Effect of airline travel on performance: a review of the literature

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ABSTRACT

The need for athletes to travel long distances has spurred investigation into the effect of air travel across multiple time zones on athletic performance. Rapid eastward or westward travel may negatively affect the body in many ways; therefore, strategies should be employed to minimise these effects which may hamper athletic performance. In this review, the fundamentals of circadian rhythm disruption are examined along with additional effects of airline travel including jet lag, sleep deprivation, travel at altitude and nutritional considerations that negatively affect performance. Evidence-based recommendations are provided at the end of the manuscript to minimise the effects of airline travel on performance.

INTRODUCTION

Elite athletes are frequently required to travel long distances for major competitions. Often, professional sport involves intermittent stints of long-haul travel throughout an entire season; international contests, such as the Olympic Games, World Cup competitions and Grand Prix events, involve many athletes coming together from different locations, and hence various time zones.

Rapid airline travel across time zones has been anecdotally noted to cause deterioration in athletic performance. Inherent to travel are multiple variables, each potentially having their own effect on athletic performance, yet it is difficult to determine the extent to which each contributes to suboptimal performance. Some factors associated with travel that may affect performance include jet lag and circadian rhythm disruption, altitude, alterations in diet and sleep deprivation.

Although there has been relatively little investigation into the topic, the available evidence suggests that there is a detrimental effect of travel on athletic performance due to jet lag and disruption of circadian rhythmicity. Study of this topic is important in order to understand effects of travel on training and performance, which in turn might allow effective timing and cueing strategies to optimise performance at the destination.

This review will discuss principles of circadian rhythms and jet lag and provide a review of the current, relevant literature relating to travel and performance. Finally, the review will offer some evidence-based recommendations for athletes that must undergo travel and perform optimally upon arrival.

METHODS

The PubMed and Scopus databases were searched between December 2011 and February 2012 using the following terms: 'travel+performance', 'travel+sports performance', 'circadian rhythm+performance', 'jet lag+performance', 'circadian rhythm+sports performance', 'altitude+performance', 'travel+nutrition+performance', 'sleep loss+performance' and 'sleep deprivation+performance'. Articles were initially excluded if they were duplicates and did not relate to aspects of travel and performance measures. The preliminary search yielded 92 relevant articles in the PubMed database and 51 in the Scopus database (figure 1). With the exception of articles used for background information, references were then considered relevant if they met the following criteria: published in English, presented or referenced an epidemiological study or provided performance data and directly assessed and/or referenced the effect of travel, factors associated with travel or circadian rhythm disruption on performance or surrogate measures of performance. The sources cited by these papers were then reviewed using the above criteria and the process was repeated. In total, 106 papers met criteria for this review.

For the purposes of this review, long-distance travel, unless otherwise defined, refers to flight across three or more time zones.

CIRCADIAN RHYTHMS

Understanding circadian rhythm

The word 'circadian' is derived from the Latin 'circa dies' meaning 'about a day'. Circadian rhythms are daily biological rhythms that have maximum or minimum function at certain times of day and are synchronised to the 24 h light–dark cycle. These biological rhythms are caused by oscillators that appear to be located in most human cells and are synchronised by a central oscillator, or 'body clock', located in the suprachiasmatic nuclei (SCN) of the hypothalamus. Each rhythm varies as to the degree to which it is affected by environmental stimuli. Some rhythms such as core body temperature, cortisol production and sleep/wake cycles are rhythms that persist in a free-running state without environmental cues.[1 2] Transmission of time information from the central oscillator to the peripheral oscillators is not completely understood but occurs via neural and humoral stimulus. Melatonin, inhibited by light and secreted by the pineal gland during the hours of darkness,[3] is thought to play an important role in transmission. The SCN is in turn synchronised with the environment by the light–dark cycle, and to a lesser degree by other environmental conditions such as social routine, physical exercise and food uptake.[4]

A circadian phase disruption results in desynchronisation between the cellular oscillators in the

