

HOW CAN TRAVELLING ATHLETES DEAL WITH JET-LAG?

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Review

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Abstract:

Sport is a global phenomenon and professional athletes travel across national boundaries for training and for competition. Circadian rhythms are desynchronized when multiple meridians are traversed, leading to the syndrome of jet-lag. Until the body clock has adjusted to the new time zone, many measures of performance are likely to be impaired. Where possible, the travelling athlete should arrive in the new country in enough time for the body clock to adjust to the new time zone. A behavioural approach is preferable to using drugs in coping with jet-lag. Key characteristics of this approach are the timing of exposure to and avoidance of light, avoiding long naps for the transitional period of adjustment and strategic use of exercise. Planning an activity on a chronobiological basis can help in ensuring that sports performance is not impaired during the trip or after returning home.

Key words: *chronobiology, circadian rhythms, fatigue, melatonin, sleep loss*

Introduction

Sport is now a global entity in the sense that the major sports are played in most countries worldwide and all nations have the opportunity to participate in international competition. The main international championships, World Cups and the Olympic Games represent the pinnacle of sports contests and capture the attention of audiences worldwide via television, radio and internet communication media. Transnational mobility of top professional athletes to secure employment in those markets that give them a competitive and material edge brings with it a dual allegiance to club and to home country. Many sports have their competitive programme based on the organization of grand-prix series, the results from separate events held in strategic locations around the world being aggregated to yield overall rankings for the year. Formula One motor racing, golf and tennis are examples where the typical professional competitor and the support staff have daunting travel itineraries. In other sports there are indoor as well as outdoor championships so that the competitive calendar is extended across the annual cycle with little opportunity for individual athletes to have a prolonged period of rest.

A variety of market forces has contributed to contemporary competitive sport being laid out in a virtual global village. Foremost has been the increased turnover of money in professional sport, facilitated by the large financial packages afforded to governing bodies by television companies. Secondly, increased competitiveness among sports

television companies has hiked up the amounts of money that flow annually to the sport's governing bodies and are passed on to participants in negotiated salaries or prize money. The performers and the governing bodies may also gain benefits from image rights or from individual deals with other sponsors. Thirdly, restrictions on international travel have been relaxed, coincident with the escalation of air-flight facilities and the growth in low-cost air travel. Mobility across the expanded European Union has accentuated movement across member countries, hardly tempered by increased hassle from security measures and a burgeoning public awareness of the carbon foot-print of airflight that contributes to environmental pollution. Finally, there has been a large growth in the adventure holiday market, in special tours to recreational events (for example, foot races, city charity marathons, hill-walking, outdoor activities, and so on). All of these trends have emphasized the transnational appeal of sport, notwithstanding the worldwide economic recession that was manifest in 2009.

The travelling of athletes is not limited to air-flight as many have to travel large distances terrestrially to fulfil training and competitive engagements, either by coach, car, train or other vehicular mode of transport. In doing so they may be exposed to air pollution, traffic hassle, restricted postures and risk of accidents. Long hours of travelling entail travel fatigue, irrespective of the means of travel. When journeys involve fast transitions across multiple time-zones, invariably by airflight, the syndrome of jet-lag is experienced and super-

imposed on an underlying travel fatigue. The concept of jet-lag and how it affects athletes is the focus of this review.

The elite performer is chosen for consideration in preference to sports participants in general for a number of reasons. First, elite athletes are more concerned about the fine details of preparation for their performance and to overcome jet-lag symptoms as quickly as possible. Secondly, they are more likely to have challenging and complicated itineraries. Thirdly, their travel arrangements may be undertaken for warm-weather training overseas, to altitude training camps or cross hemispheres to experience a different competitive season. In these cases climatic stresses may interact with the physiological responses to time-zone transitions. Finally, elite athletes are concerned about all factors that might compromise their performances whereas the amateur participant may be more forgiving.

