PERFORMANCE RECOVERY FOLLOWING LONG-HAUL INTERNATIONAL TRAVEL IN TEAM SPORT ATHLETES

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Since elite team sport athletes regularly undertake long-haul international travel, recovery from travel is important for ensuing training and competition success. However, due to an insufficient understanding of the impact of travel on sports performance, there is a paucity of related evidence-based interventions. Therefore, this article will highlight the potential mechanisms through which international travel may affect team sport performance and provide practical and evidence-based guidelines for coaches and sports medicine practitioners to implement around travel.

PERFORMANCE

Due to the logistics and cost associated with conducting travel research, few field-based studies investigating the effects of international travel on performance exist (Table 1). In addition, conclusions drawn regarding the effects of travel on team sport performance are based on studies using measures that are questionably related to performance in training or competition[1]. In an attempt to address this limitation, our research group demonstrated reduced intermittent-sprint performance on the day following 24 hours of simulated international travel[2]. Furthermore, compared to 21 hours of travel west across eight time-zones, intermittent-sprint performance was reduced for the first 3 days following 21 hours of travel east across eight time-zones[3] (Figure 1). Although it is currently unclear whether international travel interferes with training to the extent that subsequent competition performance is impaired, it is assumed it would due to the combined negative effects of jet lag and the demands of travel.

JET LAG

Circadian rhythms

Following long-haul travel across multiple time zones, a loss of synchrony occurs between endogenous circadian rhythms, such as body temperature and melatonin, and the light-dark cycle. Previous findings indicate circadian rhythms in physical performance may align with those in body temperature[4]. Hence, it could be anticipated that following long-haul transmeridian travel, a shift in the performance rhythm of a morning nadir and a late afternoon peak would occur and that performance would be reduced outside

Table 1

Reference	Participants	Travel	Performance outcome	Time of measures (local time)	Results
Fowler et al[2]	*10 physically active males*	*24 h simulated*	*CMJ; a. PP b. PV c. Height YYIR1 distance*	*Day -1 at 16:00 +1 at 09:00 & 16:00*	*↔ CMJ PP, PV & Height ↓ YYIR1 distance (16:00)*
Chapman et al[24]	*5 female national team skeleton athletes*	*16 h EAST across 8 time-zones*	*BDJ; a. t_f b. t_c c. t_f:t_c ratio SJ & CMJ; a. MV & PV b. PP c. Height d. EUR for a, b & c.*	*-2, +1, +2, +4, +5, +7, +8 & +10 09:30 - 11:00*	*↓ BDJ t_f:t_c (+5) ↓ SJ PV (+2) ↓ CMJ height (+1) ↑ PV EUR (+2) ↑ PP EUR (+2, +4, +7)*
Bullock et al[25]	*5 female national team skeleton athletes*	*16 h EAST across 8 time-zones*	*30 m sprint time (sec)*	*-2, -1, +1, +2, +4, +7 & +10 09:30 - 11:00*	*↔ sprint time*
Lemmer et al[26]	*13 male Olympic athletes (WEST) & 6 male Olympic athletes (EAST)*	*10 h WEST across 6 time-zones & 12 h EAST across 8 time-zones*	*Grip strength (kg)*	*-1, +1, +4, +6, +11 at 03:00, 07:00, 09:00, 10:30, 13:00, 16:00, 20:00 22:00 & 23:30*	*WEST; Change in trough time (hh:mm) on day 1 Change in peak time on day 6 EAST; No change in 24 h rhythm*

Table 1: Summary of studies to date with primary aim (i.e. no intervention) of investigating effects of long-haul travel on performance. PP=peak power, PV=peak velocity, CMJ=countermovement jump, YYIR1=yo-yo intermittent recovery level one test, t_f=flight time, t_c=contact time, BDJ=box drop jump, SJ=squat jump, EUR=eccentric utilisation ratio. ↑ and ↓ indicate a significant increase or decrease from pre-travel ($p<0.05$).

of its circadian peak window, although this may differ between individuals with an early, intermediate or late chronotype[5]. Considering the role of melatonin and body temperature in regulating sleep, circadian rhythm disruptions may also impact the sleep-wake cycle, which could in itself impact performance.

