation of the scientific base used to provide this advice, i.e. how is circadian phase determined, and are the proposed interventions evidence-based [119]. The consensus group cautions against the use of these until further research examining the efficacy and effectiveness of these tools in the athlete environment has been conducted.

Choosing measures to assess jet lag depends on a range of factors, such as the intention of the measure, validity and reliability, suitability for laboratory or field testing, as well as cost, time, practicality and expertise of operation. Teams or athletes are best served to select a tool that serves their direct purpose. Further research is needed to determine appropriate assessment measures of jet lag for teams and athletes [20, 120].

7.3 Current Recommendations in the Management of Jet Lag

Most literature refers to light, melatonin and preservation of sleep as the best options to mitigate jet lag. Considering the impact of sleep loss on performance, one of the main goals taking into account the athlete's training and competition schedules, should be to preserve sleep. Other strategies include exercise, nutrition, melatonin analogues, sedatives and stimulants. The literature regarding recommendations on management strategies is published mainly as opinions [4, 13, 93, 106], collective experience manuscripts [3, 5, 21, 121], laboratory research studies on how to induce a phase shift [122–125] and laboratory research studies on how to recover from a phase shift [20, 48, 49]. Considering the literature referenced in this consensus paper, extrapolating evidence from healthy community and military populations and following the findings of a recent systematic review [20], the author group collectively summarised current recommendations based on consensus (Table 4, Figs. 4, 5 and 6).

8 Theoretical Concepts to Guide Future Research

To address the gaps in knowledge, high-quality multi-centre research that is repeatable and reliable is required in athletes, and utilising multi-disciplinary methodology in an attempt to adopt a holistic approach [146]. Specific measurements are required [e.g. CBT, melatonin, electroencephalogram (EEG)] otherwise the “research” will continue to either be surrogate measures, opinions or collective experiences.

For travel fatigue, randomised trials and longitudinal studies are needed to compare interventions aiming to reduce travel fatigue. Cabin conditions including seat size

in buses, trains and planes can contribute to travel fatigue and require more research. The impact of specific parameters related to air travel, such as the average flight altitude, and the frequency and magnitude of atmospheric pressure, changes during the flight, which affects air cabin oxygen saturation levels are also worth exploring. Additionally, information on how travel fatigue is impacted following short distance (< 3 h) vs. long distance (> 3 h) travel, as well as the direction of travel (north–south/south–north, east–west/west–east) and the frequency of travel across a season is required. From a different perspective, there may be value in qualitative research evaluating how much athletes, coaches and support staff value and use monitoring tools. Determining the specific intervention, and the reason why coaches and athletes utilise these to minimise travel fatigue is also important. This is significant considering the burden which can be associated with athlete monitoring, the role of coaches and support staff in interpreting such data, concerns about whether such data are used in a meaningful manner, and the importance of athlete psychological health in perceived fatigue [147].

Well-controlled field-based jet lag studies that examine circadian adaptation and the impact of light exposure or avoidance schedules, using an appropriate phase marker, are required. To better understand risk factors and develop at-risk profiles for suitable interventions aligned to these profiles, tools to predict jet lag symptom severity and chronicity in individual travelling athletes need to be developed. Multi-centre studies exploring travel across a season, in competitions that involve frequent transmeridian travel (e.g. World Rugby 7 Series) rather than just assessing the impact of once-off travel will be valuable. Polysomnography (PSG) baseline data in more sports, sexes and age groups may be useful to identify sleep disorders in athletes and those who may be more at risk when travelling and also to compare PSG data on return to home to assess how long it takes for sleep to normalise.

9 Conclusion

This review and consensus statement highlights the complexity and lack of empirical research surrounding the measurement and management of travel fatigue and jet lag in athletes, curtailing the provision of strong recommendations. It concurs that travel fatigue and jet lag can inflict real and impactful issues on athletes regarding their performance and risk of illness or injury. Considering strategies pre-flight, during flight and after arrival at the destination, experts working in the field reached consensus on the management of travel fatigue and jet lag in athletes. Travel toolboxes covering fundamental principles and expert consensus recommendation for interventions are provided. Key interventions

Table 4 Essential information to manage jet lag [3–5, 13, 20, 21, 48, 49, 93, 106, 121–127]

Direction of travel

After a *westward* flight, the body clock is ahead of time (i.e. at a later time of day) compared to the destination time-zone and *has to delay or move backward* (to an earlier time of day) to become synchronised.

