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FIMS Position Statement

Air travel and performance in sports

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Introduction

Air travel is common for athletes participating in national and international sport competitions. In deciding whether or how to manage air travel in an attempt to minimize any reduction in performance, athletes, coaches and members of the sports medicine team may benefit by being aware of the following information.

Performance in sports following air travel within one time zone

Air travel is a complex stimulus that often involves vibration, noise exposure, immobility, sleep loss, dietary changes, and breathing poor quality air (e.g., drier air with a reduced partial pressure of oxygen). Moreover, air travel is psychologically stressful for many people, particularly now with increased concern over terrorism. There is not strong scientific evidence documenting that any one of these factors, individually or in combination, causes a significant reduction in sport performance, but such an effect is possible. Athletes can employ common sense techniques to avoid some of the discomforts of air travel. For example, ear plugs or headphones can be used to reduce noise exposure. Seated physical activities and periodic walking can be used to combat stiffness and reduce the increased risk for thrombosis. Water can be consumed and diuretics such as alcohol and caffeine can be avoided in order to minimize dehydration associated with low humidity in the cabin.

Performance in sports following air travel across multiple time zones

It is plausible that air travel across multiple time zones has greater effects on sport performance than air travel within one time zone. The two primary reasons for this possibility are related to the circadian system: (1) an assumed circadian rhythm in sport performance and (2) jet lag.

What are circadian rhythms? Circadian rhythms are self-sustained variations in biological and behavioral functions with a period of ~24 hours. Circadian rhythms are internally driven by the brain's suprachiasmatic nucleus (SCN), the "circadian clock". These endogenously produced circadian rhythms can be modified by bright light (or darkness), melatonin, and exercise because the SCN (1) receives neural input from cells in the retina that detect light, (2) has melatonin receptors, and (3) receives input from brain areas integrating information about the level of physical activity and central nervous system arousal. These inputs to the SCN allow for an individual's circadian rhythms to be synchronized to a given environment. Healthy people are usually synchronized to the environment in which they live, and the dominant synchronizer is the light-dark cycle.

The potential for circadian rhythms to influence sport performance is related to the neural outputs of the SCN. Neurons from the SCN project most densely to the hypothalamus, but there are also projections to the forebrain. The hypothalamus plays an important role in regulating a host of body and brain functions with potential relevance to athletic performance. These functions include motivation and emotions, body temperature, water balance, food intake, state of the autonomic nervous system, and the effect of multiple hormones including opioids, cortisol and melatonin. The forebrain plays an important role in both cognition and emotion. Cognitive and emotional factors play a role in the performance of athletes and in the decision-making of coaches and other members of the athlete's support staff, including the sports medicine team.

Is there a circadian rhythm in sport performance? The hypothesis that air travel across multiple time zones negatively affects performance can be based on the assumption that there is a circadian variation in sport performance. The currently available scientific evidence for this assumption is weak.

For the sake of illustration, assume that sport performance is characterized by a circadian rhythm in which the worst performance occurs each day when the body temperature rhythm is at its lowest and the best performance occurs each day when the body temperature is at its highest. People whose circadian rhythms are synchronized to their local environment and wake habitually at 8 am would be expected to have their lowest body temperature occur at ~6 am and their peak body temperature occur at ~9 pm. If the difference between the maximum and minimum of peak sport performance is assumed to be 1%, then elite male runners would be ~2 seconds faster in a 1500 meter run and ~75 seconds faster in a marathon run at ~9 pm compared to ~6 am due to this assumed circadian variation in performance. Travel across multiple time zones causes a transient change in the usual relationship between endogenous circadian rhythms and the local time of day. Air travel across 12 time zones, for instance, might result in the peak body temperature occurring at ~9 am local time rather than the usual ~9 pm. If this hypothetical example were true, then performance could be optimized either by competing when the underlying rhythm in body core temperature was expected to be highest (i.e., ~ 9 am local time in the city of arrival) or by using melatonin, bright light or exercise to induce a shift in the body temperature rhythm so that the shifted body temperature rhythm peaked at the scheduled time of competition.

