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Series Title: ENVIRONMENTAL FACTORS #4

DESYNCHRONIZATION OF BIOLOGICAL RHYTHMS IN ATHLETES: JET LAG

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(In small print:)

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Regular biological rhythms have been observed in animals and plants, from unicellular organisms to complex vertebrates (5). These biological rhythms are expressed as oscillations in physiological systems which last from minutes to months. Circadian rhythms are one category of biological rhythms which last approximately 24 hours; they derive their name from the Latin phrase circa dies ("about a day"), meaning that they change in concert with the rotation of the earth.

In humans, the following processes exhibit circadian rhythms: breathing rate, heart rate, body temperature, oxygen consumption, blood plasma volume and protein concentration, sweat rate, flexibility of major joints, grip strength, muscular endurance, physical work capacity, neuromuscular coordination, reaction time, as well as psychological factors such as short-term memory, logical reasoning, mood state, vigor and alertness (5,6,10). Circadian rhythms should not be confused with the discredited (6,9,10) "biorhythm" theory of a 23-day physical cycle, a 28-day emotional cycle, and a 33-day intellectual cycle, which has resulted in books, charts and calculators to predict "favorable" and "unfavorable" days in one's life. This discredited theory states that "biorhythms" are established at birth, do not change, and are identical for all persons with the same birthdate (8). In fact, biological rhythms may be altered by a variety of factors (5,6,9,10) and vary greatly between individuals (5,9,10).

The biological rhythms of organs and systems are probably controlled by reverberating nerve circuits in the midbrain (6). Because the rhythms of body parts may be altered independently, it is advantageous to have these rhythms synchronized. This allows for rapid, efficient interaction of organs, in response to a stimulus. Synchronization of circadian rhythms is enhanced by external cues (6,9). In most species, the level of light is the dominant external cue (6). In humans, factors such as meal timing (2), dietary nutrients (1), shift work

(5,9), group living (9), and stressful situations (10) also may alter the duration of biological rhythms.

Table 1
A variety of research studies have focused on the optimal time of day to perform work and exercise. These studies (6,9,10) have shown that the majority of performance-critical circadian rhythms are optimal in the afternoon (Table 1). The reader should note that Table 1 describes an average time of day for each factor and that differences in circadian rhythms can be expected between athletes (i.e. "larks" are different from "owls" in epinephrine secretion, psychological mood, and activity patterns; see ref. 10). The unique requirements of each competitive event will dictate how each factor in Table 1 alters performance; for example, some events require small muscle coordination and visual acuity more than others. Detailed records of previous performances may be useful in determining the optimal time of day for each athlete. Also, any reasonably intelligent athlete can determine his/her own circadian peaks, valleys and patterns. This involves taking relatively simple measurements of physical and psychological variables (e.g. vigor, oral temperature, pulse rate, grip strength, blood pressure, addition speed, mood state) several times a day (3).

DESNYCHRONIZATION OF CIRCADIAN RHYTHMS BY AIR TRAVEL

The most common disturbance of circadian rhythms involves a sudden shift of time zone (jet lag, jet syndrome), as encountered during air travel. Athletic performance may decline when internal circadian rhythms (set to the time zone of departure) are "out of synch" with environmental cues (at the time zone of arrival). This problem is accentuated if a time zone change of 3 hours or more is attempted. Flights from west to east (lengthened day) disturb circadian rhythms more than flights from east to west (shortened day) (6,9). North to south (and south to north) flights have little impact on circadian rhythms (9).

Researchers at the U.S. Army Research Institute of Environmental Medicine in Natick, MA (11) observed performance deterioration in dynamic arm strength (-6.1 to -10.8%), elbow flexor strength (-13.3%), sprint time (-8.4 to -12%) and a lift and carry task (-9.5%), after eastward transatlantic flight through six time zones. In addition, continuous travel through 5 or more time zones may result in the following (9,10): fatigue, irritability, insomnia, constipation, migraine headache, digestive upsets, altered mood, disorientation/confusion, distortion of time/distance, and hunger at unusual times of the day.