Sleep-wake cycle

Sleep onset is induced in the evening by a dark environment and increased endogenous melatonin, which causes vasodilation of blood vessels and a reduction in body temperature. Together with the alerting effects of the environment, waking is promoted in the morning by an inhibition of melatonin secretion, which causes vasoconstriction of blood vessels and an increase in body temperature[6]. Thus, when body temperature and melatonin circadian rhythms are misaligned with the light-dark cycle following long-haul travel, sleep may be disrupted. Specifically, it is assumed that delayed sleep onset and early awakening are likely to occur following long-haul eastward and westward travel, respectively. Jet lag symptoms and reductions in physical performance following international travel could therefore be a result of disruptions to both circadian rhythms and sleep (Figure 2). However to date, few studies have associated the disruption of circadian rhythms and/or the sleep-wake cycle with the detrimental symptoms of jet lag and in turn, reductions in physical, let alone team sport performance.

Symptoms

The assessment of jet lag is complicated by large variability in the types and severity of jet lag symptoms both between and within individuals, along with disparity between the aforementioned physiological rhythms and overt jet lag symptoms[7,8]. Symptoms of jet lag, such as fatigue, negative mood states and gastrointestinal disturbances can also vary in their degree of association with the overall construct of jet lag[8]. Lastly, there is currently no uniform approach for the measurement of jet lag symptoms, with several questionnaires available[8-10].

Estimated vs actual responses

Since the rate of circadian rhythm adaptation is estimated as half a day per hour of the time difference westwards and 1 day per hour of the time difference eastwards, it is purported that jet lag symptoms are worse the greater the number of time zones crossed and if travelling east rather than west. However, in reality it is rarely that simple. For example, following eastward travel across ten time zones, it is estimated that it would take approximately 10 days for circadian rhythms to adjust. Yet data from Edwards et al[11] indicates jet lag symptoms were negligible only 6 days following such travel. An individual's chronotype may also affect travel responses, with evidence suggesting that early and late chronotypes may have improved rates of adaptation to eastward and westward travel, respectively[12]. In addition, a strong correlation between jet lag and fatigue has previously been identified, together with early waking and increased sleep inertia being associated with greater morning jet lag[8]. Considering these associations and the impact of athletes training schedules on sleep and fatigue[13], subjective jet lag responses could be exacerbated in athletes due to combined travel and training demands.

DEMANDS OF TRAVEL

Travel fatigue symptoms are induced by the demands of air travel per se, including:

- Plane 'microclimate' (i.e. mild hypoxia and dry air).
- Cramped conditions and prolonged inactivity.
- Disruption of sleep patterns and nutritional intake.

Although symptoms of jet lag tend to be more severe and longer-lasting than those of travel fatigue, both may result in compromised performance (Figure 2). Separation of their individual effects is difficult in field-based environments and thus, laboratory-based studies simulating the aforementioned factors have been conducted[2].

Sleep

Since travel times of ≥ 24 hours can be enforced by long-haul travel, both phases of the sleep-wake cycle are likely to be encompassed and therefore, sleep disruption may occur during travel. Specifically, commercial flight schedules including the timing of stopovers and meals may disrupt sleep, as they can enforce waking during the sleep phase of the sleep-wake cycle. The conditions encountered during travel, such as the noise levels and impact of the seating arrangements on sleeping position may also affect sleep. Indeed, sleep quantity and quality were reduced during 24 hours of simulated international travel, which resulted in exacerbated physiological and perceptual fatigue and suppressed intermittent-sprint performance[2]. To date there is negligible information on the sleep patterns of elite athletes during and following international travel.