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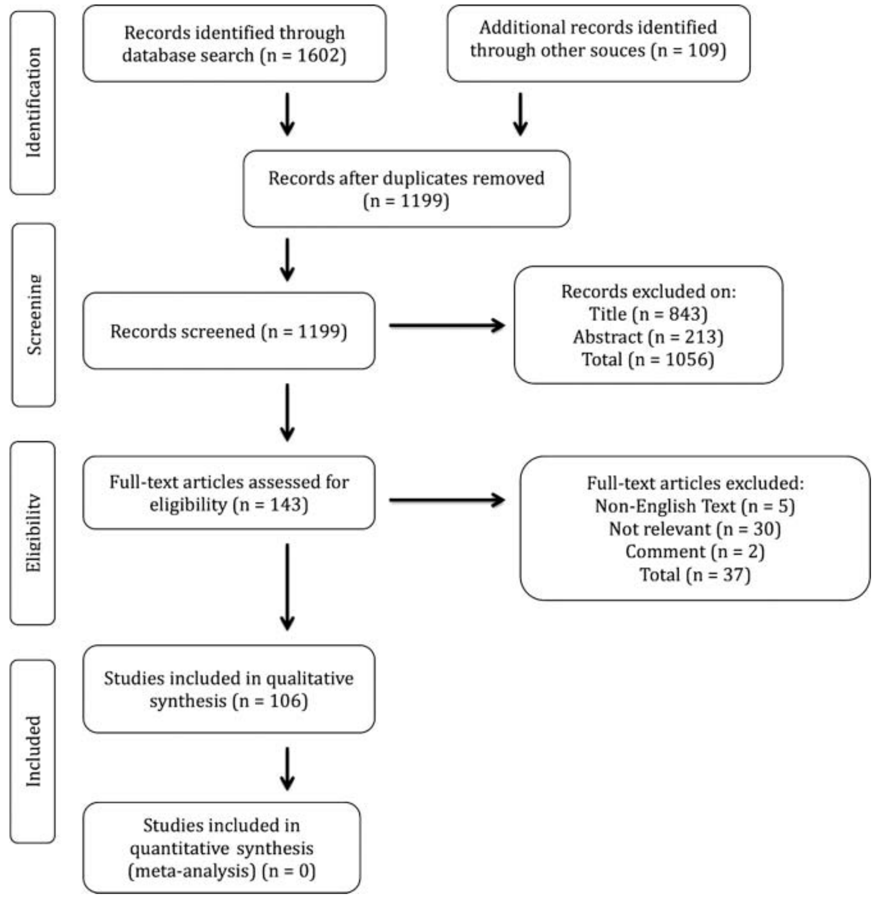
Figure 1 PRIMSA flow diagram.



SCN and the ones in the peripheral tissues. This desychronisation occurs because the central oscillators in the hypothalamus adapt more quickly than the peripheral oscillators, which become briefly lost to hypothalamic control. The human body performs optimally when the many biological rhythms that help drive its functions are in synch.[4]

Circadian rhythm of performance

It has been hypothesised that there is a circadian rhythmicity to athletic performance.[5 6] While a few studies and reviews have not supported this conclusion,[7 8] circadian rhythmicity or time-of-day effects of various aspects of physical performance have been studied and the data suggest that significant effects are evident in many areas. These include leg strength,[9–14] back strength,[15] elbow flexors,[16] jumping tasks,[17] sprint and anaerobic efforts,[18–20] and aerobic tasks.[21 22] Sport-specific tasks such as soccer,[23] cycling[24–27] and swimming[28] have also been shown to display rhythmicity. In a well-constructed experiment, Kline *et al* attempted to detect a circadian rhythm in swim performance as well as eliminate confounding variables such as sleep–wake cycle and environmental conditions in experienced swimmers. Athletes were assessed for consecutive trials in a controlled laboratory setting during which they were maintained on a 3 h sleep–wake cycle (1 h of sleep and 2 h of wakefulness in dim light). Swim performances across all participants differed significantly by environmental time of day (figure 2). Performance was significantly worse at 02:00, 05:00 and 08:00 h than at 11:00, 14:00, 17:00, 20:00 and 23:00 h. Additionally, in this study, performance was significantly correlated with body temperature rhythm and provides compelling evidence for the possibility of an endogenous rhythm of athletic performance.[29] Significant circadian rhythmicity has also been shown in surrogates of performance such as heart rate, blood pressure[30–32] and blood lactate.[33]

Establishing the existence of a daily oscillating rhythm of athletic performance is important. If an endogenous rhythm of athletic performance exists, one would expect (1) performance after travel across multiple time zones to vary over a 24 h period

