Objective: To quantify the impact of eastward long haul travel on diurnal variations in cortisol, psychological sensations and daily measurements of physical performance. Methods: Five elite Australian skeleton athletes undertook a long haul eastward flight from Australia to Canada (LH travel), while seven elite Canadian skeleton athletes did not travel (NO travel). Salivary cortisol was measured on awakening, 60 min and 120 min after awakening. Psychological sensations were measured with a questionnaire, and maximal 30 m sprints were performed once a day between 09:30 and 11:00 h local time. Results: Compared with baseline, average (SD) resting salivary cortisol decreased by 67% immediately after long haul travel (23.43 (5.71) nMol/l) (mean±90% confidence interval) in the LH travel group (p = 0.03), while no changes were found in the NO travel group (p = 0.74). There were no significant differences in 30 m sprint time between baseline and post-flight tests in the LH travel group (p>0.05). The LH travel group perceived themselves as jet lagged for up to 2 days after the flight (p = 0.01 for both midday lunch and evening dinner). Conclusions: Despite a distinct phase change in salivary cortisol rhythmicity and the athletes perceiving themselves as jet lagged, minimal disturbances in one-off maximal sprinting ability between 09:30 and 11:00 h local time were seen in a group of elite skeleton athletes after long haul eastward travel from Australia to Canada.
Title: Effect of Long Haul Travel on Maximal Sprint Performance and Diurnal Variations in Elite Skeleton Athletes

Key Words: Circadian Dysrhythmia, Time Zones, Elite Athletes, Salivary Cortisol
ABSTRACT

The aim of this study was to quantify the impact of eastward long haul travel on diurnal variations in cortisol, psychological sensations and daily measurements of physical performance. Five elite Australian skeleton athletes undertook a long haul eastward flight from Australia to Canada (LH_travel), while seven elite Canadian skeleton athletes did not undertake any travel (NO_travel). Salivary cortisol was measured on awakening, 60 min and 120 min after awakening. Psychological sensations were measured with a questionnaire and maximal 30-m sprints were performed once per day between 09:30 - 11:00 h local time. Compared to baseline, average resting salivary cortisol decreased by 67 % immediately following long haul travel (23.43 ± 5.71 nM) in the LH_travel group (p=0.03) while no changes were found in the NO_travel group (p=0.74). There were no significant differences in 30-m sprint time between baseline and post-flight tests in the LH_travel group (p>0.05). The LH_travel group perceived themselves as ‘jet-lagged’ for up to two days post-flight (p=0.01 for both midday lunch and evening dinner). Despite a distinct phase-change in salivary cortisol rhythmicity and the athletes perceiving themselves as “jet-lagged” we observed minimal disturbances in ‘one-off’ daily maximal sprinting ability between 09:30 – 11:00 h local time in a group of elite skeleton athletes after long haul eastward travel from Australia to North America.

Key Words: Circadian Dysrhythmia, Time-Zones, Elite Athletes, Salivary Cortisol
INTRODUCTION

Elite athletes tend to undertake multiple extensive flights to North America, Europe, Asia and Australia for both competition and training raisings the issue of whether ‘jet-lag’ affects performance and if so, for how long. Circadian dysrhythmia,[1] more commonly known as jet-lag, affects individuals who travel rapidly across three or more meridian time-zones.[2] It arises from transient desynchronization of the body clock, where a temporary mismatch arises between the timing of the endogenous circadian oscillator and biological rhythms. The main symptoms of jet-lag have been defined as feeling tired in the new local daytime but unable to sleep at night, less able to concentrate and/or motivate oneself, and decreased mental and physical performance.[3] These symptoms persist until the rhythms adjust to the new environment.[3-6] The major factor determining the time for resynchronization is the number of time-zones crossed during the flight.[7]

Since circadian rhythms are driven internally following rapid transmeridian travel, optimal athletic performance may depend upon the time of competition relative to the circadian system.[8] Peak performance in grip strength, minimal fatigue, maximal oxygen uptake and neuromuscular coordination are in parallel to the normal circadian ‘rhythms’ acrophase of body temperature which occurs between 1600 – 2000 h.[9] Enhanced performance in laboratory based tests was found in evening sessions compared to morning sessions in swimming and 30 s anaerobic capacity and 5 s peak power in a modified Wingate test.[10-13] Forty meter sprint time in elite women hockey players crossing six time-zones in a westward direction from Australia to Europe was significantly slower on days four and six post-flight compared to pre-flight times. By day eight performance had recovered to be similar to pre-flight values.[14] Alterations in the mood states of vigor and fatigue have been noted on the first day post-travel in elite women soccer players flying westward from the west coast of the USA to Taiwan crossing eight time-zones.[15]

