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| **Title:**  **Authors:**  **Institutions:**  **Corresponding author:**  **Running head:**  **Abstract word count:**  **Text only word count:**  **Number of Tables:**  **Number of Figures:** | Subjective jet-lag and sleep responses and URTI symptoms following long-haul transmeridian travel in professional rugby league players.  Peter M Fowler1  Rob Duffield2  Donna Lu2  Jeremy A Hickmans3  Tannath J Scott3  1Aspetar Orthopaedic and Sports Medicine Hospital, Doha, Qatar  2Sport & Exercise Discipline Group, University of Technology Sydney (UTS), NSW, Australia  3Performance Sciences Department, Brisbane Broncos Rugby League Football Club, Brisbane, QLD, Australia  Peter Fowler  Athlete Health and Performance Research Centre  Aspetar Orthopaedic and Sports Medicine Hospital  Sports City Street, Doha, Qatar  P.O. Box 29222  T: +974 4413 2196  F: +974 4413 2020  E: peter.fowler@aspetar.com  Long-haul travel and player wellness in rugby league.  250  3492  4  2 |

**Abstract**

The present study examined the effects of 24 h travel west across 11 time-zones on subjective jet-lag, sleep and wellness responses, together with upper-respiratory tract infection (URTI) symptoms in eighteen professional rugby league players. Measures were obtained one or two days prior to (Pre), and two, six and eight days following travel (Post 2, 6 and 8) from Australia to the United Kingdom for the 2015 World Club Series. Compared to Pre, subjective jet-lag remained significantly elevated on Post 8 (3.1 ± 2.3); p<0.05, d>0.90), though was greatest on Post 2 (4.1 ± 1.4). Self-reported sleep onset times were significantly earlier on Post 2 compared to all other time points (p<0.05, d>0.90) and large effect sizes suggested wake times were earlier on Post 2 compared to Post 6 and 8 (d>0.90). While significantly more URTI symptoms were reported on Post 6 compared to Pre (p<0.05, d˃0.90), no incidence of injury and negligible changes in wellness and muscle strength or range of motion (p>0.05, d<0.90) were evident following travel. Results suggest that westward long-haul travel between Australia and the United Kingdom exacerbates subjective jet-lag and sleep responses, along with URTI symptoms in professional rugby league players. Of note, the increase in self-reported URTI symptoms is a reminder that the demands of long-haul travel may be an additional concern to jet-lag for travelling athletes. However, due to the lack of sport-specific performance measures, it is still unclear whether international travel interferes with training to the extent that subsequent competition performance is impaired.

**Keywords:** Football, international travel, jet-lag syndrome, sleep patterns, upper respiratory tract infection

**Introduction**

A common travel route for elite athletes is between Australia and the United Kingdom, requiring up to 24 h of travel across 11 time-zones. In professional rugby league, long-haul transmeridian travel is a necessity for Australasian clubs for the World Club Series, which is played annually in the United Kingdom. Long-haul transmeridian travel can induce reductions in physical performance1, sleep disruption2, negative mood states3 and a greater incidence of illness4. An athlete’s ability to recover from such travel is potentially important for ensuing competition success. Limited information on the impact of long-haul travel prior to competition on player wellness5,6, particularly in elite athletes undertaking such a well-traversed route as between Australia and the United Kingdom is available though.

As a result of rapidly crossing multiple time-zones during air travel, jet-lag symptoms may occur due to the loss of synchrony between endogenous circadian rhythms, such as body temperature and melatonin, and external cues at the destination, particularly the light-dark cycle3. One of the main reported symptoms of jet-lag is sleep disruption, with delayed sleep onset and early awakening purported to occur following eastward and westward travel respectively7. Since sleep disruption itself may induce detrimental physiological and perceptual responses, and in turn impact physical performance8, this could be one of the primary mechanisms through which long-haul transmeridian travel impedes athlete preparation. Information on the impact of an episode of long-haul transmeridian travel on jet-lag symptoms and sleep patterns in elite athletes is however limited5,6.