After an *eastward* flight, the body clock is behind (i.e. at an earlier time of day) compared to the destination time-zone and must *advance or move forward* (to a later time of day) to become synchronised.

Time-zones

The number of time-zones crossed will have different implications for the timing of management strategies. Additionally, for time-zone changes of >8h EAST, it may be preferable to adapt by delay instead of advance as the body clock adjusts to extensive delays easier than to extensive advances.

CBTmin and DLMO (Fig 2)

Crucial for the estimated timing of interventions.

	DLMO (~2h before habitual bedtime)	CBTmin (~7h after DLMO)
At habitual bedtimes of:		
22:00–06:00	~20:00	~03:00
23:00–07:00	~21:00	~04:00
midnight–08:00	~22:00	~05:00

To calculate CBTmin	✈️ travelling WEST	✈️ travelling EAST
	subtract time-zone change from pre-travel CBTmin	add time-zone change to pre-travel CBTmin
Example: if CBTmin home time is 04:00	flying 8h WEST ✈️ CBTmin will be at 20:00 destination time	flying 8h EAST ✈️ CBTmin will be at 12 noon destination time

Optimal timing of an intervention

It is estimated that CBTmin naturally shifts by 0.5 days (2h per day) per time-zone crossed WEST and 1 day (1h per day) per time-zone crossed EAST. Since this shift can be accelerated when applying an intervention, it is advised to shift the timing of interventions by 2h per day when travelling WEST and 1h per day when travelling EAST.

Flight choice

Important to aid with effective adaptation. If feasible, choose a flight with an arrival time to coincide with either the optimal period of light exposure or avoidance at the destination. (Fig 6)

Short-term travel (1-3 days)

Align sleep and meal times to destination time-zone, but do not try to shift the body clock.

Ensure adequate amount of sleep and employ strategic napping to reduce cumulative sleep debt.

Consider use of short-acting hypnotics if clinically indicated (e.g. Zolpidem 10mg; according to team medical protocols)

Maintain alertness with caffeine (dietary sources or anhydrous caffeine) at a dose of 1 mg/kg body mass (proven as effective with a lower risk of side-effects compared to higher doses)

Try to schedule all activities during the period of maximum alertness in the departure time-zone if feasible; this is dependent on the number of time-zones crossed

Sleep disorders and altitude

Refer Table 3

after travel include adjusting the sleep–wake cycle to counter travel fatigue and maximising the rate at which the body clock adapts to the new time zone by specifying 3 h periods of light exposure and avoidance to reduce jet lag. Importantly, inappropriate exposure may be counter-productive

causing detrimental side effects. Lastly, this review outlines specific steps to advance theory and practice in the field, suggesting detailed areas of future research on travel fatigue and jet lag management in athletes.

