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# LONG-HAUL TRAVEL AND JET-LAG: BEHAVIOURAL AND PHARMACOLOGICAL APPROACHES

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## ABSTRACT

This review focuses on selected behavioural and pharmacological approaches that have been used to reduce some of the effects of jet-lag in sports performers. International travel is an essential part of the life of elite athletes for purposes of competition and training and when long-haul flights entail crossing multiple time-zones, jet-lag is linked with disruption of the normal circadian rhythm. Travel fatigue lasts for only a day or so and is associated with the conditions of the journey (such as cramped nature of seating), anxiety about travel and disruption to the individual's daily routine. For those who fly across multiple time zones there are also the longer lasting effects associated with jet-lag, which can reduce motivation to train effectively and impact negatively on performance. The severity and duration of these problems depend on the direction of flight (eastwards or westwards), the number of time zones crossed and the strategies used to alleviate them. Behavioural solutions to dealing with jet-lag embrace careful attention to lifestyle and activity. These methods are preferable to pharmacological means of treating the syndrome.

*Key words: circadian rhythms, drugs, time-zone transition, travel fatigue*

## Introduction

Sports participants nowadays regularly travel across international boundaries for purposes of competition, training, acclimatisation or an attractive change of setting. Sometimes this entails long journeys that induce so-called travel fatigue. The problem is compounded when the sojourners have travelled across multiple time zones. In this instance the dislocation of the body's circadian rhythms from the light-dark cycle in the new environment (or the new local time) causes symptoms, which are referred to as jet-lag. To harmonise the body's circadian rhythms with the time in the new local environment, generally a phase delay is required after a flight westwards and a phase advance after a flight eastwards. When 10-12 time zones (or more) are crossed, a phase-delay occurs regardless of direction of flight. Jet-lag symptoms tend to disappear completely when the circadian rhythms are resynchronised with the environment. An example of the mismatch between 'body clock' time and local time immediately after travelling across multiple time zones is presented in Table 1.

## Causes and symptoms of jet-lag

The cause of let-lag is the disruption of the normal circadian rhythm, which is controlled by the suprachiasmatic nucleus cells of the hypothalamus. Nerve connections via the retinohypothalamic tract relay sensory information from the eyes to the su-

Table 1. *"Body clock" time and local time are mismatched immediately after travelling across multiple time zones, illustrated by an 8-hour transition eastwards (London to Seoul) and westwards (London to Vancouver)*

| | New local time (h) | Requirement | Body disposition |
|---|---|---|---|
| **London to Seoul** | 08:00 | Wake | Sleep |
| | 16:00 | Peak activity | Wake up |
| | 24:00 | Retire | Peak activity |
| **London to Vancouver** | 08:00 | Wake | Peak activity |
| | 16:00 | Peak activity | Sleep |
| | 24:00 | Retire | Begin to wake |

prachiasmatic cells of the hypothalamus. There are further neural connections from the suprachiasmatic nuclei to the pineal gland (which secretes melatonin) via the superior cervical ganglion. Through these neural pathways the body clock responds to light in the external environment. Consequently the body responds in a rhythmic fashion to the alternations of light and darkness. Melatonin is secreted as darkness falls, causing peripheral vasodilatation and a drop in body temperature, and precipitating sleep. Light inhibits melatonin secretion and so alertness and wakefulness are normally associated with daytime light. The cyclical and repetitive alternation of light and darkness in the environment lock the timing of the internal body clock into a 24-hour period. This cycle is violated after rapid transition across multiple time-zones.

Symptoms of jet-lag include feelings of fatigue and inertia, difficulties in concentrating and in sleeping, gastrointestinal problems and a general malaise (see Table 2). The syndrome is distinct from so-called "travel fatigue" which occurs after flying north or south. The residual stiffness due to being in a cramped posture for a prolonged period of time is associated with travel fatigue rather than the disruption of the body clock. The effect of jet-lag syndrome on the individual's mental performance may be subliminal and go unnoticed whilst the more obvious symptoms may be transient during the period of adjustment to the new time zone.

## Coping with Jet-lag

Jet-lag symptoms are generally worse after a flight to the east compared to after flying westward. Adjustments to a phase delay are generally faster than adjusting to a phase advance. As exercise performance demonstrates circadian rhythmicity, athletes may be impaired temporarily after crossing multiple time zones. In travelling to

Table 2. *Main symptoms of jet-lag (based on 10)*

- Headaches, "head-buzz" specific to jet-lag.
- Fatigue, periodic tiredness.
- Difficultly sleeping, difficulty in getting to sleep, frequent awakening and broken sleep.
- Loss of appetite, bloated after mealtimes, food unpalatable.
- Bowel activity, decreased frequency, hard stools.
- Altered mood and performance, fall in motivation, decreased concentration, and increased irritability.

the 2002 World Cup in Japan and Korea European football teams required a phase advance. Estimates were that adjustment would take 6-9 days depending on the individual traveller. This estimate was based on observations of Winter Sports participants travelling to the 1998 Winter Olympics in Nagano.