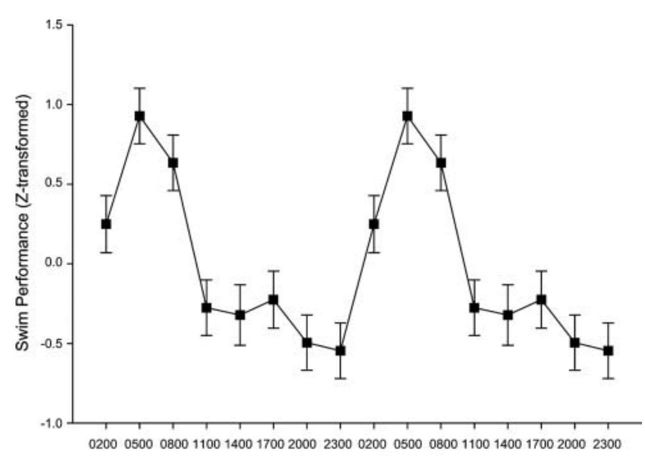


Figure 2 Swim performance versus environmental time of day. Values are double plotted to convey the cyclical nature of the rhythm. High z scores indicate worse performance. Home team winning percentage according to relative circadian advantage/disadvantage. Advantage exists when home team is time zone adapted by 1, 2 or 3 days relative to visiting team (1, 2, or 3 h advantage). Disadvantage exists when the visiting team is time zone adapted by 1, 2 or 3 days relative to the home team (1, 2, or 3 h disadvantage).

displaying peak/trough performance windows,[34] (2) a deterioration of the performance rhythm post-travel followed by a slow rate of resynchronisation,[35 36] (3) generally, a more detrimental effect of eastward travel as opposed to westward travel due to difficulties in adjustment after phase advance as compared with phase delay and (4) specifically, performance of an athletic task several hours before or after the circadian peak 'window' will potentially be completed with less than optimal efficiency.[37]

Air travel and the performance circadian rhythm

In the study by Lemmer *et al*, 15 healthy, male elite athletes were assessed for 24 h profiles of several functions including performance of a standardised training routine, body temperature, grip strength, blood pressure, heart rate, saliva melatonin and cortisol after either westbound or eastbound travel. The westbound athletes (n=13) flew from Frankfurt to Atlanta over six time zones and the eastbound athletes (n=6) travelled over eight time zones from Munich to Osaka. After travel, the rhythmic patterns in body temperature and grip strength were greatly disturbed on day 1 and jet lag symptoms, discussed below, persisted 1–2 days longer for eastbound travellers.[38]

Reilly *et al* showed deterioration of performance rhythms after travel when 17 subjects (8 elite athletes and 9 support staff) were studied to assess jet lag symptoms, performance variables and effect of temazepam on these variables after 9 h of total flight from the UK to Florida.[39] The rate of adjustment of body temperature and improvement of performance variables was unaffected by the administration of temazepam; however, jet lag symptoms and performance variables (leg, back, grip strength, simple and choice reaction time) deteriorated to their worst recorded values on the evening of the first full day following the flight. All of these variables were in phase with the circadian rhythm of intra-aural temperature and gradually improved such that performance of the measured variables had stabilised between post-flight days 5 and 7. These data indicate a perturbation in the circadian rhythm of these performance variables.

JET LAG

Understanding Jet lag

Jet lag is a circadian phase disruption that can occur when an individual experiences an alteration to the external cues that synchronise the body clock and drive biological circadian rhythmicity due to rapid air travel across multiple time zones. A disruption of this sort can also take place when an individual keeps permanent night work schedules or participates in rotating shift-work.[40] Symptoms of jet lag include fatigue and general tiredness, sleep disruption, loss of concentration, loss of drive, gastrointestinal distress, loss of appetite, headaches, general malaise and various metabolic changes.[34 40 41] When performing tasks, jet lag may result in lapses in mental attention and unusual errors in mental performance[39] such as distorted estimation of time, space and distance.[37] Additionally, chronic effects of circadian disruption and jet lag include depression, exacerbation of de novo psychiatric disorders, increased risk of developing cancer and infertility.[42–47] Symptoms of jet lag are not experienced following longitudinal travel of any length because it is the change in environmental conditions associated with crossing time zones that is fundamental to the condition. Effects of jet lag are evident with a 1 h time zone shift, but shifts of 3 h or more are more often associated with symptoms.[1]

Jet lag and performance

Previous studies and reviews have cited evidence that the combined symptoms of jet lag have been shown to contribute to deterioration of athletic performance.[1 34 48 49] Recently, in a prospective study, Chapman *et al*[50] assessed post-travel jump performance in 12 national team skeleton athletes (five from Australia and seven from Canada) and reported a significant variation in performance over the testing window. After initial performance deterioration in some jumping tasks, the peak velocity, mean velocity and jump power eccentric utilisation ratios (an indicator of power performance) for the travel group all significantly increased 2 days after the long-haul flight. These data show that airline travel may have a detrimental effect on jump performance and neuromuscular control over the first 1–2 days after travel.