The demands of long-haul travel may also have a detrimental impact on athlete preparedness. A greater incidence of illness, including upper-respiratory tract infection (URTI), was reported in professional rugby union players following outbound long-haul travel across more than five time-zones4. Since return travel had no effect on illness incidence, the risk of illness may not be related to within-travel factors, but rather issues at the destination, including environmental conditions, food and exposure to different pathogens4. The microclimate of the plane and prolonged inactivity in cramped conditions during travel could result in hypohydration, fluid shifts to the lower extremity and changes in blood coagulation9. This could impact muscle strength and range of motion (ROM) and subsequently affect physical performance10,11 and/or increase injury risk12 during ensuing training/competition. However, as yet, it is unclear whether an episode of long-haul travel results in an acute increase in URTI and/or a reduction in muscle strength and ROM in elite athletes.

The aim of the present study was to examine the effects of long-haul transmeridian travel on subjective jet-lag, sleep and wellness responses, URTI symptoms and muscle strength and ROM in professional rugby league players. It was hypothesised that travel would have a detrimental impact on all dependent variables.

**Methods**

Participants

Eighteen male professional rugby league players, representing a team competing in the Australian National Rugby League competition, participated in the present study (mean ± SD; 24.2 ± 3.3 y, height 183.9 ± 4.5 cm, body mass 99.1 ± 9.6 kg). Data were collected based on procedures cleared by the institutional human research ethics committee and as part of routine sports science servicing that the players consent to as part of their team duties.

Experimental Design

Following familiarisation with all experimental measures and procedures, data were collected from players prior to and following international travel from Sydney, Australia to London, United Kingdom for the 2015 World Club Series. Specifically, measures were obtained prior to (Pre) and two, six and eight days following travel (Post 2, 6 and 8). Table 1 provides a general description of the training schedule, along with mean (± SD) training duration and load for the week prior to and following travel. The departure and arrival times were 21:50 Australian Eastern Daylight Time (AEDT) and 12:05 on the following day Greenwich Mean Time (GMT [AEDT -11h]). In total there were two flights, 25 h and 16,991 km of travel west across 11 time-zones; Flight 1 - Sydney, Australia to Abu Dhabi, United Arab Emirates (15.5 h and 12,085 km); Flight 2 - Abu Dhabi, United Arab Emirates to London, United Kingdom (7.3 h and 5478 km). Players travelled in business class for both flights. Moreover, general sleep hygiene and light exposure guidelines were provided, and 4 mg of sustained release melatonin (Aspen Pharma Pty Ltd, Sydney, NSW, Australia) was administered by the team doctor to all players during and following travel, which are recognised as ecological valid occurrences in travelling professional athletes. Specifically, following travel, light exposure and melatonin administration were timed prior to and following the circadian nadir in body temperature, which typically occurs at 05:00 in healthy young adults13, in an attempt to accelerate the phase delay in circadian rhythms required for the body clock to adjust to the new time-zone14. All players resided in the same hotels for the duration of their stay in the United Kingdom, where they were required to share rooms.

\*\*\*Insert Table 1 here\*\*\*

Experimental Procedures

*Jet-lag and Illness*

The Liverpool John Moore’s University (LJMU) jet-lag questionnaire3 was completed at a standardised time (09:00 local time) on the day prior to and two, six and eight days after travel. Following a method previously outlined15, data with a negative outcome were given a positive score and data with a positive outcome were given a negative score. These data were then summed into five categories; jet-lag, sleep, function, diet and bowel movement, with a greater overall value indicating worse symptoms (i.e. a positive number indicates a worse than ‘normal’ response and a negative number a better than ‘normal’ response). The short version of the Wisconsin Upper Respiratory Symptom Survey (WURSS-21) was also completed at the same time to assess URTI symptoms and severity16. The WURSS-21 includes one item assessing global severity, 10 items assessing symptoms, nine items assessing functional impairments and one item assessing global change. According to methods previously described17, a URTI symptom and functional impairment score was calculated for each day by summing the ratings for their respective items.