The experience of jet-lag varies not only between individuals but also within individuals from trip to trip. Therefore it is difficult to identify individuals who are more susceptible than others to adverse effects of circadian desynchronisation. Those who deny experiencing any jet-lag usually fail to recognise its effects, including fractured sleep patterns. Besides, effects on cognitive functioning may be subliminal and go undetected.

Methods of coping with jet-lag can be described either as pharmacological or behavioural. Behavioural means include phase adjustment pre-flight, nutritional strategies, using light or physical activity to accelerate resynchronisation. The sooner readjustment to the new environment is achieved, the easier will the athlete be able to resume full training safely. Further, travelling teams gaining faster re-adjustment than normal can cut costs of participating in competition overseas by shortening the duration of the overall visit.

## Phase adjustment pre-flight

The principle in phase adjustment is that the individual changes his/her sleep-wake cycle in preparation for flight in accordance with the direction of travel. Therefore a phase delay would be attempted before travelling westwards and a phase advance prior to travelling eastwards. The question remains as to whether this manoeuvre is effective or worthwhile.

Reilly and Maskell (1) studied alterations in the sleep-wake cycle in both directions, over 3, 4 and 5 hours. In these circumstances a phase delay (wherein the subjects are effectively “staying up late” compared to their unadjusted home time) is the easier to secure since subjects are tired when permitted to retire to bed. The alterations were partially effective in altering physiological rhythms, including core temperature and heart rate. In effect the subjects behaved as if working a late evening shift since no time-tone transition was involved.

Whilst changing the sleep-wake cycle altered biological rhythms in accord with the direction of shift, the adjustment was incomplete. Furthermore, motor performance measures were impaired during the course of such adaptive changes. Caution was therefore advocated in manipulating rhythms before travelling to compete overseas. A phase advance of 1-2 h for 1-2 days prior to a long-haul flight eastwards can be of benefit in starting the process of adjustment and preventing a phase delay, which sometimes occurs when travelling 8 h or more eastwards. Otherwise it is better for the athletes to avoid any impairment to the training process in the days before travelling since any circadian phase-shift is accompanied at the expense of performance capability.

## Diet

Disturbances of the digestive system are common features of the jet-lag syndrome. These include bowel discomfort, loss of appetite and decreased palatability of food eaten (2). It is reasonable therefore that diet has been thought to be a factor in accelerating physiological adjustment to a new time zone.

It is likely that the timing of meals is an important factor in re-synchronising the body clock after long haul flights. Timing meals with local customs is an effective social mechanism for fitting into the light-dark cycle in the new environment. In effect meals can be used as a "zeitgeber" or exogenous influence in fine-tuning the circadian rhythm into a new 24-hour cycle. It is likely therefore that endogenous factors are more important, but timing meals with local customs is an effective social mechanism for fitting into the light-dark cycle in the new environment.

There have been suggestions that planning the macronutrient content of meals can help boost arousal during the day and facilitate getting to sleep at night (3). The reasoning is that a protein-rich breakfast which contains tyrosine (a pre-cursor of adrenaline) increases arousal level whereas a carbohydrate-rich diet contains tryptophan (a pre-cursor of serotonin) and taken in the late evening should aid in promoting sleep. There is no convincing scientific evidence that this diet works, and it appears that is the timing rather than the type of meal that is helpful.

The timing of meals during the flight is usually determined by the local time at the last point of embarkation. This programme may not suit the long-haul traveller, for example from London to Seoul with a short (1-2 h) stop-over in Dubai or Bangkok. It may therefore be prudent to choose to miss some meals in order to avoid eating during the night (on body clock time) to prevent feeling bloated. It would be wiser still to eat those meals that are timed appropriately for the destination.

The dry cabin air on-board flight causes respiratory heat loss by evaporation; the result is dryness in the nose and throat. A consequence is a residual dehydration that persists for some days after disembarkation, unless a definite rehydration strategy is employed. Data from British athletes after travelling from England to Florida, U.S.A. are shown in Figure 1. Urine volume was depressed over the first days after travelling, whilst urine osmolality was increased. The deterioration in hydration status can compound the effects of jet-lag. Since thirst is not an adequate indicator of fluid needs, attention should be given to drinking more water and fruit juice than normal and avoiding diuretics such as alcohol and caffeine (4). Whilst low hydration status is associated with travel fatigue, its subjective consequences can compound those directly due to circadian desynchronisation.