Studies of team performance have illustrated a decline in performance following travel across multiple time zones. Ten years of Major League Baseball retrospective data were analysed to determine the effect of travel on athletic performance.[51] The study used the convention that for every time zone crossed, resynchronisation requires one 24 h period.[52] As such, teams were assigned a value indicating the cumulative time zones crossed; wins and losses were then analysed based upon this value. Teams were said to have an 'advantage' if they crossed fewer time zones than their opponents. Teams with a 3 h advantage over other teams had a winning percentage of 60.6%, which was more powerful than home-field advantage. Additionally, teams with a 3 h advantage won more games than teams with 1 and 2 h advantages over their opponents (figure 3). It appears that crossing more time zones correlates with diminished performance.

Similarly, a retrospective analysis of archival data from six seasons of Australian National Netball Competition show support for a deterioration in the performance of teams after travel across multiple time zones.[53] Travel was categorised as local, north–south, east–west across one time zone, or across two time zones. There was a significant difference in points scored at away matches between teams travelling north–south and teams crossing two time zones. The magnitude of performance loss was greatest for teams travelling across two time zones. Additionally, the study found that crossing more time zones has an additive effect on performance deterioration. When comparing performance in the group crossing two time zones to those not crossing any time zones, the effect size was greater than

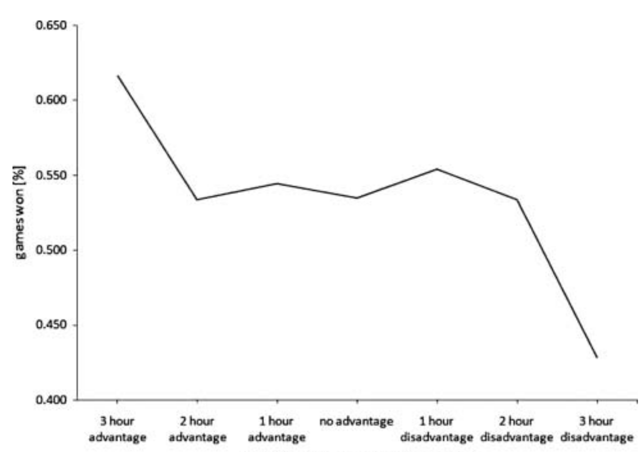


Figure 3 Home team winning percentage according to relative circadian advantage/disadvantage. Advantage exists when home team is time zone adapted by 1, 2, or 3 days relative to visiting team (1-, 2-, or 3-h advantage). Disadvantage exists when the visiting team is time zone adapted by 1, 2, or 3 days relative to the home team (1-, 2-, or 3-h disadvantage).

when comparing teams crossing two time zones to those crossing a single time zone (figure 4). This provides support for the hypothesis that travel across multiple time zones leads to increased jet lag, and thus a greater decline in performance.

Data supporting a decline in performance following travel are not always confirmatory. In a study by Bullock *et al*[54] athletes perceived themselves as jet lagged to day 7, but there were no significant differences in sprint performance.

Direction of air travel and performance

Studies investigating the impact of the direction of travel on performance have had differing results. Some data have shown that eastward travel is more detrimental to performance. This is because the body clock's rhythm is naturally longer than the 24 h light–dark cycle and is approximately 25–26 h long;[1] as a result, it is easier for the body to adapt to changes that lengthen the day as opposed to shorten it. As such, exposure to light in the early evening, for example, produces a delay in the body clock and shifts the sleep–wake cycle to a later hour; this is a phase delay. On the other hand, a light stimulus during night hours produces an advance in the body clock that shifts circadian rhythm phases to an earlier hour; this is a phase advance. This fact has implications for directionality of flight.

Many studies have shown that travellers flying eastbound tend to experience more marked symptoms of jet lag that persist longer, requiring lengthier time for resynchronisation, than those of westbound travellers due to the body's ability to more rapidly adjust by phase delay.[1 5 6 37 55] In accordance with prior studies, Lemmer *et al* found jet lag symptoms after westbound flight were most pronounced through the first three post-flight days, while symptoms after eastbound flight were more severe and persisted up to 7 days after arrival.[38]

However, other studies have shown that westward travel can be more detrimental than eastward travel. Diminished performance was most noticeable when teams competed in the evening after travelling westward so that games were played close to the visiting teams' home bed-time.[56] A separate hypothesis related to circadian rhythm of performance asserts that, as performance peaks in the evening, west coast teams should have an advantage over teams from the east coast in late night games[8] because the game would occur 'earlier' by the visiting team's body time and closer to the time of peak athletic performance.[56] Smith *et al* studied 25 years of National Football League (NFL) data in teams playing in Monday Night Football games with 2100 EST start times. Data showed that west coast teams win more often and by more points than east coast teams in such matches, presumably because the west coast teams are playing closer to their peak window.[57] Data from Winter *et al* showed Major League Baseball teams travelling from west to east were more likely to win than teams travelling from east to west. This phenomenon was also noted in an analysis of retrospective data from eight seasons of games in the National Basketball Association when visiting teams performed better than home teams after travelling west to east.[58] Jehue *et al*[59] found similar evidence in a retrospective study analysing the effect of time zone changes on NFL performance where, in night games, but not day games, west coast teams displayed an advantage over east coast teams.