Therefore, the aim of this study was to quantify the impact of long haul eastward jet travel from the east coast of Australia to the west coast of Canada (resulting in an 8 h time difference) on diurnal variations in cortisol, feelings of wellness and daily measurements of physical performance in elite skeleton athletes.
METHODOLOGY

Participants

Twelve national team skeleton athletes (4 Olympians, 1 Junior World Champion, 4 World Cup athletes and 3 America’s Cup athletes) volunteered to participate in this study and had been training consistently in a structured elite program for a minimum of 12 months (Table 1). Five skeleton athletes were from Australia (four female and one male; LH_{travel}) while seven were residents of Calgary (six female and one male; NO_{travel}). All participants were informed of the procedures to be employed and gave their written consent before participation. The study was conducted with ethical approval from the Australian Institute of Sport. All Australian athletes had traveled overseas on long haul flights on numerous occasions for competition.

Table 1: Subject characteristics (mean ± stdev)

<table>
<thead>
<tr>
<th></th>
<th>Age (yrs)</th>
<th>Height (cm)</th>
<th>Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LH_{travel} (n=5)</td>
<td>24.7±6.0</td>
<td>169.7±4.6</td>
<td>70.2±11.7</td>
</tr>
<tr>
<td>NO_{travel} (n=7)</td>
<td>31.2±6.9</td>
<td>170.8±8.4</td>
<td>70.9±12.4</td>
</tr>
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LH_{travel} = athletes who undertook long-haul eastward jet travel. NO_{travel} = athletes who did not undertake any jet travel or time zone changes.

The first flight left Canberra, Australia at 06:50 h local time with Australian athletes changing flights four times, crossing the International Date Line and arriving in Calgary, Canada at 13:50 h local time. The travel period lasted for a total of 24 h. Athletes were requested to refrain from sleep medication during the flights and throughout the duration of the study. All athletes underwent similar training, eating and sleeping schedules as they all shared rooms, ate together at the same restaurants and underwent similar training sessions at the same time of day.
Diurnal Variation

Diurnal variations in the LH_travel group were monitored over 13 days. Baseline testing occurred two days before flying (days -2 and -1). On awakening or 06:45 h local time – which ever occurred first (Canada 06:45 h corresponded to 22:45 h Australia EST), athletes provided a saliva sample which was immediately frozen and later analyzed for cortisol. The maximum time difference between awaking and being woken at 06:45 h was 20 min. Athletes were asked to produce a midstream urine sample on awakening to assess hydration status. Urine samples were analyzed within the hour using a digital urine refractometer (UG1, Atago, Tokyo). Further salivary sample were collected at 60 and 120 min post awakening, also for the determination of salivary cortisol. The awakening, 60 min and 120 min values were averaged to give a single value. During the 3 h salivary sampling period athletes were asked to drink only water, to abstain from drinking 10 min before sampling and to refrain from eating and brushing their teeth. Saliva and urine were collected on days -2, -1, 1, 2, 4, 7, 9 and 11. All salivary samples were completed by 09:00 h local time. The LH_travel athletes underwent similar light exposure, waking cycles and dietary habits in the baseline, travel and post-travel periods.

Jet Lag Questionnaire

The Liverpool John Moores University jet-lag questionnaire was used as previously described by Waterhouse et al. [16] The LH_travel group filled in the questionnaire before breakfast (~09:00 h local time), lunch (~13:30 h local time) and dinner (~18:30 h local time) on days -1, 1, 2, 4, 7, 9, and 11. The questionnaire looked at subjective ratings of jet-lag, sleep duration and quality, ratings of feelings, concentration, motivation, irritability, hunger and tiredness. The NO_travel group filled out the questionnaire on days two and nine.