Recommended interventions to help prevent or reduce the effect of jet lag

Non-pharmacological Interventions	<p>← WEST (Phase-delay)</p> <p>CBTmin advance by 0.5 days (2h per day) per time-zone crossed during adaptation [5]</p>	<p>→ EAST (Phase-advance)</p> <p>CBTmin delay by 1 day (1h per day) per time-zone crossed during adaptation [5]</p> <p>[Consider delaying (moving backward) rather than advancing (moving forward) especially for large time-zone changes >8h]</p>
<p>Light [38-39]</p>		
<ul style="list-style-type: none"> Sunlight is the most dominant environmental signal for the circadian system even on overcast days When required at sunrise or sunset, supplement with artificial bright light (light boxes, bright indoor light, light-emitting sunglasses) Blue light spectrum filter glasses can limit light transmission by up to 85% Maximum delays or advances are subject to the duration of light exposure (0-6h), shorter blue light 400-495nm, at ≥2500 lux intensity Inappropriate light exposure may interfere with sleep 	<p>Pre-flight (3-4days)^a</p> <p>← Maximise light exposure in the evening (before CBTmin), avoid light in the morning (after CBTmin)</p> <p>During and Post-flight</p> <p>← Maximise light exposure 0-3h prior to CBTmin, avoid light 0-3h after CBTmin (by sleeping if possible)</p>	<p>Pre-flight (3-4days)^a</p> <p>→ Avoid light in the evening (before CBTmin), maximise light exposure in the morning (after CBTmin)</p> <p>During and Post-flight</p> <p>→ Avoid light 0-3h prior to CBTmin (by sleeping if possible), maximise light exposure 0-3h after CBTmin</p>
<p>Sleep^b [2,13,94,128-132]</p> <ul style="list-style-type: none"> Optimal sleep: minimum of 7-9h per day Sleep preservation is the mainstay of jet lag management as it counteracts the effects of desynchronisation and sleep deprivation suffered from long flights A short interval between the last full sleep pre-travel and the first full sleep post-travel may reduce jet lag When travelling west (phase delay), flight timing has to be strategic to allow for players to sleep in to minimise sleep deprivation Attempt to arrange for housekeeping not to interfere with team sleep schedule Do not exercise or train in periods of recommended sleep time 	<p>Pre-flight (3-4days)^b</p> <ul style="list-style-type: none"> Sleep enough to minimise sleep debt <p>← Delay sleep later by up to 1h each successive day prior to travel but still keep to a minimum of 7-9h per day</p> <p>During flight</p> <ul style="list-style-type: none"> Attempt to sleep when possible, considering the "sleep window" aligned with night at the place of departure as the physiological drive for sleep will be higher, and sleep initiation easier Consider the use of pharmacological aids, i.e. melatonin, sedatives. Inappropriate timing of melatonin ingestion can induce a phase shift in the wrong direction <ul style="list-style-type: none"> Avoid caffeine and alcohol Wear comfortable, loose-fitting clothes Minimise use of electronic equipment Use sleep aids to cancel noise and movement, i.e. eye masks, neck pillows, earplugs <p>Post-flight</p> <ul style="list-style-type: none"> Apply good sleep hygiene practices at destination: i.e. ensure cool (~20°C), quiet and dark conditions when sleeping, dim room lights 1h before bedtime, minimise use of electronic equipment, avoid caffeine ±6h before sleep <ul style="list-style-type: none"> Strategic napping may be useful. If the window is short the nap should be <30min to prevent sleep inertia. Schedule napping between 13h00 – 16h00 Follow a sleep schedule that allows gradual re-alignment with the destination time-zone (Fig 6) <p>← Bed and wake times will initially be earlier, but need to move later</p>	<p>Pre-flight (3-4days)^b</p> <ul style="list-style-type: none"> Sleep enough to minimise sleep debt <p>→ Advance sleep earlier by up to 1h each successive day prior to travel but still keep to a minimum of 7-9h per day</p> <p>During flight</p> <ul style="list-style-type: none"> Attempt to sleep when possible, considering the "sleep window" aligned with night at the place of departure as the physiological drive for sleep will be higher, and sleep initiation easier Consider the use of pharmacological aids, i.e. melatonin, sedatives. Inappropriate timing of melatonin ingestion can induce a phase shift in the wrong direction <ul style="list-style-type: none"> Avoid caffeine and alcohol Wear comfortable, loose-fitting clothes Minimise use of electronic equipment Use sleep aids to cancel noise and movement, i.e. eye masks, neck pillows, earplugs <p>Post-flight</p> <ul style="list-style-type: none"> Apply good sleep hygiene practices at destination: i.e. ensure cool (~20°C), quiet and dark conditions when sleeping, dim room lights 1h before bedtime, minimise use of electronic equipment, avoid caffeine ±6h before sleep <ul style="list-style-type: none"> Strategic napping may be useful. If the window is short the nap should be <30min to prevent sleep inertia. Schedule napping between 13h00 – 16h00 Follow a sleep schedule that allows gradual re-alignment with the destination time-zone (Fig 6) <p>→ Bed and wake times will initially be later, but need to move earlier</p>