How strong is the evidence for a circadian rhythm in sport performance? Circadian rhythms have been demonstrated for several physiological variables, such as core body temperature, that are either known or thought to be relevant to performance. And it often has been assumed that sport performance is optimal in the evening when the circadian rhythm in body temperature is higher than in the morning. Support for this idea stems in part from the observation that most world record performances have been set in the evening. However, no clear interpretation of the world record results is possible because the frequency of athletic competitions has not been equally distributed throughout the day. The assumption of better sport performance in the evening was only partially supported by a comprehensive review performed 18 years ago which concluded that performance in different events peaks during afternoon and evening hours varying widely from 1200 to 2100 hours (Winget et al., 1985). More recent experimental evidence shows that pre-cooling improves endurance performance (Marino, 2002), suggesting that endurance performance may be optimized by competing at a time when core body temperature is at its *lowest*. The mechanisms that underlie sport performance are complex and vary depending on the type of task. For instance, 100-meter dash performance relies to a greater extent on muscle stores of ATP and creatine phosphate while marathon performance relies to a greater extent on muscle glycogen stores. Therefore, it is unlikely that all types of sport performance will be tightly linked to the circadian rhythm of a single physiological variable such as core body temperature.

In general, experimental investigations into the issue of whether there is a circadian variation in sport performance have used weak methods. For example, the reliability with which study volunteers are able to consistently perform sport tasks is rarely established. Those tasks that have been established as reliable have been used infrequently in studies of circadian rhythms and sport performance. Moreover, investigations usually have involved small numbers of test subjects who often were non-athletes performing novel, laboratory tasks and the tasks typically were performed only a few times during the day. A commonly studied task is grip strength. The generalizability of laboratory findings of grip strength to more complex types of sport performance is questionable.

The biggest research shortcoming is the failure to demonstrate that sport performance rhythms are internally driven by the suprachiasmatic nucleus. This could be accomplished using established procedures such as the "constant routine" or the "ultra-short sleep-wake cycle" techniques (Carskadon & Dement, 1975; Duffy & Dijk, 2002). These procedures can separate the presence of an internally-driven circadian rhythm from an apparent circadian rhythm that is actually caused by behavioral or environmental masking effects. Masking effects are likely to contribute to variations in sport performance. For example, morning exercise typically follows an 8- to 12-hour fast, while evening exercise usually does not. It is possible that reduced sport performances in the morning compared to the evening are due to the masking effects of overnight fasting-related glycogen depletion rather than an internally-driven circadian rhythm. Also, reduced early morning performance, potentially related to muscle stiffness, may be associated with the preceding 5-9 hours of bed rest rather than a circadian influence.

In summary, it is widely believed that there is a circadian rhythm in sport performance. Circadian rhythms are so ubiquitous that it is plausible that circadian rhythms in athletic performance exist. Special experimental techniques are required to document accurately the presence and magnitude of circadian rhythms in sport performance, but these experiments have not yet been conducted. Thus, at the present time it is unknown whether there is an internally-driven circadian rhythm in sport performance.

Does jet lag negatively influence sport performance? Travel across multiple time zones causes the air traveler's circadian rhythms and sleep-wake cycles to be out of synchrony with the light-dark cycles in the city of arrival. This asynchrony is thought to cause jet lag.

Jet lag is a syndrome characterized by sleep loss, headaches, dizziness, reductions in both alertness and cognitive abilities, and mood disturbances such as increased feelings of fatigue and reduced feelings of energy (Spitzer et al., 1999). The American Sleep Disorders Association's diagnostic criteria for jet lag are presented in Table 1. It is plausible that the biological mechanisms that cause signs and symptoms of jet lag also could cause a transient reduction in sport performance. Alternatively, it is possible that jet lag symptoms could reduce sport performance via a psychological mechanism such as feelings of sleepiness that reduce an athlete's expectations about being able to perform optimally.