Physical Tests

Maximal 30-m sprints were carried out once on days -2, -1, 1, 2, 4, 7, and 10 between 09:30 h and 11:00 h local time (09:30 h Canadian time was 01:30 h Australian time). Ambient temperature and relative humidity in Australia was 11 °C and 70 % and Canada 16 °C and 50 %. A sprint competition warm-up was replicated at the beginning of every testing session and involved aerobic activity to elevate muscle temperature followed by stretching, bounding, jumping and two 30 m accelerations at 90 % effort. Following the warm-up two 30-m maximal sprints were carried out (5 min recovery
between sprints). Splits were measured at 5, 10, 15, 20, 25 and 30 m and recorded to the nearest 0.01 s using a laser device focused on the bottom of the athletes back by an experienced operator (LaVeg, 300c, Jenoptick, Germany). All athletes commenced the sprints with a two-point standing start in a stationary position 1 m before the start line. Athletes were instructed to hold the start position for a few seconds prior to starting and to continue accelerating past the 30 m mark to achieve maximal velocity in minimal time over 30 m. All sprints were conducted at an indoor running track. The fastest 30-m sprint time was used for analyses.

The NOtravel athletes underwent the same physical test on day 2 and day 9 only, as these athletes were involved in a respective national team training camp. The NOtravel athletes were tested on a synthetic outdoor track between 10:00 h – 11:30 h (15 °C, 2 m.s⁻¹ wind speed) during a national team testing session. Before the session the NOtravel athletes had given saliva samples on awakening, 60 min and 120 min post awakening. As these athletes were not living on site they did not present to the laboratory, but were asked to freeze the saliva sample immediately following collection and store the urine sample at 2 to 8 °C. [17] Urine and saliva samples were returned to the investigators with the urine analyses occurring ~ 4 h after the sample collection. Saliva samples were kept frozen (-5 to -10 °C) until analysis.

Throughout the testing period immediate feedback was given to the athletes and individual’s results from each test were communicated to the entire group. This was intentional to encourage competition between athletes.

Methods of Analysis

Unstimulated whole mixed saliva was collected by passive drool into a commercially available 6 ml tube. Athletes were in a seated position and were requested to provide saliva over a 3 min period. Samples were immediately frozen at -20 °C and later transported to Australia on dry ice. Samples remained frozen until analysis.

Salivary cortisol was measured using a commercially available luminescence immunoassay (IBL Hamburg, Germany) according to the manufacturer’s instructions. Saliva samples were thawed at
room temperature before centrifugation at 5000 rpm and 4 °C for 5 min to remove any particulate matter. All samples were analyzed in duplicate and results accepted if the coefficient of variation between the duplicates was <10 %. All samples from individual subjects were analyzed on the same plate. A series of six standards ranging in concentration from 0.0 – 110 nM and two quality controls were included on each plate. Briefly, 20 μL of saliva was incubated with 100 μl of enzyme conjugate in a microtitre plate for 3 h at room temperature. The wells were then washed four times before the addition of 50 μl of substrate solution to each well. The luminescence units were then counted using a Victor³ 1420 Multilabel Counter (PerkinElmer, Massachusetts, USA). Cortisol concentrations in samples were determined by extrapolation against the standard curve using Workout 2.0 Software (Dazdaq Ltd, East Sussex, England). The limit of detection for salivary cortisol was 0.41 nM. The inter-assay variability was 3.4 % for high (~32 nM) and 10.7 % for low (~4.5 nM) controls respectively.

Data Analysis

All analyses were performed using Statistica for Windows version 5.5 (StatSoft Inc., Tisa, USA). Results are expressed as the mean ± 90 % confidence intervals. Cortisol, 30 m sprint and urine specific gravity on day -2 and -1 were averaged to give an overall baseline result (day 0). Paired t-tests were used to compare the effect of travel against the baseline value. Statistical significance was set at p=0.05. The within-subject standard deviation was calculated by using the standard deviation of the difference between the two baseline days for the LH_travel divided the square root of two (SD_within = Stdev Δ / v2) [18]. The two testing sessions (days 2 and 9) were used to calculate the SD_within for the NO_travel group.