The purpose of this review is to consider the ways in which jet-lag may have an impact on athletes and their performances. Attention is given to methods of ameliorating jet-lag and coping better with the phenomenon, as evidenced in the position statement of the European College of Sport Science (Reilly, et al., 2007a). Pharmacological as well as behavioural approaches to dealing with jet-lag are addressed. Individual differences and the direction of travel are also considered. Prior to these issues, the chronobiological basis of jet lag needs to be explained.

The body clock and jet-lag

Jet-lag refers to a dissociation of the human body clock from the time cues in the environment. The body clock is located in the suprachiasmatic nuclei cells of the hypothalamus and is responsible for regulating circadian rhythms. These rhythms refer to fluctuations every 24 hours in physiological functions, an example being core temperature which varies about .4°C around a mean value of 37°C and has a peak value at around 17.00 hours. Many variables related to exercise performance demonstrate circadian rhythms, a summary of which is shown in Table 1. These variables include measures of muscle performance that are important in competitive sport, determinants of exercise

performance and simulations of competition in time-trials or field-based studies. Circadian rhythms have been demonstrated in physiological responses to set exercise intensities (Reilly, et al., 1986) and to performance in self-determined exercise intensity (Reilly & Garrett, 1995). Reilly and Waterhouse (2009) have argued that many of these measures have strong endogenous components and it is therefore reasonable to expect that they would be impaired when circadian rhythms are desynchronized.

The time-keeping functions of the body clock are related to interactions between clock genes and clock proteins (Waterhouse, Reilly, Atkinson, & Edwards, 2007). The suprachiasmatic nuclei have receptors for melatonin, a hormone that is produced in the pineal gland during the hours of darkness and is inhibited by light. The body clock represents the endogenous component of circadian rhythms which are fine-tuned to an exact 24-hour period by environmental factors such as light, temperature, food intake, physical and social factors. The natural alternation of the light-dark cycle is shifted in phase when the individual crosses over multiple meridians. In order to resynchronize circadian rhythms to the time in the new time-zone, a phase delay is required after travelling westward and a phase advance after eastward flights. The problem is essentially different from that presented by nocturnal shiftwork where the sleep-wake cycle is shifted in phase but there is no change in environmental conditions.

Jet-lag persists until the body clock has adjusted to match the new environment. It is manifest as an inability to sleep at the right time, difficulty in keeping awake during the day and a general fall in mental and physical performance (see Table 2). It is accompanied by feelings of irritability, transient fatigue, difficulty in maintaining concentration and sometimes headaches. It may be accentuated by dehydration following the flight and particularly if the new location is at altitude or is hotter than in the home country. The symptoms may vary with time of day and have been monitored using the Liverpool Jet-Lag Questionnaire (Reilly & Waterhouse, 2008).

The effects of jet-lag differ according to the direction of travel. Flights to the east cause more severe jet-lag than flights to the west and symptoms

Table 1. Areas in sports performance where circadian rhythms have been demonstrated

Circumstances of Measurement	Type of Performance
Simulated time-trials or contests	Running, swimming, cycling, rowing and jumping
Tasks specific to particular sports	Skills associated with tennis, badminton, football, darts
Muscle groups	Leg, back and arm muscles
Action modes	Concentric, eccentric, isometric, isokinetic
Variables linked with performance	Maximal aerobic/anaerobic power/minute ventilation; surrogates for performance (blood lactate, core temperature, grip strength, reaction time, flexibility)

Table 2. Common symptoms of jet-lag

Difficulty in sleeping at the correct time
Transient fatigue during the day
Lack of concentration and situation awareness
Motivation decreased
Gastrointestinal disturbances
Loss of appetite
Feelings of disorientation or 'head-buzz'
Impaired mental and physical performance

last longer. Travelling eastwards requires a phase delay of circadian rhythms, whereas a phase delay is called for after flying westwards. The body clock adjusts more easily to a phase delay than to a phase advance because the natural length of circadian rhythms is about 24.5 hours and it is easier to fall asleep when the journey entails a prolonged rather than a shortened day of travelling. Generally it takes about one day per time zone crossed for complete adjustment to take place and, apart from around-the-world trips, the traveller must negotiate trips in both directions, on outward and return journeys.