In the absence of an effective jet lag countermeasure, the time necessary for resynchronization of circadian rhythms and the amelioration of jet lag depends on the number of time zones crossed. The more time zones crossed the more time needed for resynchronization. It has been estimated that amelioration of jet lag symptoms and resynchronization of circadian rhythms occurs 30% to 50% faster following east-to-west flights compared to west-to-east flights (Hauty & Adams, 1966a; Hauty & Adams, 1966b). This is thought to be due to most people's circadian clock having an inherent periodicity of slightly greater than 24 hours, resulting in circadian phase delays (necessary to adjust to east-to-west flights) being somewhat easier to accomplish than phase advances.

Although some athletes, anecdotally, report impaired performance after air travel, there is no consistent or compelling evidence showing that either air travel across multiple time zones or jet lag symptoms cause a reduction in sport performance. Elite athletes who have honed their skills by performing tens of thousands of practice trials over years of training may be especially reliable in their ability to perform and particularly resistant to the potential effects of jet lag. Most of the research evidence has been generated with small samples performing novel laboratory tasks (e.g., grip strength) of questionable relevance for more complex types of sport performance. These investigations also have been frequently characterized by design flaws (e.g., lack of a control group or condition, failure to document reliable performance preflight) that prevent the ability to draw a defensible scientific conclusion from the results.

In summary, it is widely believed that jet lag adversely influences sport performance. Jet lag symptoms are unpleasant and it is plausible that they could cause a reduction in sport performance. Nonetheless, there is no consistent or compelling scientific evidence showing that either air travel across multiple time zones or jet lag symptoms causes a reduction in sport performance.

Interventions of potential utility

Despite a lack of solid scientific evidence, some athletes and coaches will decide it is worthwhile to attempt to shift circadian rhythms in association with air travel in the hope that it will optimize performance. Three strategies for shifting circadian rhythms involve bright light, exercise and melatonin.

Bright light/darkness. Bright light is generally regarded as the strongest stimulus for resetting the circadian clock in humans. Bright light shifts circadian rhythms via a direct retinohypothalamic pathway to the suprachiasmatic nucleus. The phase-shifting effects of light are influenced by the timing of light, and also by several other factors including the intensity and duration of the light stimulus, and the pattern of prior exposure to darkness and light.

There is consensus that bright light elicits phase delays when administered before the body temperature minimum (average about 5 am) and elicits phase advances when administered thereafter, with smaller or negligible effects near the temperature peak (Minors, Waterhouse, Wirz-Justice, 1991; Khalsa et al., 2003).

Evidence indicates that the phase-shifting effects of light are related to the cube root of brightness (Boivin et al., 1996). Thus, phase shifts in response to a bright living room (500 lux) are about 1/3 the magnitude of responses to being outside on a very bright day (10,000 lux). Evidence suggests that 1 hour is about 40% as effective as 3 hours of bright light, with little added effects beyond 3 hours.

***Melatonin*.** The circadian system can be influenced by taking melatonin (Lewy & Sack, 1997). A low dose (0.5 mg) of melatonin taken from the morning to mid-afternoon tends to delay the circadian system, whereas melatonin taken in the mid-afternoon until bedtime tends to advance the circadian system. Too high a dose of melatonin can result in melatonin remaining in the blood too long and influence the undesired portion of the phase response curve. Melatonin has about 1/4 to 1/3 the phase-shifting potency of bright light. The available evidence indicates that melatonin may reduce the symptoms of jet lag, particularly after eastward air travel that involves 10 or more time zones, but enhancements in the rate of resynchronization of the body clock to the shifted time zone have not been well-documented.

Exercise. The effects of exercise on circadian rhythms in humans have been less well studied than bright light or melatonin. Research conducted with rodents first revealed that physical activity could shift circadian rhythms. During the last decade, exercise of 1 to 3 hours has been found to induce significant circadian phase shifts in humans. Early morning exercise performed before the body temperature minimum consistently has been associated with circadian phase delays (Baehr et al., 2003; Youngstedt et al., 2002; Van Reeth et al., 1994), while recent evidence suggests that early evening exercise results in phase advances (Buxton et al., 2003).