*Sleep, wellness and training load*

As part of the clubs regular training monitoring procedures, a battery of measures were collected at a standardised time (07:00 local time) two days prior to and two, six and eight days following travel. Specifically, players estimated their sleep onset and wake times, which were used to calculate sleep duration. Naps were not recorded, which is recognised as a limitation of the present study, as this is a common symptom of jet-lag and could have added to the total sleep duration reported. In addition, players rated their sleep quality (0 = insomnia, 10 = excellent) and overall wellness (0= very poor, 10 = excellent) on a Likert scale in increments of 1. An adductor squeeze, sit and reach and knee to wall test were also conducted prior to training in a rested state to assess muscle strength and ROM18-20. Players were also required to rate their level of muscular soreness in specific regions of the body on a Likert scale of 1 to 10 in increments of 1. Additional data collected two and three weeks following travel on the same day of the week as two days prior to travel and at the same standardised time was also used as baseline data, with an average of the three data points calculated. Training loads (arbitrary units [AU]) were calculated by multiplying each player’s training session or match duration (min) by their session rating of perceived exertion (CR10 scale) provided approximately 30 minutes after each training session and match21. Lastly, any injuries sustained during training were diagnosed and recorded by a full-time team physiotherapist. The definitions of injury used in the present study are similar to those used in previous research22. An injury was defined as any physical complaint sustained by a player during training that led to the player being unable to take full part in future training.

Statistical Analysis

Data are presented as mean (± SD). One-way analysis of variance (ANOVA) determined the effects of time. Where a significant effect was observed (p<0.05), a post-hoc test (Tukey HSD) was used to determine differences between means. Standardized effect size (Cohen’s d) analyses were used to interpret the magnitude of any differences, though only large effect sizes (ES; d>0.90) are reported. Analysis was performed using the Statistical Package for Social Sciences (SPSS v16.0, Chicago, IL).

**Results**

Compared to Pre, subjective jet-lag was significantly greater on Post 2, 6 and 8 (p<0.01, d˃0.90; Figure 1). Though no significant effects of time were observed for sleep, function, diet or bowel movement ratings (p˃0.05; Figure 1), large ES indicated that overall, sleep was better on Post 8 compared to Pre (d=0.90).

\*\*\*Insert Figure 1 here\*\*\*

Except for significantly less irritability on Post 6 compared to all other time points (p<0.05, d˃0.90; Figure 2), no significant effects of time were observed for sleep and function sub-scales (p˃0.05; Figure 2). However, large ES suggested that compared to Post 2, sleep onset was closer to normal on Post 6 and 8 (d˃0.90), sleep quality was better, with fewer waking episodes, on Post 2 and 8 compared to Post 6 (d˃0.90), and sleep inertia was reduced on Post 8 compared to all other time points (d˃0.90). Additionally, large ES indicated fatigue was reduced on Post 8 compared to Post 2 (d=0.96) and motivation was reduced on Post 6 compared to Pre and Post 8 (d˃0.90).

\*\*\*Insert Figure 2 here\*\*\*

Compared to all other time points, sleep onset times were significantly earlier on Post 2 and wake times were significantly later on Post 8 (p<0.05, d˃0.90; Table 2). Sleep duration was significantly greater on Post 8 compared to Pre and Post 6 (p<0.05, d˃0.90; Table 2). Large ES indicated sleep onset times were later on Post 8 compared to all other time points (d˃0.90) and wake times were later on Post 6 compared to Pre and Post 2 (d˃0.90). Large ES also suggested sleep duration was greater on Post 8 compared to all other time points (d˃0.90) and on Post 2 compared to Pre (d˃0.90). No significant differences or large ES for differences over time were observed for sleep quality (p˃0.05, d<0.90).

\*\*\*Insert Table 2 here\*\*\*

Significantly more URTI symptoms were reported on Post 6 compared to Pre (p<0.05; d˃0.90; Table 3), and large ES indicated they were also greater compared to Post 2 and 8 (d˃0.90). Large ES also suggested that URTI severity and functional impairment were greater on Post 6 compared to Post 2 (d˃0.90; Table 3).