RESULTS

Diurnal Variation

Figure 1 shows the daily salivary cortisol concentrations for individual athletes and the average of the LH_travel group. The SD_within was 4.4 % for the LH_travel group and 7.9 % for the NO_travel group. The salivary cortisol concentrations significantly decreased in the LH_travel group by 67 % day 1 post-flight compared to baseline (p=0.03). Two days post-flight concentrations remained suppressed by 47 %
compared to baseline values, although this difference was not significant (p=0.17). No significant differences were found between salivary cortisol on days 4, 7, 9 and 11 when compared to baseline (p>0.05). No differences were found in mean salivary cortisol between the two samples collected from the NO_travel group (18.29 ± 2.44 and 19.15 ± 3.42 nM; p=0.74).

Insert Figure 1 about here

Sprinting Parameters

The post-travel 30-m sprint time in the LH_travel group was not significantly different compared to baseline values (4.12 s ± 0.08; SD_within 0.19 %). For the NO_travel group the average sprint times (4.44 s ± 0.22; SD_within 0.40 %) were significantly different between the two trials, with performance decreasing by 2.5 % (p=0.05). The sprints were further analyzed in five meter splits with the 0 - 5 m segment discarded from this analysis as it was deemed unreliable due to the high variability between athletes running styles (changes in the position of the upper body during the start). For all other splits no significant difference were found when compared to the pre-travel test (p>0.05).

Insert Figure 2 about here

Urine Specific Gravity

No significant differences were found in urine specific gravity for the LH_travel group on any day post-flight (average 1.02 ± 0.01; SD_within 0.02 %; p>0.05). No significant differences were found between samples in the NO_travel group (1.02 ± 0.01; SD_within 0.12 % p=0.64).

Questionnaire Results

Before lunch (~13:00 h local time) and dinner (~18:30 h local time) the LH_travel group rated themselves jet-lagged on days 1, 2 and 4 compared to baseline (p<0.05). In addition, before lunch on day 7 the LH_travel group still rated themselves as jet-lagged (p<0.05). Before dinner on day 11 the LH_travel group were feeling ‘better’ and less irritable compared to baseline (p=0.02; p=0.04
respectively). No differences were seen in hunger, motivation, concentration and tiredness for the LH_{travel} group, while no significant differences were found in any of the Canadian athletes (NO_{travel}).

DISCUSSION

The present data indicate that the abrupt time-zone change in the LH_{travel} group disrupted the normal cortisol circadian rhythm. Although athletes perceived themselves as “jet-lagged” we did not observe any detrimental effects of eastward long haul travel on maximal 30-m sprinting. By establishing rigorous baseline values, a competitive environment and using ‘elite’ status athletes, the current study addresses many previously identified limitations of existing 'jet-lag' studies. [2]

Cortisol baseline values were comparable to those previously reported in healthy subjects.[19] On day one post-flight the salivary cortisol concentrations were similar among all athletes in the LH_{travel} group as demonstrated by the small confidence interval. However, during the first four days post-flight salivary cortisol concentrations varied to a greater extent between individuals as shown by the larger confidence interval. These findings suggest rates of resynchronization of the circadian rhythms differed between athletes. This is in accord with findings of 1.7 - 6.0 days for complete resynchronization following eastward air travel across six time-zones.[20] In the current study, only on the 9th day post-flight were the mean and 90 % confidence intervals similar to baseline levels, which suggest that the resynchronization process had been completed. These results are in keeping with the estimates of one day needed for each time-zone crossed to readjust the circadian rhythms to the new environment.[7]

Non-significant differences were found in 30-m sprint times pre- and post-travel for the LH_{travel} group. Similarly, no diurnal variations were found in peak and mean power, as determined by a Wingate test. [21] Yet, in the same study the stair run and standing broad jump tests exhibited weak circadian rhythmicity.[21] The rhythms in performance of the stair run and broad jump were low in amplitude, however the 2 – 3 % variation would have marked effects in competition.[21] Conversely, sprint times slowed by 8 – 12 % in military personnel traveling westward across a six hour time-zone change.[22] However, many of the military personnel had not engaged in any
consistent physical training for 3 – 6 months before deployment, thus the increased sprint times could potentially be attributed to fatigue and muscle damage rather than jet-lag.