In cannot be overemphasized that these three methods for shifting circadian rhythms depend critically on the timing of the intervention. Ill-timed bright light, exercise or melatonin could plausibly exacerbate jet lag symptoms or delay resynchronization beyond the time it usually takes to adapt to a new time zone.

Practical recommendations

While the insufficient quality and quantity of research in this area is acknowledged, certain practical recommendations for the traveling team physician can be made which are based on circadian principles and empirical evidence collected by experienced team physicians.

Practical recommendations can be summarized as follows:

I. Before the flight, athletes*:*

(1) should be provided basic educational information about jet lag and circadian rhythms.
(2) should carefully plan for the trip to make it less stressful and more enjoyable.
(3) should avoid sleep deprivation.
(4) may wish to consider gradually shifting the sleep schedule (30-60 min per day) toward that of the destination for a few days prior to departure.
(5) may wish to consider using appropriately timed bright light and darkness, melatonin or exercise to shift circadian rhythms (see details in section IV below).

II. During the flight, athletes:

(1) should drink plenty of water or fruit juices and limit alcohol and caffeine intake in order to combat dehydration due to the dry air.
(2) should stretch, perform mild isometric exercises and walk, at least every hour, in order to minimize muscle stiffness and the risk for thrombosis associated with prolonged inactivity.
(3) should consider using earplugs to minimize stressful noise exposure.
(4) should avoid taking sleeping pills in the absence of a consultation with a physician.

III. After arriving, athletes:

(1) should avoid heavy or exotic/spicy meals since GI distress is one of the most common symptoms of jet lag,
(2) should consider engaging in a low intensity exercise session. The exercise could be helpful for reducing muscle stiffness. The exercise might need to be performed indoors since light exposure at the destination might counter the desired circadian phase shift.
(3) should consider avoiding heavy training for the first few days after a long flight.
(4) may wish to consider using appropriately timed bright light, melatonin or exercise to shift circadian rhythms (see details in section IV below).

IV. Examples of how bright light, melatonin or exercise might be effectively used.

Note: From a chronobiological standpoint, the maximum change in time zones is 12 hours.

(1) <u>Regarding travel less than 9 time zones eastward.</u>

A. Travelers will want to advance their body clock to adjust to the new time zone. They can begin advancing the body clock before travel by maximizing light exposure in the morning (after awakening) and minimizing light exposure at night before bedtime. If begun a few days before travel, travelers can gradually advance wake time and bed time (about 30 min per day).

B. After arriving at the new destination, travelers should refer to their pre-flight home time-zone to determine when to get light exposure. They should maximize light exposure from about 5-10 am in the pre-flight time zone and minimize light exposure from midnight to 4 am in the pre-flight time zone. To determine when one should receive and avoid light in the new time zone, simply add one hour for each time zone traveled eastward. For example, following travel 8 time zones eastward, travelers should maximize light exposure from 1-6 pm in the new time zone and minimize light exposure from about 8 am to noon in the new time zone. This timing should be advanced by 1 hour each day. For example, on the 2nd day after travel, travelers should maximize light exposure from ~noon to 5 pm and minimize light exposure from 7-11 am; on the 3rd day, they should maximize light exposure from 11 am - 4 pm and minimize light exposure from 6-10 am.

(2) Regarding travel of 12 hours or less westward.

A. Travelers can begin delaying their clock before travel by maximizing light exposure during the 4 hrs before bedtime and minimizing light exposure during the 4 hrs after awakening. Travelers would also benefit from a gradual delay of bedtime and wake time (30-60 min later per day for the few days before travel).