Illness

Outbound international travel across more than five time zones was associated

1

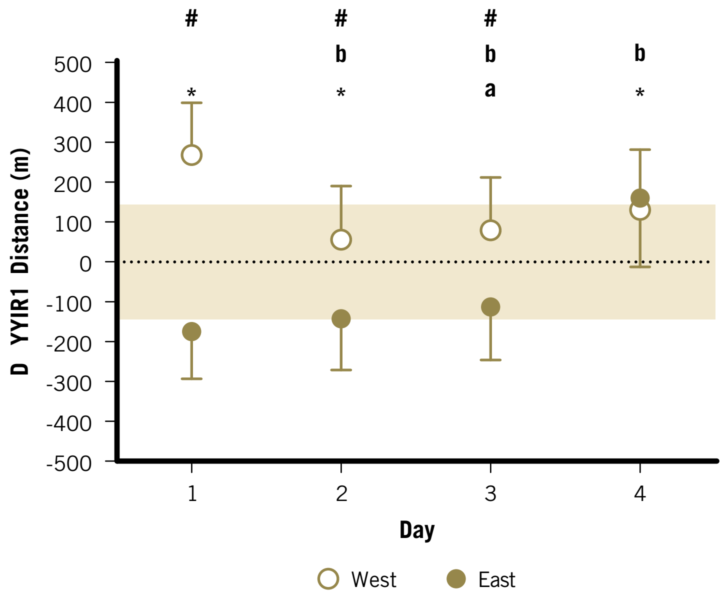


Figure 1: Absolute change in distance covered during the yo-yo intermittent recovery level one test in the afternoon (5pm local time) of the first 4 days following 21 hours travel west and east across eight time zones. *significantly different from baseline (p<0.05) (east). $^{\#}$significantly different to west (p<0.05). ^{a}large effect size for difference to baseline (d>0.90) (east). ^{b}large effect size for difference to baseline (d>0.90) (west). Shaded area indicates the typical error of the measure.

2

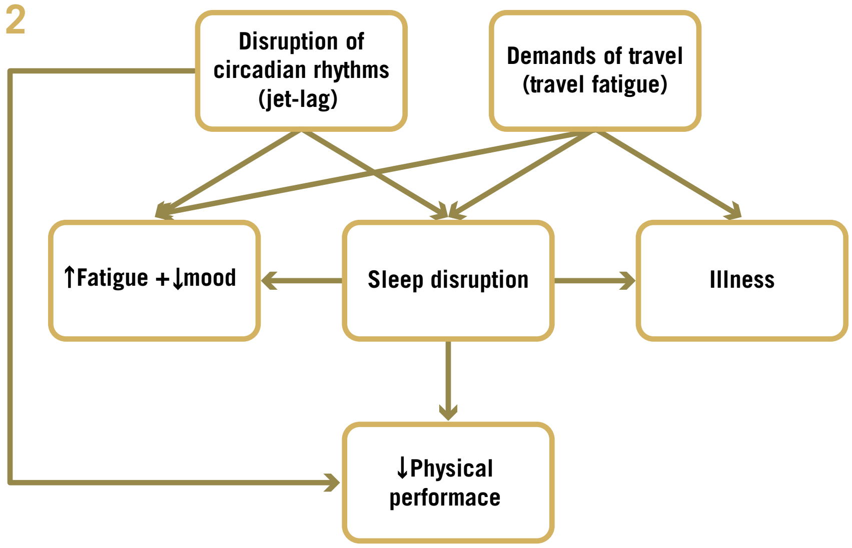


Figure 2: Potential mechanisms through which jet-lag and travel fatigue may impact team sport performance. Not only may a combination of the disruption of circadian rhythms and demands of travel impact physical performance through other factors, particularly sleep disruption, the disruption of circadian rhythms may affect physical performance itself.