## Physical activity and light exposure

It is possible that exercise has a role to play in accelerating adjustment to the new time zone. Exercise becomes part of the habitual routine of the athlete and forms an integral part of individual life-style. It is imperative therefore that training patterns

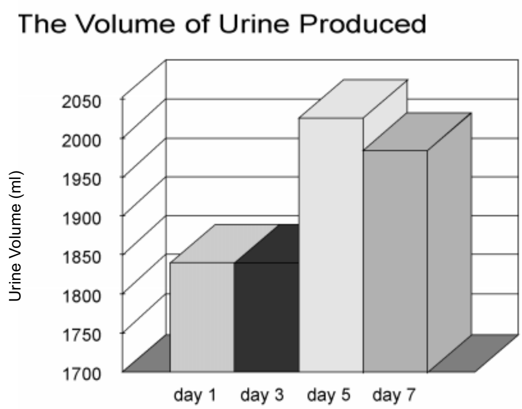


Figure 1. *Urine volume data collected on British athletes after travelling from England to Florida, U.S.A.*

are resumed as soon as it is safe to do so: training complex skills at a high intensity may not be prudent in the first days immediately following a long-haul flight in case of incurring injury due to mistakes in motor control.

There is no reason why easy or moderate training should not be pursued following time-zone transitions and indeed such activities may be beneficial. There is some evidence that exercise can change the circadian phase of some hormones (such as melatonin) and body temperature (5). The amount of exercise (duration and intensity), and the size of any phase shifts have yet to be fully investigated (6). Should exercise have the same effect as does light (7, 8), then exercise performed just after the body temperature minimum may advance the phase of circadian rhythms, exercise taken just before may delay the circadian phase, and exercise some 6 h after the minimum would have no effect. Hence exercise should be avoided in the mornings and performed in the afternoon following a long journey eastwards (see Table 3). However, this explanation is rather tentative, since no convincing phase advances of the circadian rhythm due to exercise have been demonstrated in humans (6, 9). Nevertheless it would be appropriate that exercise be taken as part of the light exposure strategy and avoided when light is to be avoided.

The adjustment of core (intra-aural) temperature following a trip from London to Brisbane (Australia) is illustrated in Figure 2. The journey entailed a 10-hour time zone transition, arriving in Brisbane at 06:00 hours (Local time). The groups remained awake, starting with business meetings at breakfast (local time) and worked immediately and completely on local time. After 5 days, the core temperature curves for the group as a whole were evidently adjusted by means of a phase delay (see Figure 2), as opposed to the expected phase advance. These data confirm that light exposure prior to the trough in body temperature (the early morning local time) promotes a phase delay whilst exposure to light in a 3-4 hour period after this trough facilitates a phase advance.

Table 3. *Appropriate and inappropriate times for use for bright light to re-adjust circadian rhythms (from 11)*

| | Bad local times for exposure to bright light | Good local times for exposure to bright light |
|---|---|---|
| Time zones to the west | | |
| 4 h | 01:00-07:00 a | 17:00-23:00 b |
| 8 h | 21:00-03:00 a | 13:00-19:00 b |
| 12 h | 17:00-23:00 a | 09:00-15:00 b |
| Time zones to the east | | |
| 4 h | 01:00-07:00 b | 09:00-15:00 a |
| 8 h | 05:00-11:00 b | 13:00-19:00 a |
| 10-12 h | Treat this as 12-14 h to the west c | |

Notes:
a, this will advance the body clock;
b, this will delay the body clock;
c, this is because the body clock adjusts to large delays more easily than large advances.

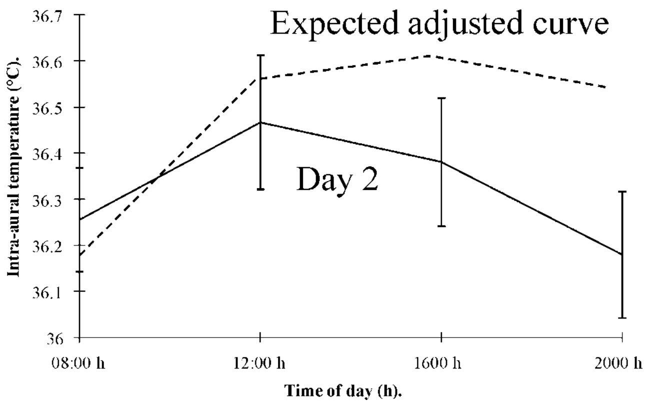


Figure 2. *The adjustment of core (intra-aural) temperature following a trip from London to Brisbane (Australia, a 10-hour time zone transition) for day 5 four times of day compared to the expected adjusted curve.*