Based on the above studies, the time of competition is a critical factor affecting performance post-travel. Athletes travelling west to east for early afternoon competition may not perform optimally since their home time is closer to morning hours. Similarly, athletes travelling east to west may have a disadvantage in late afternoon competition when their home time is closer to bedtime. It may be advantageous to gradually shift the body clock prior to competition when a disadvantageous travel schedule is anticipated.

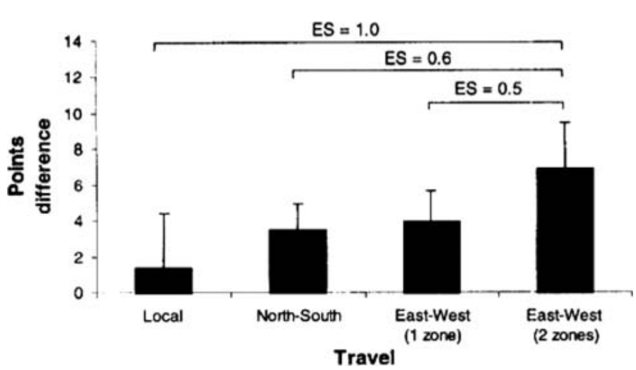


Figure 4 Mean±SE for points difference (home margin—away margin) for each pair of games for four groups of travel, including local travel, north–south travel, east–west travel across one time zone and east–west travel across two time zones.

EFFECTS OF POST-TRAVEL SLEEP DEPRIVATION ON PERFORMANCE

Disturbances in the sleep–wake cycle following travel result in periodic fatigue during the day, inability to sleep at night, sleep fragmentation, premature awakenings, difficulty in sleep initiation and overall sleep loss.[8 35 60] Takahashi *et al* found total sleep time was significantly reduced on the second post-travel day following long-haul flight and elevated activity during sleep that persisted until the second post-travel day in 10 subjects travelling to destinations with 8–11 h time differences.[61] Sleep loss is associated with sizeable effects on alertness,[62 63] negative disturbances in mood, cognition and motivation and may have an affect on performance via these mechanisms.[64–66] Additionally, each individual uniquely experiences vulnerabilities in their cognitive functioning as a result of sleep loss and may be more susceptible to the effects of sleep deprivation when performing one cognitive task over another.[67 68]

Results are wide ranging in literature regarding the effect of sleep loss on physical performance. Early reviews on the subject have concluded there was little evidence to support consistent effects.[69 70] Many studies test the effect of >30 h of sleep deprivation on performance[71–73] though it is unlikely that the sleep loss experienced as a result of long-haul travel reflects a similar deficit. Bambaeichi *et al*[74] assessed muscle strength of knee extensors in eight women after one night of partial sleep loss (2.5 h) and did not find any significant change in strength. However, Reilly *et al*[75] studied eight male weight lifters restricted to 3 h of sleep for three successive nights and found deterioration in submaximal lift performance that was significant after the second night of sleep loss. In another study, Waterhouse *et al*[76] found that a short nap improved sprint times and measures of alertness, sleepiness and short-term memory in 10 healthy men restricted to 4 h of sleep the night before. Therefore, employing strategies to shift circadian rhythms and minimise the impact of sleep loss as a result of circadian disruption prior to competition may benefit athletic performance.[35]

PHASE SHIFTING CIRCADIAN RHYTHMS

Athletes travelling for competition do not often have the flexibility to schedule competitions during their peak performance hours and instead must adapt to a predetermined schedule of events. As a result, it may be beneficial to shift circadian rhythms so that the scheduled event falls during a peak performance window. Studies have shown that the circadian phase manipulation can be effective in shifting the body clock and that it is easiest to try gradual shifts rather than to attempt a rapid preadaptation and risk suffering jet lag prior to the trip.[49 77 78] Socioenvironmental limitations make adaptations more aggressive than 1–2 h/day over 3 days unrealistic, and research has shown no clear benefit for adjustments of 2 h rather than 1 h/day.[77] Thus, shifting the body clock 1 h/day is recommended.[52 62 77 79]. Preadaptation by means of a gradually advancing sleep schedule has been achieved in controlled environments[77 78] using timed light exposure, which suppresses melatonin and facilitates wakefulness, and exogenous melatonin, which enables sleep.[49 80–83]