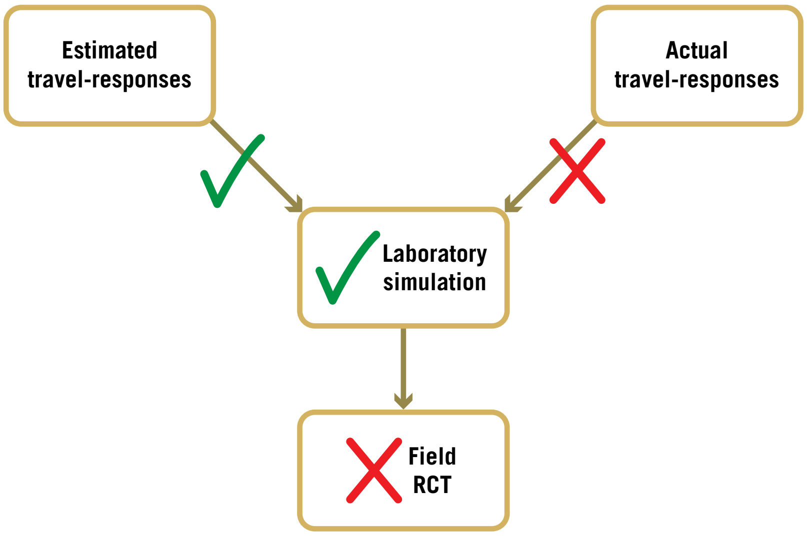


Figure 3: The 'translational pathway' of travel research adapted from Atkinson et al[7].

with a two- to three-fold increase in the incidence of illness in professional rugby union players[14]. This could be related to factors during travel, including drying of the respiratory epithelium, close contact with fellow travellers and exposure to re-circulated air and/or factors associated with the destination, such as environmental conditions, food and exposure to different pathogens. However, the incidence of illness following return travel was similar to baseline, suggesting the risk of illness may not be directly travel-induced, but rather due to factors associated with the destination[14]. A large climatic contrast between the place of departure and destination could also be a risk factor for illness. Therefore, athletes travelling to altitude or warm climates to utilise the environmental conditions for training adaptations may be at an increased risk of infection, which could reduce the effectiveness of their training. Research into the development of interventions that reduce the risk of illness as a result of international travel is therefore warranted.

INTERVENTIONS

The majority of travel interventions are based on an understanding of chronobiology rather than the specific effects of travel on team sport performance[15]. While these interventions are sound in theory, they may lack efficacy in the real world with elite team sport athletes[16] (Figure 3).

Following long-haul transmeridian travel, external cues referred to as 'zeitgebers' (time-givers), gradually resynchronise circadian rhythms. Jet lag symptoms are purported to persist until circadian rhythms are aligned with the light-dark cycle of the destination. While it is recommended that athletes allow sufficient time in a new destination for circadian rhythms to fully adjust prior to competition[15], this is often not plausible due to training and competition schedules. Improving the rate of adaptation would therefore be beneficial. Though attempts to shift circadian rhythms to align with the new time-zone are not recommended for short stays (1 to 2 days), a 'travel management programme', which is a comprehensive approach to the management of jet lag and travel fatigue that includes pre-, during and post-travel periods, has been advocated for longer stays[17].

Pre-travel

The most effective way to avoid jet lag is proposed to be through commencing circadian rhythm adjustment to the new time-zone prior to arrival, which has been successfully achieved in laboratory settings through light exposure and melatonin administration[18]. Given the stringent compliance required to implement this strategy and that national team coaches and medical staff often have limited contact with athletes prior to travel, this is likely to be impractical for team sport athletes. To date no randomised controlled trials

> **Outbound international travel across more than five time-zones was associated with a two- to three-fold increase in the incidence of illness in professional rugby union players**

have assessed the effectiveness of pre-adjustment at alleviating jet lag symptoms and improving the recovery of physical performance following international travel. Therefore, whether disruptions to optimal training outweigh the need to induce phase-shifts prior to travel is unknown.

During travel

It is currently recommended that sleep during travel should be scheduled according to when it is night at the destination and must be avoided when it is daytime at the destination, otherwise circadian rhythms may remain 'anchored' to the time zone of the place of departure[15]. However, these guidelines may be difficult to implement in practice, as during travel circadian rhythms will still be aligned with the departure time zone. Consequently, passengers could be attempting to sleep when melatonin and body temperature are inducing the physiological state for waking and endeavouring to stay awake when they are promoting sleep onset. Therefore, since disturbed sleep during travel is likely regardless of sleep timing, it may be more appropriate to schedule sleep according to when it is night at the place of departure and a more optimal time to initiate sleep. However, no studies have assessed the impact of sleep timing during travel on the subsequent resynchronisation of the sleep-wake cycle. The following sleep hygiene interventions may assist with reducing sleep disruption during travel[3] (Table 2):

- Minimise the use of electronic devices.
- Avoid caffeine.
- Use a neck pillow, eye mask, earplugs and/or noise cancelling headphones.
- Wear comfortable, loose fitting clothing to aid rest and relaxation and prevent overstimulation.