<p>Exercise [125,133]</p> <ul style="list-style-type: none"> The appropriate time, intensity and duration of exercise may induce a phase shift. However, limited evidence exists to provide accurate advice Effects of exercise coincide with the times for bright light exposure and avoidance Coordination and agility are impaired following travel Low-intensity aerobic exercise assists in feeling less fatigued following travel 	<p>Pre-flight (3-4days)^a</p> <ul style="list-style-type: none"> Switch from long-duration training to moderate training intensity, of medium duration (30-60min) <p>During flight</p> <ul style="list-style-type: none"> Periodic activity, every ~2h outside of the "sleep window", e.g. isometric exercises, walks along the aisles or stretching exercises <p>Post-flight</p> <ul style="list-style-type: none"> On arrival: follow a reduced exercise schedule for the first few days (≤72h). Limit exercise intensity and complexity of movement patterns in the first few days. Consider hand-eye coordination drills <ul style="list-style-type: none"> Vigorous exercise ≤1h before bedtime may interfere with sleep 	<p>Pre-flight (3-4days)^a</p> <ul style="list-style-type: none"> Switch from long-duration training to moderate training intensity, of medium duration (30-60min) <p>During flight</p> <ul style="list-style-type: none"> Periodic activity, every ~2h outside of the "sleep window", e.g. isometric exercises, walks along the aisles or stretching exercises <p>Post-flight</p> <ul style="list-style-type: none"> On arrival: follow a reduced exercise schedule for the first few days (≤72h). Limit exercise intensity and complexity of movement patterns in the first few days. Consider hand-eye coordination drills <ul style="list-style-type: none"> Vigorous exercise ≤1h before bedtime may interfere with sleep
<p>Nutrition^c [20,82,134-137]</p> <ul style="list-style-type: none"> Upfront planning and preparation to improve food choices and meet nutrition needs (for optimal training, recovery, and performance) remain a key focus (Table 3) Dietary intake can further amplify or reduce circadian adaptation and/or side-effects of travel (e.g. fatigue, sleep disturbance, gastrointestinal (GI) symptoms) Meal composition (carbohydrate, protein, fat) may potentially influence sleep architecture; and eating pattern or routine of main meals (in tune with light-dark cycle at destination) may enhance circadian adaptation 	<p>Pre-flight (3-4days)^a</p> <ul style="list-style-type: none"> Gradually shift eating (and sleep) schedule by 30–60 min each day towards the destination time for a few days before departure. <ul style="list-style-type: none"> Carbohydrate-rich meals eaten 1-4h pre-bedtime promote sleep (high-glycaemic index or easily digested meal) Avoid insufficient energy (calorie) intake, it may disturb sleep quality Avoid high fat intake (over 4-7 days), it may negatively affect total sleep time <p>During flight</p> <ul style="list-style-type: none"> Follow the pattern of small, regular meals and/or snacks (better tolerated, improve GI comfort) and general advice (Table 3) <p>Post-flight</p> <ul style="list-style-type: none"> Adjust to a pattern of eating regular meals that align with the light-dark cycle at the destination Follow a pattern of small, regular meals or snacks (better tolerated, improve GI comfort) and general advice (Table 3) <ul style="list-style-type: none"> Implement personal and food hygiene standards (Table 3) 	<p>Pre-flight (3-4days)^a</p> <ul style="list-style-type: none"> Gradually shift eating (and sleep) schedule by 30–60 min each day towards the destination time for a few days before departure. <ul style="list-style-type: none"> Carbohydrate-rich meals eaten 1-4h pre-bedtime promote sleep (high-glycaemic index or easily digested meal) Avoid insufficient energy (calorie) intake, it may disturb sleep quality Avoid high fat intake (over 4-7 days), it may negatively affect total sleep time <p>During flight</p> <ul style="list-style-type: none"> Follow the pattern of small, regular meals and/or snacks (better tolerated, improve GI comfort) and general advice (Table 3) <p>Post-flight</p> <ul style="list-style-type: none"> Adjust to a pattern of eating regular meals that align with the light-dark cycle at the destination Follow a pattern of small, regular meals or snacks (better tolerated, improve GI comfort) and general advice (Table 3) <ul style="list-style-type: none"> Implement personal and food hygiene standards (Table 3)
<p>Nutrition^c (fluids) [78,82,134]</p> <ul style="list-style-type: none"> Increased loss of water from dry cabin air Poor hydration can amplify negative side-effects associated with travel (headaches, constipation) 	<p>Pre-, During and Post-flight</p> <ul style="list-style-type: none"> Follow current sports nutrition guidelines for maintaining optimal hydration. Urine colour can be used as a guide for hydration status (urine should be pale yellow like lemon juice, low in odour) Habitual coffee or tea drinkers should not totally abstain, as it may result in reduced fluid intake and caffeine withdrawal symptoms (headaches, irritability) Avoid alcohol altogether, and caffeine or caffeine-containing drinks ±6h before bed- or sleep time (interferes with quality of sleep and complicates resynchronisation) Do not consume fluids too late in the evening and/or large volumes just before bedtime as it may interrupt sleep due to nocturia 	<p>Pre-, During and Post-flight</p> <ul style="list-style-type: none"> Follow current sports nutrition guidelines for maintaining optimal hydration. Urine colour can be used as a guide for hydration status (urine should be pale yellow like lemon juice, low in odour) Habitual coffee or tea drinkers should not totally abstain, as it may result in reduced fluid intake and caffeine withdrawal symptoms (headaches, irritability) Avoid alcohol altogether, and caffeine or caffeine-containing drinks ±6h before bed- or sleep time (interferes with quality of sleep and complicates resynchronisation) Do not consume fluids too late in the evening and/or large volumes just before bedtime as it may interrupt sleep due to nocturia