Light

The timing, intensity and wavelength of light provide important cues for phase shifting the circadian rhythm.[49] One of the simplest adaptation strategies involves timing light exposure to delay or advance the body clock. To achieve phase delays, athletes should seek light exposure in the early evening hours (according to home time) and avoid exposure in the second half of the night and early morning. If phase advances are desired, begin light exposure in late evening to early morning (according to home time).[49 62 78 84] Sunglasses may be helpful to avoid inadvertent exposure to light.[49 62] Natural, outdoor light is preferable to commercial light boxes if possible. The circadian system is most affected by blue light and outdoor light contains more blue light and is much more intense than commercial light boxes.[3 49 77]

Melatonin

The American Academy of Sleep Medicine recommends the appropriately timed use of melatonin supplements to promote adaptation.[85] Studies show oral melatonin (in doses of 2–5 mg) reduces subjective symptoms of jet lag and improves sleep in the laboratory environment; however, the use of melatonin may be counterproductive if taken at an inappropriate time of day.[49 52] In order to phase advance the circadian clock, melatonin should be taken in the late afternoon or early evening, and in order to phase delay, the supplement should be taken close to the sleep period and in the morning.[77 78]

Benzodiazepines

The literature regarding the use of benzodiazepines for travel is limited; however, it is anecdotally recognised as a treatment method and regularly used by some athletes to help limit symptoms of jet lag when travelling for competition. Previous studies in seasoned travellers and aircrews on transatlantic missions have shown that treatment with benzodiazepines can improve overall sleep quality, lengthen total sleep time, reduce time to fall asleep and number of awakenings.[86 87] In two double-blind, placebo-controlled trials of adaptation with triazolam to an 8 h phase delay simulating westward travel, Buxton *et al*[88] found that triazolam was significantly more efficacious than placebo treatment in all subjects, accelerating re-entrainment of circadian rhythms markers and normalising parameters of sleep/wake homeostasis such as sleep onset/awakening, and amount and distribution of rapid eye movement (REM), non-rapid eye movement (NREM) and slow-wave sleep in six men. In order to determine the effect of benzodiazepines on sport performance, Golby and Hutson assessed performance following administration of temazepam (40 mg) compared with placebo in 12 volunteer professional soccer players who underwent reaction time testing, soccer skills testing and critical flicker fusion testing (a reliable assessment of sedation and drowsiness). The authors found no significant difference in any measures between the temazepam and control groups and no interaction effect, suggesting that perceptual-motor performance is not impaired with the use of temazepam.[89] More research is needed to determine optimal dosing and effect of benzodiazepines on re-entrainment of circadian rhythms, symptoms of jet lag and performance following travel, as well as its efficacy as compared to other chronobiotic supplements such as melatonin. However, the existing data suggest that benzodiazepines may be helpful in treating symptoms of jet leg without hindering sports performance.

EFFECTS OF TRAVELLING AT ALTITUDE ON PERFORMANCE

Regulatory agencies have established safety guidelines that allow airlines to pressurise cabins to a maximum altitude of 8000 ft (2440 m). Average cabin pressures are 5000–6000 ft (1520–1828 m), which is equivalent to an inspired oxygen pressure (PO_2) of 132–127 mm Hg. In a prospective study, the degree of decline in oxygen saturation in athletes during long-haul flights was investigated in 63 athletes and staff (45 athletes, 18 staff). The study showed that oxygen saturation levels declined significantly after 3 and 7 h of flight (figure 5).[90] Modest falls in oxygen saturation levels reflect acute exposure to hypoxia at altitude and are equivalent to those experienced by athletes upon arrival at a similar altitude. It is plausible that time spent on long-haul flights should be considered as time spent at altitude.[90]

In general, studies have suggested that altitude exposure results in a significant decline in time trial performance in aerobic sports.[90] These results are supported by Clark *et al* who assessed 10 well-trained, male cyclists and triathletes not acclimatised at altitude for peak oxygen consumption and mean power output at simulated altitudes of 650, 3940 and 7220 ft (200, 1200 and 2,200 m).[91] The study found a significant dose–response effect of hypoxia on both peak oxygen consumption (decrease of 7.2%/3280 ft or 1000 m of altitude) and mean power output (decrease of 7.0%/3280 ft or 1000 m of altitude). In another study, time to exhaustion decreased by 9.4% between 985 ft (300 m) and 2620 ft (800 m) simulated altitude and continued to decrease by 14.3%/3280 ft or 1000 m of