Nerve conduction velocity and metabolic enzyme reaction rates are all influenced by the acrophase and nadir of body temperature which in turn affects performance.[23] Therefore, it is plausible that the competition specific warm-up undertaken before each physical testing session negated any negative effects of core temperature on performance. The competition specific warm-up was used to enhance the ecological validity of the study to replicate as much as possible a competition environment and allow for the best possible performance. Reilly and Down (1992) suggested that the stair run and jumps before the Wingate tests may have inducted a sufficient warm-up stimulus to the active muscles to help override an inherent rhythm in muscle function. They also postulated that when pre-experimental warm-up is insufficient to elevate core temperature to reach the optimal level then the circadian rhythms in short term muscle performance may follow the pattern of the body temperature.[21]

No changes in motivation were reported by the athletes in the LH_travel group. The lack of change in motivation as well as the physical performance parameters could in part be attributed to the group being elite athletes. The researchers created a unique competitive environment by sharing individuals’ performance results with the entire group. What is more, the athletes in the LH_travel group were still competing against each other for places on the Australian World Cup skeleton team. By creating a competitive environment the ecological validity of this study was enhanced for athletes traveling to compete overseas in maximal intensity alactic sprinting tasks. It is possible that this competitive environment contributed to the reduced impact of the suggested negative effects of long haul travel on circadian rhythms.

Several characteristics of individuals might alter their rate of adjustment to a time-zone transition. A circadian rhythm of arousal has been shown with the acrophase ~ 11:30 - 14:00 h and the nadir ~ 03:00 h. This arousal circadian rhythm can be a major predictor of athletic performance with the acrophase coinciding with periods of highest performance. [7] Athletes have been shown to exhibit a more positive mood profile than non-athletes and are generally more extroverted and have a stable personality. [24] Therefore, it could be possible they are able to cope with the demands of
travel better than non-athletes. However, it is unknown if long-haul travel with have similar psychological consequences on athletes and non-athletes. [2]

The athletes in the LH_{travel} group perceived themselves as ‘jet-lagged’ before lunch and evening meals on days 1, 2 and 4 post flight. This pattern is similar in those flying eastwards from the UK to Australia undergoing 10 h time zone change with ‘jet-lag’ most marked on the first day post-flight and decreased thereafter but remaining significantly greater than baseline on day six.[16] The LH_{travel} group did not demonstrate any major differences in indices of concentration and hunger. This differs from a study involving eastward travel from the UK to Australia where concentration, motivation and irritability were reported as disrupted for up to four days post-travel.[16]

Unfortunately for the current study the sample size was limited due the individual nature of skeleton competition and the related small squad sizes. Therefore it is possible that the lack of change in some performance test could be a type II error.[25] Secondly, performance tests were only carried out once a day, nothing is known about how performance would be affected in the afternoon and evening. It has been suggested that short exercise durations may lead to a lack of sensitivity of jet-lag consequences and not reveal significant deleterious effects.[26] Circadian rhythms in muscular activity may not always be detectable and measurement error associated with repeated ergometric assessments is higher than the underlying circadian rhythms in muscle performance when dynamic ergometric tests are used in measurements of anaerobic power and capacity.[12] No differences were found in the questionnaire responses in the NO_{travel} group. It is also possible that the questionnaire results could be biased as it was not possible to blind athletes to travel.

In conclusion ‘one-off’ daily alactate sprinting ability between 09:30 – 11:00 h local time in a group of elite skeleton athletes was not significantly impaired by eastward long haul travel when full-warm-up procedures were followed. In contrast, salivary cortisol, displayed a typical time course response to the change in time-zones with athletes reporting being ‘jet-lagged’ for up to 7 days post-travel.
ACKNOWLEDGMENTS

Special thanks to Professor Greg Atkinson for his advice on the methodological design of this study, Dr. Jason Gulbin for his tireless efforts associated with many logistical aspects of this study. Finally, we would like to thank the Australian national skeleton coach Terry Holland and the Canadian skeleton high performance director Teresa Schlachter for their support and all of the skeleton athletes from Australia and Canada that gave maximal efforts during these trials.

Information Box

What is already known about this topic:

Optimal athletic performance may depend upon the time of competition relative to the circadian system

What this study adds:

‘one-off’ alactate sprint ability between 09:30 – 11:00 h local time in elite athletes was not impaired by eastward long haul travel when full-warm-up procedures were followed
REFERENCES


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Figure 2: Individual and mean (bold line) ± 90% CI for 30 m sprint for the long haul travel group (LH_travel)