Fig. 4 Recommended interventions to help prevent or reduce the effect of jet lag

Pharmacological Interventions	← WEST (Phase-delay) CBTmin advance by 0.5 days (2h per day) per time-zone crossed during adaptation [5]	→ EAST (Phase-advance) CBTmin delay by 1 day (1h per day) per time-zone crossed during adaptation [5] [Consider delaying (moving backward) rather than advancing (moving forward) especially for large time-zone changes >8h]
Melatonin^d [21,48,138-139]		
<ul style="list-style-type: none"> Exogenous melatonin is both hypnotic (sleep-inducing, higher dose) and chronobiotic (phase-shifting, lower dose) and proves more beneficial when travelling east and crossing more time-zones Dosages range from 0.5-10mg with 3-5mg the optimal dose to assist with faster sleep onset and better sleep Administer until full adjustment has occurred at the destination Appropriate administration time to aid circadian adaptation determined by PRC of melatonin (Fig 1) Timing of ingestion may differ depending on travel direction and number of time-zones crossed Consider potential side-effects (headaches, nausea, daytime drowsiness, vivid dreams, nightmares) Athletes are strongly advised to clear melatonin use with their physician 	<p>Pre-flight (3-4days)^a Athletes should clear pre-flight melatonin consumption with their medical doctor</p> <p>During flight Consider the use of melatonin Inappropriate timing of melatonin ingestion can induce a phase shift in the wrong direction</p> <p>Post-flight</p> <ul style="list-style-type: none"> 1st day after travel, estimate the timing of CBTmin relative to the new time-zone <ul style="list-style-type: none"> Be sure to consider any potential shift due to pre-travel adaptation <p>← Take melatonin 4h after CBTmin</p>	<p>→ Take melatonin 11.5h before CBTmin</p>
Melatonin Analogues^d [20,140-141]		
e.g. Tasimelteon, Ramelteon		<p>During and Post-flight</p> <ul style="list-style-type: none"> Shows significant improvement in sleep and daytime alertness and large phase-shifts in melatonin onset <ul style="list-style-type: none"> Only investigated in non-athlete populations and laboratory-based studies
Sedatives^d (Hypnotics)		
<ul style="list-style-type: none"> Careful consideration of the possible risk of deep venous thrombosis Preferably administer only for up to 4 days after arrival at the destination Consider reintroduction for those athletes suffering insomnia after 4 days Only if previous use was tolerated, i.e. slept well with no adverse events A decision by a medical doctor based on individual assessment 		<p>During and Post-flight</p> <ul style="list-style-type: none"> Short-acting sleep aids (non-diazepine Z-drugs e.g. zolpidem, zopiclone) to induce sleep in athletes who have previously tolerated the medication
Stimulants^d (Armodafinil, slow-release caffeine) [94,126,142-143]		
		<p>During and Post-flight</p> <ul style="list-style-type: none"> Armodafinil at a dose of 150mg/day is successfully used for daytime sleepiness Caffeine supplementation at a dose of 1mg/kg (during the local morning and early afternoon) can be used to reduce sleepiness and increase alertness around training and competition Avoid late-afternoon or evening caffeine as it may interfere with night-time sleep

Footnote:

a: Pre-flight adaptation: This strategy is only an option for a very small category of athletes (team athletes may find it difficult). Training and competition schedules may interfere with this strategy. Further potential disadvantages of pre-adjustment include social interference, sleep disruption e.g. sleep onset insomnia, complicating the estimation of CBTmin (important for appropriate timing of interventions) upon arrival at the destination, and the lack of stringent compliance due to limited supervision [21]. In laboratory settings, this strategy was successfully achieved, but randomised controlled field trials are required to prove a reduction of jet lag symptoms and improved performance.

b: Sleep hygiene: Inappropriate light exposure may interfere with sleep; Minimise use of electronic equipment; Use sleep aids to cancel noise and movement i.e. eye masks, neck pillows, earplugs. Good sleep hygiene practices at destination: i.e. ensure cool (~20°C), quiet and dark conditions when sleeping, dim room lights 1h before bedtime[#], minimise the use of electronic equipment, avoid caffeine ±6h before sleep [132]; Caution athletes not to exercise or train in periods of recommended sleep time.