Effects of jet-lag on performance

One of the early studies of travelling athletes was based on the British Students Rugby League team during their trip to Australia and New Zealand (Reilly & Mellor, 1988). The normal superiority of evening performance over morning performance was reversed for grip strength, often used as a marker of the performance rhythm in field conditions, for 5 days after arrival at destination. The dislocation of core temperature was in line with the changes in performance. It was estimated that it took subjects 7-10 days to adjust to the new time zone.

Subsequently, Jehue, Street, & Huizenga (1993) demonstrated how travelling coast-to-coast affected performance in American Football teams. Teams travelling to play on the west coast were at a disadvantage in evening games, due to the lateness of the match according to body clock time. The trends were replicated in an analysis by Smith, Guillemineault and Efron (1997) who demonstrated that performance in the National Football League could be enhanced if teams travelling for away matches on the opposite coast adopted chronobiological principles in preparing for their matches.

British Olympic athletes were monitored after travelling across five time-zones to the USA (Reilly, Atkinson, & Budgett, 2001). Leg and back strength were adversely affected for five days, maintaining their rhythms but with a morning peak initially. Similar alterations were noted in simple reaction time and choice reaction time. Jet-lag symptoms disappeared once sleep patterns had returned to normal and the circadian rhythm in rectal temperature had assumed its normal characteristics.

Whilst many factors may disrupt sleep (see Table 3), jet-lag reflects a difficulty in the appropriate timing of sleep.

The range of studies demonstrating disturbances in endocrinological and physiological variables has been reviewed elsewhere (Reilly, Waterhouse, Burke, & Alonso, 2007b; Waterhouse, et al., 2007).

Table 3. Causes of sleep disorders

Depression, anxiety
Sleep apnoea, serious breathing conditions
Pain
Daytime naps, especially late in the day
Evening consumption of alcohol, nicotine, or caffeine
Large late meal
Primary insomnia
Parasomnia: sleep-walking, sleep talking, restless legs
Delayed sleep phase
Nocturnal shiftwork
Jet-lag

Variables with largely exogenous rhythms adjust more quickly than do endogenous rhythms. Hence, the pattern of eating meals and digestive function adapts to a time-zone transition sooner than does core temperature or melatonin secretion. The difficulties in monitoring the rhythms of athletes due to methodological considerations have been highlighted by Reilly and Bambaiechi (2003), especially because multiple measures are required during the day to establish rhythm characteristics.

On board flight

Typically in transcontinental flights across multiple time zones normal sleep is disturbed and travellers may sleep during the journey for less than half their customary nocturnal sleep. Difficulty in sleeping arises in the absence of any cause of sleep disorder other than disruption of circadian rhythms (see Table 3). While adverse effects may be apparent the next day on mental performance and mood states (Reilly & Waterhouse, 2008), the difficulty in sleeping is eventually self-correcting. A concern in the interim is that the immune system is suppressed, increasing susceptibility to common colds and viral infections. Cohen, Doyle, Alper, Janicki-Deverts and Turner (2009) reported that those who slept less than 7 hours a night were particularly vulnerable to the common cold virus compared to those who slept 8 hours or more.

Although the plane may fly at an altitude in excess of 10,000 m, the cabin air pressure corresponds to that at about 2,000 m above sea level. A consequence of the dry pressurized cabin air is that water is lost in breathing, due to evaporation of fluid from the mucous membrane of the upper

respiratory tract. The fluid lost needs to be replaced by drinking more than usual, about 200 ml extra in a 12-hour flight. Water, fruit juices or sports drinks are preferable to alcohol or caffeine which act as diuretics and accentuate fluid losses. Dry nose and throat are common after flying, similar to responses on acute exposure to altitude.

Another factor to consider during flight is the timing and type of meals. The schedule is dictated by the airline carrier but the traveller does have the choice to miss some meals. This choice may be expressed to facilitate sleep and can be determined in advance. An example would be the missing of the last meal, usually breakfast, before arriving at an eastward destination in order to extend the period available for sleep. In such cases the use of ear plugs and eye shades can be important.