\*\*\*Insert Table 3 here\*\*\*

Compared to Pre (6.9 ± 0.9), no significant differences (p˃0.05) in wellness were observed on Post 2 (6.9 ± 1.0), 6 (6.4 ± 1.6) or 8 (7.3 ± 0.9). However, large ES indicated that wellness was reduced on Post 6 compared to Post 8 (p=0.11; d=1.02). No significant differences or large ES for differences over time were detected for muscle strength, ROM or soreness measures (p˃0.05, d<0.90; Table 4). Compared to the week prior to travel, total training load was significantly reduced (p=0.01, d=2.31; Table 1) and large ES suggested total training duration was also reduced (p=0.06, d=0.92; Table 1) during the week following travel. No incidences of injury were recorded following travel.

\*\*\*Insert Table 4 here\*\*\*

**Discussion**

The present study examined the effects of 24 h westward travel across 11 time-zones on subjective jet-lag, sleep and wellness responses, URTI symptoms and muscle strength and ROM in professional rugby league players. Subjective jet-lag was still elevated on day 8 post-travel (Figure 1), which differs from the estimated timelines inferred from chronobiology, suggesting full adjustment would be evident by day 57. Self-reported sleep/wake patterns, but not quantity or quality, were disrupted on the first night of arrival, though were returned to normal by day 5 (Table 2). Despite no change in muscle strength, ROM or soreness (Table 4), URTI symptoms were exacerbated on day 6 post-travel (Table 3). While long-haul westward transmeridian travel may reduce player preparedness and increase URTI risk, it remains unclear as to the impact on subsequent training performance.

The present results indicate that while subjective jet-lag was highest on day 2 and decreased thereafter, it was still elevated on day 8 compared to Pre. Previous data indicates jet-lag symptoms were negligible on day 6 following long-haul travel east across 10 time-zones from the United Kingdom to Australia3. Based on estimated rates of circadian rhythm adaptation being half a day per hour of the time difference westwards and one day per hour of the time difference eastwards7, it is presumed jet-lag symptoms would be negligible on approximately day 5 and 10 following travel in the present and aforementioned3 studies, respectively. Despite such predictions, the noted differences between estimated and real-world travel responses may result from discrepancies between physiological circadian rhythm shifts and overt jet-lag symptoms. It is therefore recognised as a limitation of the present study that circadian rhythms in body temperature and/or melatonin were not assessed to confirm their rate and direction of adjustment. Jet-lag symptoms are estimated to be worse the greater number of time-zones crossed7. Yet, subjective jet-lag was also elevated for five days following long-haul air travel north across just one time-zone6. Though the authors suggested jet-lag may have been misinterpreted as fatigue from sleep disruption and competition6. A strong correlation between subjective jet-lag and fatigue has previously been identified, together with early waking and increased sleep inertia being associated with increased morning jet-lag3. Similarly, in the present study, earlier waking on Post 2 was noted at the same time as the highest morning jet-lag, whilst reduced fatigue and sleep inertia were both evident on Post 8 alongside reduced morning jet-lag. Considering these responses, and the potential impact of athletes training schedules on sleep and fatigue23, subjective jet-lag may have been elevated for longer than estimated in the present study due to combined travel and training demands.

Since there is considerable evidence for the recuperative nature of sleep27, from an athletic perspective, sleep disturbances following travel could impair preparation for ensuing training and competition. Sleep is regulated by body temperature and melatonin circadian rhythms, in synchrony with the light-dark cycle25. When a loss of synchrony occurs between these endogenous rhythms and the light-dark cycle following long-haul transmeridian travel, sleep is therefore likely to be disrupted2,26. Delayed sleep onset and early waking are purported to occur following eastward and westward travel, respectively7, though this may not be a uniform response2,26. In the present study, self-reported sleep onset and wake times were earlier on the first night following arrival. Indeed, players woke at a similar time at baseline for a 07:00 training start as they did for an 11:00 start on day 2. A plausible explanation for earlier sleep onset times on the night of arrival could be an increased homeostatic drive for sleep as a result of sleep disruption during travel, which may override any sleep disturbances from circadian influences over the first few days following arrival28. However it is recognised as a limitation that sleep was not recorded during travel in the present study, especially as it is feasible that sleep disruption may be reduced in business compared to economy class, despite the lack of evidence to support. It is also acknowledged as a limitation that sleep was monitored subjectively, since discrepancies between subjective and objective sleep measures have been reported29. Indeed, in contrast to the present study, sleep onset and waking determined via actigraphy were delayed for five days following long-haul air travel west across 8 time-zones2. The participants in this particular study may have gone to bed and woke later than usual as they had no commitments on some of those days2. Similar to the present study, no effect of travel on sleep quantity or quality was evident2. Considering the limited baseline and lack of measures on day 3, 4 and 5 in the present study, it is difficult to ascertain whether the sleep-wake cycle returned to normal by day 5 as expected. A later wake time and greater sleep duration was reported on Post 8, which is probably due to the later training start (12:00) and again highlights the difficulty in distinguishing the impact of travel within the context of training demands in athletes. Despite these limitations, the present study provides novel information on the effects of long-haul transmeridian travel on sleep patterns in elite athletes.