[#]Dimming room lights 1h before bedtime is independent of DLMO that typically occurs ~2 hours before habitual sleep. Manipulating light intensity in the few hours before habitual bedtime causes little change in sleep times, but it has the potential to shift the DLMO phase and impact circadian timing [144].

c: Nutrition: Feeding and fasting cycles follow a circadian pattern that acts as *zeitgebers* for peripheral clocks. For example, the gastrointestinal (GI) system (GI motility, digestive secretions, absorption and blood nutrient concentrations) follows a rhythmic cycle of activity and the liver clock shows sensitivity towards the timing and composition of food [82,134]. Although some food factors and nutritional strategies (e.g. intermittent fasting, meal composition and timing) have shown promise in modulating circadian clocks, much of the evidence remains animal-based [134-135]. With the limited number of human studies,[20,136] the application and effectiveness of these strategies for athletes remain unclear. It would be important to investigate and assess the potential negative impact any such "chrono"-nutritional strategies may have on interfering with well-proven nutritional strategies in support of optimising training, recovery and competition performance [137].

d: WADA: For caffeine and all pharmacological interventions, the most recent World Anti-Doping Agency (WADA) regulations need to be considered [145].

NOTE: **Watch time:** The author group could not reach consensus; some felt that it is better to keep watches aligned to sleep and wake at the destination time-zone. Utilising a smartwatch, an individual can keep 1 clock on departure time and 1 on destination time.

Fig. 4 (continued)

Combined interventions and short-term travel recommendations to help prevent or reduce the effect of jet lag

← WEST (Phase-delay) CBTmin advance by 0.5 days (2h per day) per time-zone crossed during adaptation [5]	→ EAST (Phase-advance) CBTmin delay by 1 day (1h per day) per time-zone crossed during adaptation [5] [Consider delaying (moving backward) rather than advancing (moving forward) especially for large time-zone changes >8h]
Combined interventions^{a,b,c,d} [2,5,13,20-21,48,82,94,138]	
Pre-flight (3-4days)	
<ul style="list-style-type: none"> Education: discuss travel and expected effects. Make clear the policy on sleeping medication. Minimise anxiety around sleep disruption versus performance decrement <ul style="list-style-type: none"> Athletes should clear pre-flight melatonin consumption with their medical doctor 	
<ul style="list-style-type: none"> Gradually move bedtime, wake-up time and nutrition schedule later (i.e. 30-60min/day) Maximise evening light exposure, minimise morning light exposure 	<ul style="list-style-type: none"> Gradually move bedtime, wake-up time and nutrition schedule earlier (i.e. 30-60min/day) Minimise evening light exposure, maximise morning light exposure
During flight	
<ul style="list-style-type: none"> Attempt to sleep when possible, considering the "sleep window" aligned with night at the place of departure as the physiological drive for sleep will be higher, and sleep initiation easier <ul style="list-style-type: none"> Plan appropriate food and fluid intake for athletes, including adaptations around travel delays Melatonin during flight not recommended 	
<ul style="list-style-type: none"> Maximise light exposure 0-3h before CBTmin, avoid light 0-3h after CBTmin (by sleeping if possible) 	<ul style="list-style-type: none"> Maximise light exposure 0-3h after CBTmin, avoid 0-3h light prior to CBTmin (by sleeping if possible)
Post-flight	
<ul style="list-style-type: none"> Follow a sleep schedule that allows gradual re-alignment with the destination time-zone and assist with sleeping aids and sleeping tablets if needed, but based on an individualised basis. <ul style="list-style-type: none"> Appropriate times to conduct exercise for its phase-shifting properties coincide with the appropriate times for light exposure Avoid eating heavy meals before bedtime, eat smaller meals more frequently to minimise gastrointestinal discomfort Structure the training day regarding alertness for complex tasks, shorten session time, use social interaction to maintain wakefulness at time of predictable sleepiness 	
<ul style="list-style-type: none"> Maximise light exposure 0-3h before CBTmin, avoid light 0-3h after CBTmin (by sleeping if possible) Take melatonin 4h after CBTmin 	<ul style="list-style-type: none"> Maximise light exposure 0-3h after CBTmin, avoid 0-3h light prior to CBTmin (by sleeping if possible) Take melatonin 11.5h before CBTmin