Factors during travel, particularly close contact with fellow travellers and exposure to different pathogens, may increase the risk of illness. Implementing practical measures during and following travel, such as using a hand sanitiser with residual activity and not self-inoculating by touching the eyes, nose and mouth, could therefore help with reducing the incidence of illness[19].

Post-travel

Behavioural interventions:

Light exposure

Promoting and restricting exposure to natural light at specific times may be the simplest intervention, as no specialist equipment is required. It is proposed that following westward travel, light exposure should be sought in the evening (body clock time) and avoided in the morning, whereas the opposite is required after eastward travel (Figure 4). Compared to bright sunlight, light intensity is significantly reduced on an overcast day and/or if exposure is required at sunrise or sunset. Artificial bright light glasses or boxes that emit short-wavelength blue-green light may therefore be used to supplement natural light exposure. Converesly, wrap-around sunglasses (if outside) and amber-tinted glasses (if indoors) should be utilised to prevent light-exposure. Though light exposure interventions may have efficacy in laboratory-based studies, negligible impact has been observed in the field. Indeed, several compromises were required to implement a light exposure intervention with a group of elite team sport athletes, including sharing light boxes, reducing the duration of light exposure due to team commitments and difficulty in controlling incidental light exposure and exercise, which may have masked the effects of the intervention[16]. Hence, due to the level of control required for light exposure to be effective, it may not be feasible to implement with team sport athletes in field-based environments.