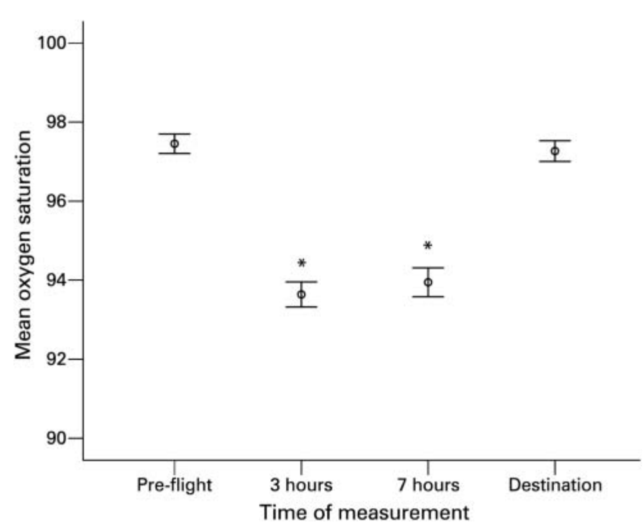


Figure 5 Mean oxygen saturation before flight, during flight and upon arrival at destination. Measurements obtained by pulse oximetry (error bars represent 95% CI of the mean).

altitude subsequently.[92] Additionally, Gore *et al*[93] found a 67–76% decrease in peak oxygen consumption that was accounted for by a decrease in O_2 delivery, indicating that reduced O_2 tension even at altitudes as low as 1900 ft (580 m) leads to impairment of performance in a maximal effort lasting 5 min. Faulhaber *et al*[94] reported significant decreases in mean power output during time trial performances in 11 healthy male athletes from low (1970 ft or 600 m) to moderate (6470 ft or 1970 m) altitude. Interval sprint efforts, as well as interval endurance trials, in eight elite female cyclists were significantly impaired during exposure to hypoxic conditions simulating a moderate altitude of approximately 6890 ft (2100 m).[95]

Given that biological responses to hypoxia begin during acute exposures such as hypoxic conditions associated with air travel, it would be beneficial to understand the extent to which any negative effects of hypoxia remain once travellers reach their destination. Eight elite cyclists were studied at sea level and after 1, 7, 14 and 21 days of exposure to 7680 ft (2340 m) of altitude. On day 1, max O_2 consumption and time to exhaustion decreased by 12.8% and 25.8% respectively. Afterward, the same measures increased dramatically from day 1 to day 14 suggesting that endurance athletes competing at moderate altitudes should expose themselves to similar altitude at least 14 days before competition.[96]

There are no published studies testing performance at sea level following travel; however, it is plausible that athletes would require a period of adaptation for optimised performance. For long flights (>10 h) it is be recommended that athletes avoid arriving the same day of competition.[90]

AIR TRAVEL AND NUTRITION

When athletes travel for competition, they introduce unfamiliar stress to their normal body function at the time when maximal and optimal performance is important. Nutrition is essential for performance and the circadian desynchronisation that contributes to feelings of jet lag also affects gastrointestinal function and digestion.[97,98] Circadian disruption can cause a delay in the absorption of food from the gastrointestinal tract after eating at night.[98] A large meal eaten late in the evening could lead to bloating and sleep disruption,[97] making timing of meals important for re-entrainment of the digestion rhythm.[97] However, patterns of activity and eating vary in different locations, causing challenges when adapting to new mealtimes and rhythms of activity. Travelling athletes may also have difficulty finding access to palatable foods that are typically included in their usual diet, given a new environment. Thus, appropriate timing of meals may be more important than the energy content of the meal[52,99] and small meals before and during flights are better tolerated than large meals.[1,100]

Studies have suggested that particular foods/diets are important for re-entrainment of the peripheral circadian clock. For example, a meal high in carbohydrate, but low in protein may facilitate uptake of tryptophan and its conversion to serotonin, inducing drowsiness and sleep. On the other hand, a meal high in protein but low in carbohydrate might enhance tyrosine uptake and conversion to epinephrine, increasing arousal levels.[1,37] Animal studies have shown that hypercaloric, high-fat diets can impair adaptation to environmental signals after circadian disruption[101] and circadian rhythms are readily adapted when a restricted feeding diet is administered.[102,103]

Gastrointestinal infections related to travelling are quite frequent among athletes as hygiene standards for food and water vary in foreign countries. Traveller's diarrhoea is a common, and usually self-limiting, condition; however, the associated dehydration can be detrimental to athletes. As such, athletes should avoid raw, or minimally cooked, foods and non-bottled water.