A negative consequence of the restricted posture on board flight is the risk of deep-vein thrombosis. A useful guideline to travellers is to move periodically around the aisle of the plane to reduce the pooling of blood in the legs. Occasional flexibility exercises also help in alleviating joint stiffness and many airlines now provide a list of exercises that travellers can perform in their seats. Compression stockings are thought to be useful in providing a preventive role. As the condition can occur in motor vehicle passengers on long uninterrupted journeys, the condition has been referred to as travellers' thromboses.

Pharmacological and behavioural strategies

Accordingly, travel strategies encourage the use of either pharmacological agents or behavioural measures to help readjustment to the new time zone. Putative chronobiotic drugs (ones that adjust the body clock) include benzodiazepines, non-benzodiazepines such as zolpidem or zopiclone, melatonin and melatonin agonists such as tasimelteon, or central nervous stimulants such as modafinil (which is on the list banned by the World Anti-Doping Agency (WADA) or caffeine.

Temazepam was found to provide no advantage to Olympic Games athletes travelling between the United Kingdom and USA (Reilly, et al., 2001). There was no benefit in either subjective jet-lag responses or in the rate of adjustment of physiological and performance markers of circadian rhythms. In this instance the travellers arrived at their destination in the evening and an immediate retreat to bed facilitated falling asleep.

The evidence for melatonin as an antidote to jet-lag is equivocal. Whilst there are positive reports of the benefits of melatonin, its use is by no means a guarantee that symptoms of jet-lag are eased or that adjustment is accelerated. Melatonin was found to be ineffective in a large group of travellers between the United Kingdom and Australia (Edwards, et al.,

2000). In view of its phase-response curve, use of melatonin may be counterproductive if taken at an inappropriate time of day according to body clock time. Melatonin taken in the evening would advance the body clock whereas a phase delay would ensue when melatonin is taken in the morning in the hours after the trough in core body temperature.

Caffeine can be beneficial in helping to maintain arousal during the day. It acts as a stimulant on the nervous system and so would be inappropriate late in the evening when it would offset the drowsiness that facilitates falling asleep. Other stimulants used by military personnel may be inappropriate for athletes, modafinil for example being on the list of drugs banned by the WADA.

In general, the behavioural approach is favoured for athletes (Reilly, et al., 2007a); it involves attending to lifestyle factors that include nutrition (Reilly, et al., 2007b) and the timing and intensity of training. Until the body clock readjusts to the new time-zone, prolonged naps are discouraged since naps contrive to anchor sleep in the time-zone just departed. Travellers' diarrhoea is an exigency that can be prevented by attention to proper hygiene and avoiding uncooked foods. Exercise may act as a synchroniser of rhythms and assist adjusting to the new time-zone (Atkinson, Edwards, Reilly, & Waterhouse, 2007). Exercise in the morning is discouraged after flying eastwards since it usually entails exposure to light. The exposure to daylight and the avoidance of natural or artificial light are key to facilitating adjustment. The times for promoting adjustment to the new time-zone depends on the direction of travel and the number of time zones crossed, as shown in Table 4 for travelling eastward. This scheme was designed to hasten the readjustment of circadian rhythms following flights across multiple meridians. Light inhibits the production of melatonin and has a phase-response curve that is the direct opposite to it.

Another behavioural factor to consider is the taking of a nap. A short nap is normally helpful in recovering from sleep debt and restoring homeostatic state of arousal. Prolonged napping after time-zone transitions is not advised since long naps would tend to anchor circadian rhythms in the time-zone departed. Once adjustment has occurred, any individual preferences to nap in the afternoon can be allowed.