The strategies adopted for travel of British Olympic Athletes to the Summer Olympics in Sydney in 2000 was to drive behaviour towards achieving a phase advance. Groups arrived early in the morning, but retired immediately to sleep until midday. The extent of the lie-in at mornings was reduced over three consecutive days, whereupon normal routines were reinstated. For these days also napping (defined as sleep lasting more than 1 hour) was not advocated to avoid "anchoring" sleep. Short periods of sleep at the time individuals would have been asleep (home time) would work to "anchor" circadian rhythms to the old time-zone and operate against adjustment to the new local time (8). These measures serve to reinforce the behavioural strategy, integrating life style, activity and light exposure into an overall approach.

Behaviour adopted after arrival may be effective only if it is preceded by appropriate activity prior to boarding and especially during flight. Arriving at the airport fresh and prepared for the long flight has been associated with reduced jet-lag symptoms (10). Avoiding prolonged stiffness by periodically moving around the plane and even performing stretching exercises can help decrease travel fatigue (4). A number of airline carriers now advocate exercises for travellers, including isometric actions: the main motivation for these programmes has been to reduce the risk of deep vein thrombosis due to sitting in a cramped seated posture for too long. The episode may not occur until some days following disembarkation.

Exposure to natural daylight is a major factor in influencing phase adjustment following desynchronisation of circadian rhythms. There are neural connections between the retina, the suprachiasmatic nucleus cells of the hypothalamus, the anatomical site of circadian rhythm regulation and the pineal gland. In view of the phase-response curve to light, there are inappropriate times for exposure to light as shown in Table 3 (from 11). Melatonin is inhibited by light and when exposure to light is chronobiologically desirable during darkness, light of domestic intensity can be sufficient (12).

## Pharmacological approaches

The sleep-wakefulness cycle is a major factor in synchronising circadian rhythms. Minor tranquillisers such as benzodizepines promote sleep and thereby could in theory accelerate the adjustment of the body clock after time-zone transitions. Reilly et al. (13) investigated the effects of temazepam in a group of gymnasts travelling from the United Kingdom to Florida in the U.S.A. prior to the Summer Olympic Games in Atlanta 1996. No difference was observed between experimental and placebo groups, each of which included non-athletes. The Olympic athletes adjusted more quickly than their sedentary counterparts. Although the use of sleeping pills was found to be ineffective, the normal pattern of sleep was recovered earlier compared to the restoration of body temperature to its normal circadian phase. Only when body temperature was readjusted, after 5 days, did the performance rhythms (including leg strength, back strength and reaction time) resume their normal circadian shape. Body temperature is the conventional marker of the body clock and appears to be a relevant measure for monitoring the rate of adjustment after disturbance.

Synthetic melatonin is thought to counteract jet-lag symptoms and is frequently used by travellers for that purpose. Edwards et al. (14) examined the effects of oral melatonin in alleviating jet-lag in subjects who had travelled from London to Eastern Australia, 10-time zones to the east. Melatonin (5 mg/day) was administered to experimental and control subjects in a double-blind study: the time of the administration was in accord with the current consensus for maximising its hypnotic effect (15). In the schedule followed by the subjects, which resulted in frequent and erratic exposure to daylight, melatonin had no beneficial effect on the components of jet-lag. Nor did it influence the process of phase adjustment.

These results informed the travel strategy of the British athletes travelling to the Olympic Games in Sydney in 2000. Reilly et al. (16) advised against the use of pharmacological methods of adjusting the body clock, whilst acknowledging that some athletic travellers will continue to use melatonin. Follow-up studies indicated that "fatigue" is caused by the ingestion of melatonin, even during the dead-zone period of the phase-response curve, and persists for a few hours, but hangover effects of ingestion the night before can be discounted (17).

## Overview

The effects of jet-lag are transient, periodic and should not entail cessation of training in travelling sports teams. Rehydration is important, especially if the temperature in the new country is high, as heat stress may compound fluid losses incurred during the flight. Behavioural means of coping with jet-lag should be sufficient, provided the sports group arrives in good enough time to allow the body clock to adjust before the first competitive engagement. A behavioural strategy can be implemented by raising awareness of the issues and providing clear guidelines on actions required as well as things to avoid. This educational programme should be extended to support staff as well as the active members of the travelling sports team.

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