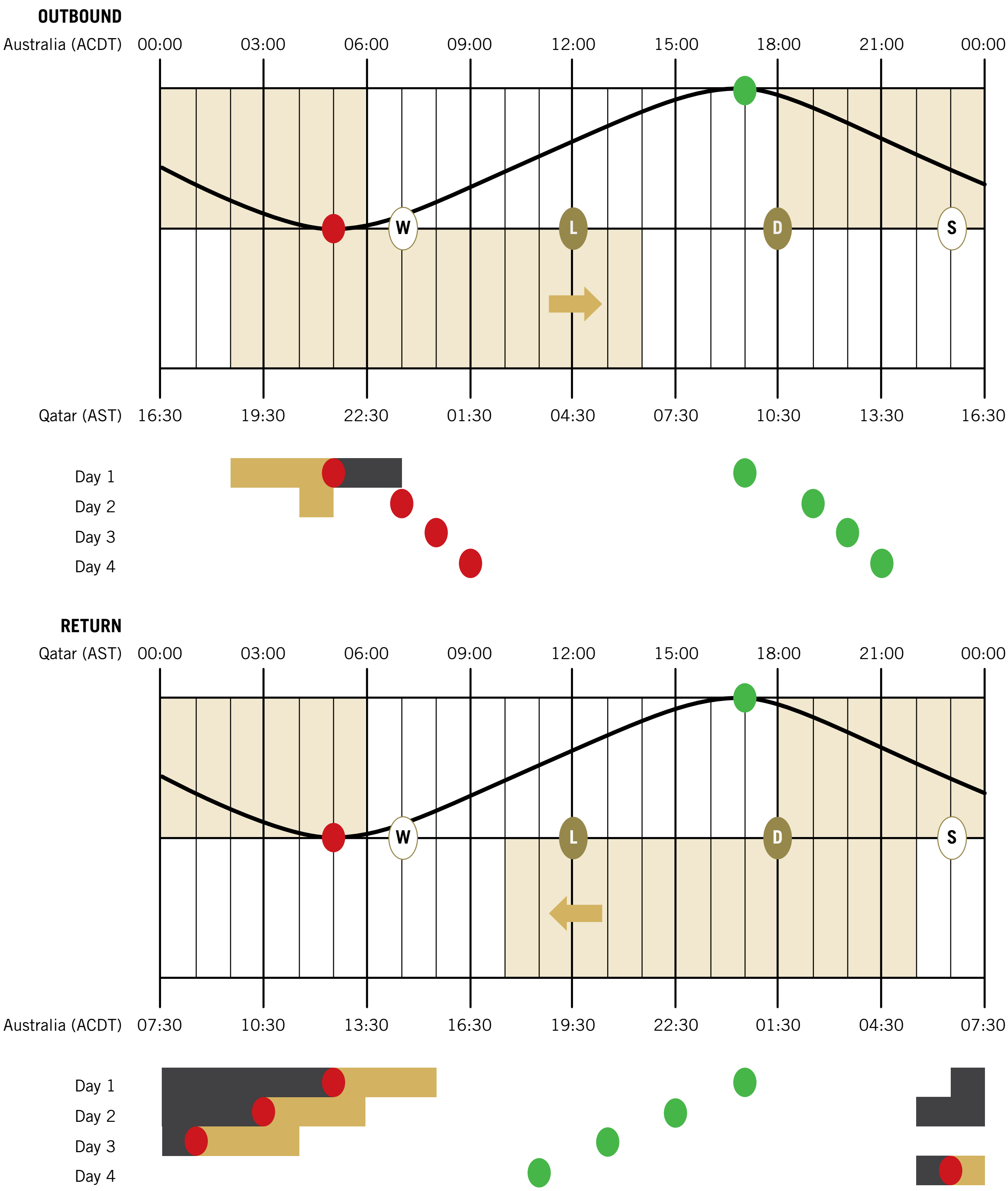
Sleep hygiene

Sleep hygiene guidelines may also have efficacy for reducing sleep disruption following travel. For instance, total sleep duration during and following 24 hours simulated international travel was increased through sleep hygiene recommendations, which attenuated symptoms of travel fatigue, but did not improve performance recovery[20]. Since phase shifts in body temperature and melatonin circadian rhythms – which regulate sleep – were unlikely, further research into the effect of optimising sleep hygiene on sleep patterns following actual travel is required. While it is recommended that computers, tablets and mobile phones should be avoided prior to bed, athletes may use them for psychological recovery, particularly following evening competition. Incidental exposure to short-wavelength blue-green light from these devices may not only induce phase-shifts in the wrong direction, but also suppress

TABLE 2

	CON			INT		
	Baseline	*Outbound*	*Return*	*Baseline*	*Outbound*	*Return*
Sleep duration (hh:mm)	06:08 (05:25-06:52)	03:11 (02:08-04:14)[b]	03:42 (02:41-04:43)[b]	06:40 (06:13-07:08)	07:47 (07:18-08:16)[ab]	05:48 (04:43-06:53)[abc]
Sleep Efficiency (%)	80.7 (77.5-83.9)	69.5 (60.1-78.8)[b]	70.0 (57.7-82.4)[b]	83.8 (79.6-88.0)	73.5 (66.6-80.3)[b]	78.6 (73.8-83.4)[b]

Table 2: Sleep quantity and quality during 21 hours travel across 8 time zones WEST (Outbound) and EAST (Return), with (INT) and without (CON) the use of sleep hygiene recommendations. [a]Large ES for difference to CON (d>0.90). [b]Large ES for difference to Baseline (CON; d>0.90). [c]Large ES for difference to Outbound (CON; d>0.90). ES=effect size.



Key

W Walking
L Lunch
D Dinner
S Sleep onset
Seek light/exercise at this time
Avoid light/exercise
Core body temperature minimum
Core body temperature maximum

Figure 4: An example of a light exposure schedule for an Australian team travelling to and from Qatar for a pre-season heat training camp. The upper panel shows the time at the place of departure and the lower panel shows the corresponding time at the destination. Shaded boxes indicate night and white boxes indicate daylight. Light exposure is timed in relation to the core body temperature minimum, which typically occurs around 5am in healthy young adults. Each day the schedule is moved by 1 to 2 hours, to align with the expected phase-shifts in circadian rhythms and to ensure that the light continues to be administered at optimal times to achieve maximal phase shifts. ACDT=Australian central daylight time, AST=Arabian standard time

melatonin and negatively impact sleep. The use of amber-tinted glasses may be beneficial in this scenario, as they have been reported to block this spectrum of light and improve sleep[21].