The U.S. Olympic Committee recognized the potential for decreased performance in athletes who travelled to the 1988 Summer Olympics in Seoul, Korea. They prepared a brochure titled, "From the U.S. to Seoul--How to Avoid Jet Lag", which included guidelines to help athletes avoid rhythm desynchronization. Seoul lies 11 time zones from New York and 7 time zones from Los Angeles. Previous publications have cited jet lag as the cause of poor team and individual performance in international volleyball (Russia vs Japan) and shooting (England vs New Zealand) matches (6).

It is advisable to avoid time trials or competitive simulations shortly after arrival. This may lead to discouragement (6). Approximately 25 - 30% of air travellers have great difficulty in adjusting to desynchronized biological rhythms, while 25 - 30% exhibit little or no difficulty (9). It also has been reported that flight crews experience difficulties during transmeridian flights (9). On the first day of travel, 59 - 78% experience sleep loss (25 - 30% on the second day); 41% of these crew members reported gastrointestinal disturbances.

Sleep deprivation itself must be considered during jet lag, because sleep onset and sleep duration are related to circadian body temperature changes (9). Two lengthy review articles have examined sleep deprivation effects on

cardiovascular function, muscle strength and metabolism (4,6). Both articles agree that performance decrements are minor, when sleep deprivation is less than 54 consecutive hours; this is much greater than typical cases of jet lag-induced insomnia. Thus, it appears that performance decrements results more often from circadian rhythm desynchronization than from sleep deprivation.

RESYNCHRONIZING CIRCADIAN RHYTHMS

Several factors influence the degree of biological rhythm desynchronization (9). These factors (e.g. introversion/extroversion, age, previous sleep habits, "lark" vs "owl") suggest that some athletes adapt to jet lag more effectively than others. The specific mechanism(s) underlying disturbances of biological rhythms—which lead to decreased performance and discomfort—are not well understood. Yet, if an athlete suddenly shows signs of jet lag, it is prudent to have a plan of attack.

Resynchronization does not occur rapidly. Athletes required 6 and 2 - 10 days to regain maximal performance, during international volleyball and shooting matches (see above). Table 2 presents the number of days required to fully resynchronize circadian rhythms.

The following measures have been published by a variety of authors, as guidelines to either reduce desynchronization or speed resynchronization of circadian rhythms:

1. The athlete should arrive several days prior to performing at distant sites (see Table 2) (10). Shepard (6) has recommended that a minimum of 14 days be allowed for adaptation to a major time zone difference.
2. Upon arrival, the athlete should immediately adjust his activity/rest schedule to local time, and should maintain constant sleep/wake

schedules (10). Exposure to daylight and darkness are important external cues; the athlete should not remain in a room which has no windows (10).

3. Mild exercise speeds resynchronization of biological rhythms (6,10). Intense exercise late in the day, however, will probably increase arousal and may disrupt sleep.
4. It has been suggested that time zone changes of 3 hours or more may be counteracted if athletes shift their daily schedule by 2 hours, for several days prior to travel (6). However, experience with athletes has shown that this approach was not satisfactory, with respect to the effort involved (10).
5. A dietary plan has been proposed to reduce the negative effects of jet lag (1). This dietary plan regulates protein and carbohydrate intake, which supposedly mediates blood and brain hormone levels, to speed resynchronization of circadian rhythms. On the basis of subjective reports (1), this diet was reported to be successful. However, the benefits of such dietary adjustments of protein and carbohydrate intake have not been confirmed experimentally.

Because circadian rhythm desynchronization is complex, and because each situation is unique, the techniques above should be tested to identify those which are most successful for each athlete.

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Table 1 - Optimal time of day for circadian rhythms which affect athletic performance.

<u>Circadian Rhythm Peak</u>	<u>Time of Day</u> [*]	<u>Reference No.</u>
speed and accuracy of psychomotor performance	1200h	2, 10
tolerance to an all-out effort, lowest anxiety, lesser fatigue	1600h	2
trunk flexibility	1400h	10
grip strength	1400 - 1800h	10
esophageal temperature, threshold of forearm blood flow, chest sweating	1600h	7
maximal breathing rate	1500h	10
maximal oxygen consumption	1500 - 2000h	10
blood catecholamine and cortisol levels	0600 - 1000h	10
hand-eye tracking control	- 2000h	10
short term memory	0800-1300h	10
vigor (self-rating)	1500h	10
mood (self-rating)	1400 - 1600h	10
logical reasoning	1400h	10

* - to nearest hour; 24-hour time