An educational programme that alerts athletes to the effects of jet-lag is recommended. It may take the form of a lecture or workshop with individuals or the entire team. Where a large group is concerned, a booklet giving advice and tips is helpful. This advice may be reduced to a summary of key points, such as shown in the case of teams travelling from the United Kingdom to Brazil (Table 5) and to New Zealand (Table 6), respectively. While some of the points are common, the direction of

Table 4. Adverse and favourable times in local time for exposure to light after time-zone transitions to the east (^a denotes promotion of a phase advance, ^b indicates a phase delay is promoted, and ^c reflects that the body clock adjusts more easily to large phase delays than to large advances)

Time zones to the east	Bad times for light exposure	Good times for light exposure
3	24.00 - 06.00 ^b	08.00 - 14.00 ^a
4	01.00 - 07.00 ^b	09.00 - 15.00 ^a
5	02.00 - 08.00 ^b	10.00 - 16.00 ^a
6	03.00 - 09.00 ^b	11.00 - 17.00 ^a
7	04.00 - 10.00 ^b	12.00 - 18.00 ^a
8	05.00 - 11.00 ^b	13.00 - 19.00 ^a
9	06.00 - 12.00 ^b	14.00 - 20.00 ^a
10	Can be treated as 14 hours to the west ^c	
11	Can be treated as 14 hours to the west ^c	
12	Can be treated as 14 hours to the west ^c	

flight must always be taken into account. The trip to New Zealand entails a time-zone transition of 11 hours, in which case a phase delay is more likely than the phase advance expected if adjustment simply followed the direction of the flight.

Table 5. Key points for travelling to Brazil from the United Kingdom

Before leaving: A minor adjustment in getting to bed will help. Retiring 1-2 hours later than normal and sleeping in the next morning prepares the body for the adjustment to come. The change in getting to bed and getting up should only be used for 1-2 days in advance of flying and will have no adverse effects.

Make sure you take with you what you need to keep you comfortable during the flight.

On the plane: Try to get to sleep soon after the first meal on board, as it should be dark outside at this time. Use eye shades and ear plugs to avoid being disturbed.

Once on the plane you can change your watch to Brazil time. Do not worry if you cannot sleep soundly.

The body loses more fluid than normally due to the dry cabin air. Regard this in your rehydration plans.

After arrival: It is critical to stay awake and be exposed to daylight on the first day in Brazil. Think in terms of clock time in Brazil only.

On the first evening, it is best to retire early, any time after about 9 p.m. Do not worry if you wake early the next morning, but do not get up until it is daylight. You can delay getting to bed for the next couple of evenings, and then you can retire at the time you normally do at home.

Fit into the local pattern of breakfast, lunch and dinner as soon as possible.

Avoid afternoon naps while you are adapting to time in Brazil. Naps slow up the adjustment process. Feel tough mentally while you are adjusting over these first few days.

Light exercise can help over the first few days – not strenuous or competitive at this time.

Final notes: Jet-lag symptoms are periodic and gradually disappear. There is enough time before the first match for everybody to have completely recovered from the flight.

Advice about the return journey will be given to you before your departure.

Individual differences

There are differences between individuals in their circadian characteristics that can affect how they adjust to jet-lag. Morning types have earlier times for arising from sleep and retiring to bed than

Table 6. Travel to New Zealand: key points

Before leaving: A minor adjustment in getting to bed would be helpful. Retiring 1-2 hours later than normal and sleeping in the next morning helps prepare the body for the adjustment to come. The change in getting to bed and getting up should only be used for 1-2 days in advance of flying.

Make sure you have the necessary means with you to keep you comfortable during the flight.

On the plane: Try to get to sleep soon after the first meal on board, as it should be dark outside at this time. Use eye shades and ear plugs to avoid being disturbed.

Stay awake and alert during the stop-over in Singapore.

There is another opportunity for further sleep on the last leg to Christchurch. Again, try to sleep when it is dark outside. Do not worry if you cannot sleep soundly.

The body loses more fluid than normally due to the dry cabin air. Regard this in your rehydration plans.

After arrival: It is critical to stay awake and be exposed to daylight on the first day in New Zealand. Think in terms of New Zealand time only.

On the first evening, it is best to retire early, any time after 6 p.m. Do not worry if you wake early the next morning, but do not get up until it is daylight. You can delay getting to bed for the next couple of evenings, but still retire earlier than you normally do at home.