DISCUSSION

Analysing the effect of air travel on performance is problematic for many reasons. First, the data strictly analysing an episode of travel and subsequent results on performance are limited; therefore, it is difficult to glean an overall understanding of its impact. Second, it is clear that many factors affect performance in general, and distinguishing any aspect of travel as a cause for deterioration of performance is challenging and met with a variety of methodological issues. Thus far, attempts to remove confounding factors have had limited success.[56] Third, much of the literature is based on performance measures that are questionably related to athletic performance such as grip strength or performance of one particular muscle group. It is unclear as to whether these measures can serve as generalised benchmarks of athletic performance. Fourth, the predominance of data available investigates the effect of jet lag or alterations in circadian rhythms on athletic performance; however, the process of travel encompasses many more variables. Studies isolating effects of variables such as dehydration or alterations in diet following travel are unavailable. Finally, there is significant variation in many of the available results that contribute to the base of knowledge on this topic highlighting the difficulties in studying this issue. In many studies, sample size is small possibly due to the logistics of organising air travel among a population of elite athletes willing to participate in a scientific study.

Athletic performance is undoubtedly a composite of many interacting variables. And, in testing the impact of travel on performance, study designs are met with the challenging task of eliminating a multitude of confounding variables associated with individual performance. While it is relatively less difficult to control environmental factors that may influence circadian rhythms such as light, activity or meals, it is decidedly more difficult to control for elements that display a circadian rhythm all their own such as sleep–wake cycles.[56] Inability to eliminate this variable, for example, blurs the ability to determine whether a decline in performance is due to a shift in circadian rhythm, or to sleep deprivation. Additionally, athletes exhibit differing rates of resynchronisation following flight[1] which could contribute to variability in results. It is also necessary to consider chronotype, or an individual's propensity to prefer activity during certain times of day, as this factor may inject inconsistency in results. Additionally, mood and activity rhythms differ by several hours between morning and evening types which will also have an effect on circadian rhythm performance.[34] Motivation and arousal level can affect performance as well, factors that vary greatly among individuals. The extent to which one individual is excited by competition cannot be controlled and will certainly affect their desire to perform maximally during a given task. Additionally, teams competing in their home environment enjoy a home court/field advantage and travelling teams are met with a considerable task of overcoming such an advantage. This advantage is often hard to separate from detriments in performance related to travel.[51,53,104] All of these factors taken together highlight the difficulty in generalising the results of current literature as some factors may play a more significant role than originally anticipated.

This topic can be more adequately investigated with studies that utilise designs that better control for some of these confounding variables. Additionally, more research is needed to analyse the effect of other aspects associated with travel and not

What this study adds

- Reviews the most recent literature regarding the effect of air travel on athletic performance.
- Includes multiple factors associated with air travel that potentially effect athletic performance, not simply jet lag.
- Offers evidence-based recommendations that can be quickly referenced to reduce the effect of air travel on athletic performance.

just the effects caused by jet lag or alterations in circadian rhythms.

RECOMMENDATIONS TO DECREASE THE EFFECT OF AIR TRAVEL ON PERFORMANCE

1. In advance of travel, shift the body clock to the new time zone through means of gradual, 1 h/day, shifts in sleep scheduling.[52 62 77 79]
2. Circadian phase shifting can be facilitated by proper timing of light exposure[49 62 83] and the use of supplemental melatonin, taken by mouth, in doses ranging from 2 to 5 mg.[49 78 80–82 84]
3. Exposure to natural daylight is preferred over exposure to artificial light.[3]
4. Expose travellers to social contact at times appropriate for local time at the destination.[4]
5. Avoid caffeine during travel, as this stimulant can interfere with appropriately timed restorative sleep and alter ability to effectively adapt to a new time zone.[52 105]
6. Short (20–30 min) naps can be helpful in recovering from sleep deprivation and restoring a normal state of arousal.[3 62]
7. Consume extra fluids for the duration of air travel to combat dehydration. Avoid alcohol or caffeine, which act as diuretics and can add to fluid losses.[3]
8. If possible, make arrangements for dietary selections that are optimal for individual performance. While travelling, eat smaller meals before and during flight; and, upon arrival, time meals to match habits appropriate to the destination.
9. If travelling outside of the country, avoid non-bottled water, raw or minimally cooked foods, and peel fruits and vegetables that have been washed.[106]

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