Footnote:

Combined interventions: Consider the best net result e.g. referring to Figure 6 flying 4h WEST – proposed light exposure and sleep time coincides; depending on the immediate need of the athlete (fatigued or not) the decision will be to either opt for sleep or to rather get light exposure before bedtime.

a: Pre-flight adaptation: This strategy is only an option for a very small category of athletes (team athletes may find it difficult). Training and competition schedules may interfere with this strategy. Further potential disadvantages of pre-adjustment include social interference, sleep disruption e.g. sleep onset insomnia, complicating the estimation of CBTmin (important for appropriate timing of interventions) upon arrival at the destination, and the lack of stringent compliance due to limited supervision [21]. In laboratory settings, this strategy was successfully achieved, but randomised controlled field trials are required to prove a reduction of jet lag symptoms and improved performance.

b: Sleep hygiene: Inappropriate light exposure may interfere with sleep; Minimise use of electronic equipment; Use sleep aids to cancel noise and movement i.e. eye masks, neck pillows, earplugs. Good sleep hygiene practices at destination: i.e. ensure cool (~20°C), quiet and dark conditions when sleeping, dim room lights 1h before bedtime[#], minimise the use of electronic equipment, avoid caffeine ±6h before sleep [132]; Caution athletes not to exercise or train in periods of recommended sleep time.

[#]Dimming room lights 1h before bedtime is independent of DLMO that typically occurs ~2 hours before habitual sleep. Manipulating light intensity in the few hours before habitual bedtime causes little change in sleep times, but it has the potential to shift the DLMO phase and impact circadian timing [144].