Fit into the local pattern of breakfast, lunch and dinner as soon as possible.

Avoid afternoon naps while you are adapting to New Zealand time. Naps slow up the adjustment process. Feel tough mentally while you are adjusting.

Light exercise can help over the first few days – not strenuous or competitive at this time.

Final notes: Jet-lag symptoms are periodic and gradually disappear. There is plenty of time before the first match for everybody to have adjusted completely and to have been prepared fully. The next time you will experience jet-lag will be after the return journey when the above points will apply similarly. More precise advice will be provided when the departure time and date are confirmed.

do evening types. These preferences are reflected in an earlier peak of their circadian rhythms in markers such as core body temperature. Theoretically morning types should cope more easily with a phase advance, whereas evening types have an advantage when a phase delay is required. Most athletes tend to be intermediate in circadian phase types and so this influence appears to be small.

There is no compelling evidence that women suffer more than men from jet-lag symptoms. Secondary amenorrhoea is a common occurrence in female flight attendants, likely due to the interactions of melatonin and the female reproductive hormones. Female athletes too are frequent flyers, but there is little information about how their travel itineraries affect their menstrual health. There is concern that females whose circadian rhythms are disturbed by years on nocturnal shiftwork schedules are at increased risk of cancer (Bartsch, Bartsch, & Peschke, 2009). There is an urgent need to establish the health consequences of frequent flying for female athletes.

It has been thought that younger people cope better with circadian phase disturbances than do ageing individuals. With ageing there is a phase advance of circadian rhythms, with a tendency towards morning-type behaviour. This effect has been

found to begin at around 47 years of age (Reilly, Waterhouse, & Atkinson, 1997) and would have relevance for travelling support personnel, including trainers and physicians. Waterhouse and colleagues (2002) failed to show an effect of ageing among travellers from the United Kingdom to Australia; it seems that any deterioration in the body clock is compensated by the benefit of learning how to cope with jet-lag with experience from previous trips.

Overview

In planning for international competition, it is clear that the hassles of travel must be accommodated in the preparations for the trip. The details of a travel strategy vary according to the direction of travel and the time available before competitive engagements. The strategy may need to accommodate additional environmental stressors if the trip is to an altitude or to a climate much hotter than the home environment. In these cases, a programme of acclimatization prior to travel can be of benefit. Travellers need to be careful about the risk of travellers' diarrhoea when visiting countries where standards of food hygiene are low. Plans for the journey may also need to fit snugly with other commitments such as domestic competitions before and after the trip away.

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KAKO SE SPORTAŠI MOGU NOSITI S POREMEĆAJIMA DNEVNOG RITMA, IZAZVANIMA PUTOVANJEM KROZ VREMENSKE ZONE?

Sport je globalni fenomen, stoga profesionalni sportaši zbog treninga i natjecanja moraju putovati na udaljena odredišta kroz vremenske zone. Dnevni se ritam sportaša pri tome remeti što dovodi do sindroma vremenske razlike, poznatog pod nazivom *jet-leg*. Dok se sportašev bioritam ne prilagodi vremenskoj zoni odredišta, mnogi elementi sportske uspješnosti često su ugroženi i oslabljeni. Kada je god to moguće, pri putovanju u drugu zemlju s vremenskom razlikom, sportaš bi na odredište trebao stići dovoljno rano da se njegov tjelesni bioritam adaptira na novu vremensku zonu. Bihevioristički pristup je bolji od korištenja lijekova

za uspješnu borbu s poremećajem dnevnog ritma. Ključne karakteristike prilagodbe ponašanja jesu vrijeme izloženosti svjetlu, odnosno izbjegavanje svjetla, izbjegavanje dugotrajnog drijemanja u prijelaznom periodu adaptacije i strateško planiranje treninga. Planiranje aktivnosti u skladu s kronobiološkim zakonitostima može pomoći da se smanji narušavanje sportaševe uspješnosti na odredištu ili po povratku kući.

Ključne riječi: *kronobiologija, dnevni ritam, umor, melatonin, gubitak sna, jet-leg*