B. After arriving in the new destination, travelers should maximize light exposure from ~ midnight to 4 am in the pre-flight time zone and minimize light from 5-9 am in the pre-flight time zone. To determine when one should receive or avoid light in the new time zone, simply subtract one hour for each time zone traveled westward. For example, following travel 8 time zones westward, travelers should maximize light exposure from ~4-8 pm and minimize light exposure from ~ 9 pm to 1 am. Each day following travel, the timing of the light should be delayed by an hour. That is, on the second day, travelers should maximize light exposure from ~ 5-9 pm and minimize light exposure from ~10 pm to 2 am. On the 3rd day, travelers should maximize light exposure from 6-10 pm and minimize light exposure from ~11 pm to 3 am, respectively.

(3) Regarding travel eastward 9 or more time zones.

A. For many people, it is easier to delay the body clock by 15 hours than advance the body clock 9 hr after eastward travel. To begin delaying the body clock before travel, follow instructions for 2A above.

B. After arriving in the new destination, travelers should maximize light exposure from ~ midnight to 4 am in the pre-flight time zone and minimize light from 5-9 am in the pre-flight time zone. To determine when one should receive or avoid light in the new time zone, simply add one hour for each time zone eastward. For example, following travel across 9 time zones eastward, travelers should maximize light exposure from ~ 9 am to 1 pm in the new time zone and minimize light exposure from ~ 2-6 pm in the new time zone. The timing of the light should be delayed by an hour each day following travel. That is, on the second day, travelers should maximize light exposure from 10 am to 2 pm and minimize light exposure from ~3-7 pm. On the 3rd day, they should maximize light exposure from 11 am-3 pm and minimize light exposure from ~4-8 pm, respectively.

Melatonin

Melatonin shifts the body clock in the opposite direction as bright light. Melatonin delays the body clock at times in which bright light advances the body clock and melatonin advances the body clock at times in which bright light delays the body clock. Since melatonin also induces sleepiness when taken in the morning (for phase delays), it should not be taken if wakefulness is desired. Typically, melatonin should therefore be used for phase advances only. Care should be taken to obtain a high quality formulation of known dose.

Exercise

The maximum phase-delaying effects of exercise are about the same time as the maximum phase-delaying effects of light. Thus, for every recommendation of delaying the body clock with light, exercise can be inserted. Limited evidence suggests that phase advances may be obtained in the later afternoon and early evening (4-7 pm) in response to exercise.

Limitations of the available evidence

Ideally, sports medicine interventions are based on strong scientific evidence that the interventions are effective in helping athletes. One widely accepted method of generating strong evidence of effectiveness is a placebo-controlled, randomized clinical trial. No adequately designed randomized clinical trials have been conducted regarding air travel among athletes, and compelling scientific evidence has not been generated regarding the key issues related to air travel and sport performance. Specifically, there is no compelling scientific documentation that (1) athletes exhibit an internally-driven circadian rhythm in performance; (2) air travel across multiple time zones causes a reduction in performance; or (3) interventions designed to reduce symptoms of jet lag are beneficial for the post-flight performance of athletes. Despite the lack of ideal evidence, it is plausible that performance by some athletes is reduced following air travel and that certain interventions may minimize the performance decrement. However, the lack of adequate scientific evidence regarding these issues attenuates the certainty that advice given by the sports medicine staff to air traveling athletes will help, rather than harm, their performance.

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Table 1: Jet lag diagnostic criteria of the American Sleep Disorders Association

A. The patient has a primary complaint of insomnia or excessive sleepiness.
B. There is a disruption of the normal circadian sleep-wake cycle.
C. The symptoms began within 1 or 2 days after air travel across at least two time zones.
D. At least two of the following symptoms are present:
    1. Decreased daytime performance
    2. Altered appetite or gastrointestional function
    3. An increase in frequency of nocturnal awakenings to urinate
    4. General malaise
E. Polysomnography and the Multiple Sleep Latency Test demonstrate loss of a normal sleep-wake pattern.
F. No medical or mental disorder accounts for the symptoms.
G. The symptoms do not meet criteria for any other sleep disorder producing insomnia or excessive sleepiness.

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