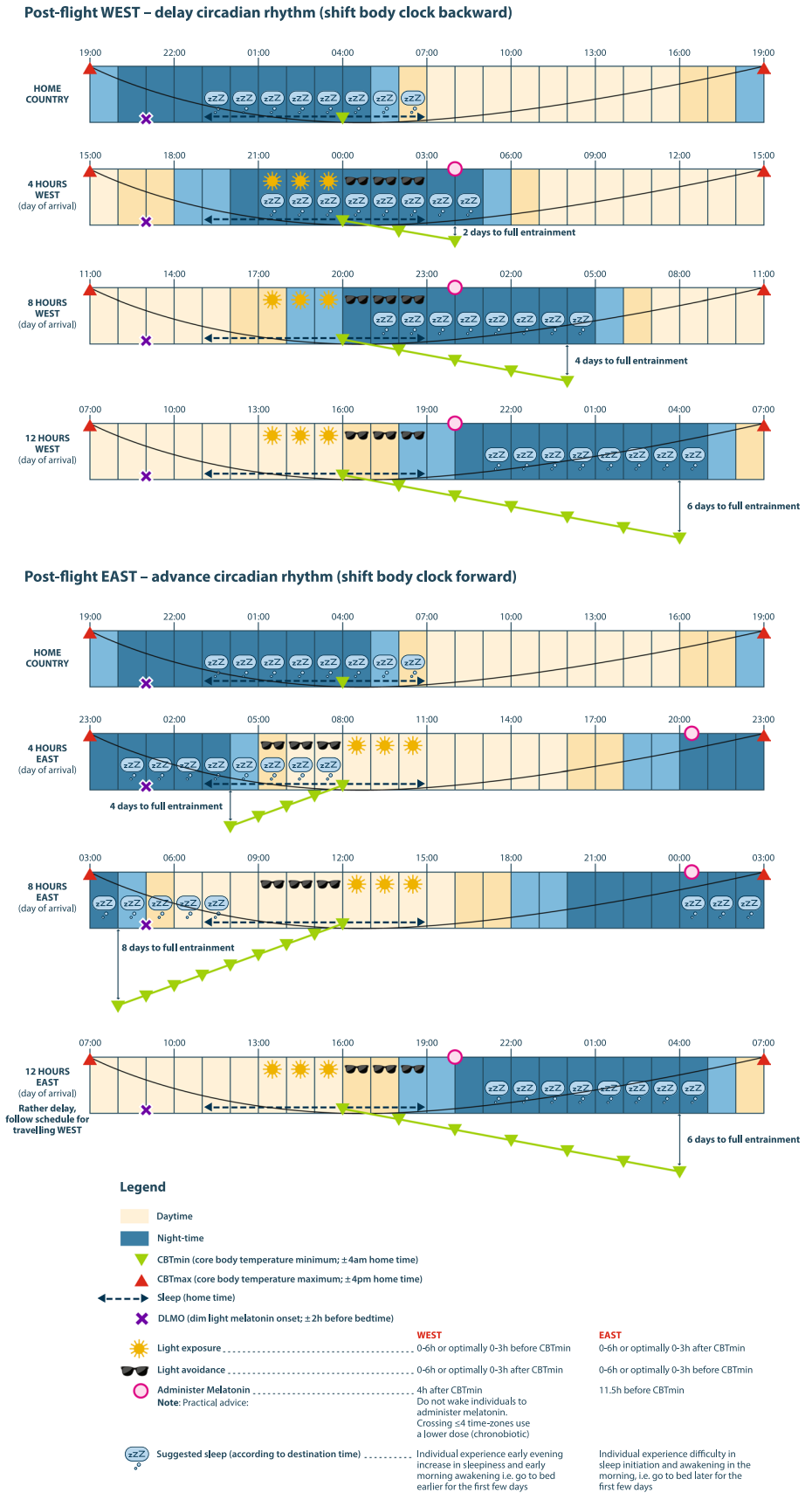
c: Nutrition: Feeding and fasting cycles follow a circadian pattern that acts as *zeitgebers* for peripheral clocks. For example, the gastrointestinal (GI) system (GI motility, digestive secretions, absorption and blood nutrient concentrations) follows a rhythmic cycle of activity and the liver clock shows sensitivity towards the timing and composition of food [82,134]. Although some food factors and nutritional strategies (e.g. intermittent fasting, meal composition and timing) have shown promise in modulating circadian clocks, much of the evidence remains animal-based [134-135]. With the limited number of human studies the application and effectiveness of these strategies for athletes remain unclear [20,136]. It would be important to investigate and assess the potential negative impact any such "chrono"-nutritional strategies may have on interfering with well-proven nutritional strategies in support of optimising training, recovery and competition performance [137].

d: WADA: For caffeine and all pharmacological interventions, the most recent World Anti-Doping Agency (WADA) regulations need to be considered [145].

NOTE: **Watch time:** The author group could not reach consensus; some felt that it is better to keep watches aligned to sleep and wake at the destination time-zone. Utilising a smartwatch, an individual can keep 1 clock on departure time and 1 on destination time.

Fig. 5 Combined interventions and short-term travel recommendations to help prevent or reduce the effect of jet lag

Fig. 6 The combined use of light (exposure or avoidance), exogenous melatonin ingestion and administration of short-acting hypnotics to facilitate adaptation to phase shifts from the day of arrival. **a** Depicts westward travel with the first row illustrating normal home time. The next three rows illustrate travel crossing 4, 8 and 12 h time zones, respectively. Each row represents the current phase of the circadian system on the day of arrival. The CBTmin shifts by 0.5 days per time zone crossed, i.e. delays by 2 h per day and application of interventions need to be adapted according to the shifting of the CBTmin. **b** Depicts eastward travel with the first row illustrating normal home time. The next three rows illustrate travel crossing 4, 8 and 12 h time zones, respectively. Each row represents the current phase of the circadian system on the day of arrival. The CBTmin shifts by 1 day per time zone crossed, i.e. advances by 1 h per day and application of interventions need to be adapted according to the shifting of the CBTmin. We constructed a recommendation based on a scientific measurement (CBTmin and DLMO) that can be reasonably applied for any number of time zones crossed. Travelling > 8 h EAST, it may be preferable to adapt by delay (moving backward) instead of advance (moving forward) as the body clock adjusts to large delays more easily than to large advances). Once CBTmin at the destination occurs within the scheduled sleep period, partial adaptation is achieved, and the individual is likely to encounter less sleep disruption. Once CBTmin at the destination occurs at the same time as pre-travel (home time), complete adaptation is achieved



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