Pharmacological interventions:
Melatonin

Exogenous melatonin administration may reduce the impact of long-haul transmeridian travel through both hypnotic (sleep-inducing) and chronobiotic (phase-shifting) effects. Importantly, the timing of administration required for these separate effects may differ depending on the direction of travel and number of time zones crossed. Based on the melatonin phase response curve, exogenous administration in the evening (body clock time) may induce a phase advance in circadian rhythms following eastward travel, whereas administration in the morning could induce a phase-delay after westward travel. While this may have efficacy in a laboratory under stringent conditions, following long-haul travel east across 10 time-zones, 5 mg of melatonin administered at local bed time had neither a hypnotic or chronobiotic effect[11]. Further, only 40% of participants' circadian rhythms shifted in the correct direction (phase advance), with 50% adapting by a phase delay and 10% remaining unchanged. This could be a consequence of the inter-individual variation in melatonin phase response curves, which questions the efficacy of the generic timing of intervention administration. Recent analysis of studies on melatonin has raised questions regarding its efficacy for reducing jet lag symptoms[7] and since many countries still have restrictions on its purchase and use, current recommendations are that it should be administered with caution in athletes.

Caffeine

Due to the psychostimulant properties of caffeine, it could be effective at combating the sleep debt accrued as a consequence of long-haul travel. 300 mg of slow-release caffeine administered in the morning (local time) for 5 days following long-haul travel assisted with the maintenance of alertness and grip-strength[23]. Whilst a slow-release form was used to prolong plasma concentrations, some adverse side effects on sleep were reported. This serves as an important reminder of the potential unwanted side effects of pharmacological interventions for team sport athletes. While the ingestion of fast-acting caffeine prior to training and competition could help to overcome the detrimental impact of international air travel on physical performance, to date, there are no studies that have investigated this.

Combined interventions:

Theoretically, compared to the aforementioned exposure to just one zeitgeber, the appropriate timing of exposure to two or more zeitgebers could have a cumulative effect and therefore, accelerate the rate of adaptation of circadian rhythms following long-haul transmeridian travel. Considering the phase response curves for light and exercise may be similar, combining appropriately timed bright light exposure with outdoor activity is a strategy that has been advocated to enhance adaptation to a new time zone[15]. Furthermore, recent reviews have provided examples of 'zeitgeber exposure schedules' for various travel scenarios[22]. While a combination of zeitgebers is sound in theory and has been successful in shifting circadian rhythms in laboratory-based studies, again, negligible effects have been observed in field-based environments.

Generic vs individualised interventions:

Applying generic interventions assumes that an average direction and rate of circadian rhythm adaptation to a new time zone exists. Yet in reality, significant intra- and inter-individual variation occurs and therefore, responses to generic interventions will also vary. This explains why even in well controlled laboratory-based experiments, when a generic intervention is applied, significant variation in the rate and direction of circadian rhythm adaptation occurs. Generic interventions are even less likely to be effective in field-based studies, with greater confounding factors, such as accidental exposure to zeitgebers at inappropriate times. The alternative – to individualise interventions – is also complicated. In theory, the timing of exposure to zeitgebers should be based on individual phase response curves and subsequently adjusted following travel based on individual rates and directions of circadian rhythm adaptation. While the rate of adaptation can be inferred from an individual's minimum body temperature and/or sleep timings, the practicality of individualising interventions with team sport athletes is questionable. For example, due to team commitments, such as training, meal and meeting times, it would be difficult to have individualised bright light exposure schedules.

SUMMARY

There is currently an insufficient understanding of the effects of international travel on team sport performance and the underlying mechanisms. As a result, travel interventions are based on estimates rather than actual travel responses and while they are sound in theory and have efficacy in laboratory-based studies, their impact in applied settings remains uncertain. Consequently, many coaches and sports medicine practitioners still currently rely on accumulated personal experience or anecdotal evidence for travel arrangements. While it has been suggested that in order to improve the effectiveness of these interventions, they may need to be more demanding and intrusive[16], this would reduce the practicality and feasibility of their use with athletes. Therefore, further research is required to find a balance between the efficacy and practicality of travel interventions.

References

Available at www.aspetar.com/journal

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Table 3: Practical applications

1. PRE-TRAVEL

a) Practice good sleep hygiene in the lead up to travel to ensure no sleep debt is accumulated.

b) If feasible, replace long-duration moderate-intensity training (which may be immunosuppressive) with shorter, high-intensity, high-quality sessions.

c) Consider the use of vitamin C, zinc acetate or gluconate and probiotic supplements to reduce the risk of illness.

2. DURING TRAVEL

a) Attempt to sleep whenever possible, but particularly when it is night time at the place of departure.

b) Practice good sleep hygiene:

- *Minimise the use of electronic equipment.*
- *Avoid caffeine.*
- *Use eye masks, neck pillows, ear plugs and/or noise cancelling headphones.*
- *Wear comfortable, loose fitting clothing.*

c) The aeroplane cabin is a 'high-risk' environment for infection/illness, therefore:

- *Don't self-inoculate by touching eyes, nose and mouth.*
- *Avoid contact with most frequently touched area of door handles and avoid using the whole hand.*
- *Cough and sneeze into the elbow not hands.*
- *Practice good hand hygiene by washing them frequently and using a hand sanitiser with residual activity.*
- *Minimise hand shaking and close contact with people outside the team (i.e. fans and media).*

d) Consider wearing compression garments (if comfortable enough to sleep in) and following sleep period, ensure frequent movement around the aeroplane cabin to minimise venous pooling and lower-limb swelling.

3. POST-TRAVEL

a) Physical performance may be reduced in the first few days (≤ 72 hours) following arrival. Take this into account when scheduling training sessions.

b) Practice good sleep hygiene:

- *Minimise the use of electronic equipment and dim room lights 1 hour prior to bed. If this is unavoidable, use amber-tinted glasses when using such devices.*
- *Avoid caffeine approximately 4 to 5 hours prior to sleep (this may vary between individuals).*
- *Ensure cool (~19 to 21°C), quiet and dark conditions throughout the sleep period. Eye masks and ear plugs may be helpful, particularly with reinitiating sleep onset if early waking occurs.*
- *Napping can be useful to counteract night time sleep disruption. However, naps should be kept to ≤ 1 hour and not too close to bed time as this may interfere with sleep.*

c) Light exposure and training times:

- *Westward travel (phase-delay required): seek light/exercise for the 2 to 3 hours prior to core body temperature minimum (T_{min}; ~05:00 body clock time) & avoid light/exercise for the 2 to 3 hours following T_{min}.*
- *Eastward travel (phase-advance required): avoid light/exercise for the 2 to 3 hours prior to T_{min} and seek light/exercise for the 2 to 3 hours following T_{min}.*
- *If the timing of light exposure is outside daylight hours or it is an overcast day, supplementing natural with artificial light may be beneficial.*
- *Be careful of light exposure and training too close to bed time as this may interfere with sleep.*

d) Melatonin administration (3 to 5 mg has typically been used in field studies):

- *Westward travel - administration in the morning (body clock time) around the T_{min}.*
- *Eastward travel - administration in the evening (body clock time).*

e) Caffeine administration:

- *Could be utilised to reduce sleepiness/increase alertness around training and competition.*

f) Take care if combining interventions (particularly behavioural and pharmacological) as they may have counterproductive effects if they cross over.

g) Take care with the dose and pharmokinetics of pharmacological interventions as they can induce negative side-effects and/or phase-shifts in the wrong direction.

h) Due to potential side-effects, behavioural interventions (i.e. light exposure) should be preferred over pharmacological.

i) Use the aforementioned behavioural interventions and consider the use of the aforementioned supplements to reduce the risk of illness.