Compared to sedentary populations, athletes may be at an increased risk of illness following international travel as a result of compromised immune function due to intensive training30. Compared to pre-travel, a greater number of affected players and URTI symptoms were evident on day 6 following travel in the present study. Limited information currently exists on the effect of long-haul transmeridian travel on illness in elite athletes. In the only other known study, outbound international air travel across more than five time-zones was associated with a 2 - 3 fold increase in the incidence of all illness in professional rugby union players4. However, the incidence of illness following return travel was similar to baseline, suggesting the risk of illness may not be directly travel-induced, but rather due to factors associated with the destination, such as environmental conditions, food or exposure to different pathogens upon arrival4. Since the present study was conducted in February, which corresponds to the summer in Australia and winter in the United Kingdom, one of the potential contributing factors to the acute increase in URTI reported could be the large climatic contrast between the place of departure and destination. Further research isolating the impact of travel from factors associated with the destination on all illness, including gastrointestinal illness, which together with URTI is most common following international travel4, is required to substantiate this. Despite the present study providing novel information on the acute impact of long-haul travel on URTI in elite athletes, the findings are potentially limited by a number of factors. First, self-reported symptoms do not necessarily reflect illness as diagnosed by a physician or detected by the presence of a pathogen30. It is also unclear whether these symptoms were associated with a reduction in training quality in the present study. Though, it could be speculated that since players reported feeling worse as a result of these symptoms, then performance may have been affected. Lastly, the restricted number of measures, particularly the single baseline measurement and the failure to document exposure (i.e. person days or weeks), should also be noted as limitations.

Not only is it likely that athletes will lose training days as a consequence of long-haul travel, but the enforced prolonged inactivity may also reduce muscle strength and ROM, which could also increase injury risk12. However, negligible changes in wellness and muscle strength and ROM, together with no incidence of injury were evident following travel in the present study. These findings may indicate that the effect of prolonged inactivity during long-haul travel on muscle strength and ROM may be acute and ameliorated within 24 h following arrival. Though, further research isolating the impact of prolonged inactivity on muscle strength and ROM and subsequent exercise performance is required to substantiate this. While no injuries were reported following travel in the present study, due to the experimental design, conclusions regarding the impact of travel on injury risk cannot be drawn. Instead, prospective, cohort studies are warranted to address this. Similar to the present study, negligible changes in recovery status were evident following long-haul air travel west across four time-zones in professional football players5. However, a recent study reported that compared to the week prior, total training duration and load, together with mean wellness were reduced during the week following long-haul travel north across one time-zone6. Though, rather than an effect of travel, it was suggested that the reduction in wellness was due to differences between the two weeks in training and competition schedules6. Similar changes in total training duration and load were observed in the present study, but with negligible changes in wellness, which may indicate the modified training schedule post-travel assisted with players’ recovery and preparedness for subsequent competition.

In conclusion, results from the present study suggest that subjective jet-lag and sleep responses, together with URTI symptoms could be exacerbated for up to eight days following westward long-haul travel between Australia and the United Kingdom in professional rugby league players. The acute increase in self-reported URTI symptoms indicates coaches and athletes should not only be concerned with effects of jet-lag, but also the impact of the demands of long-haul travel. It is however unclear whether these detrimental effects had an impact on players’ training quality and therefore, preparation for competition. Moreover, though the provision of sleep hygiene and light exposure guidelines, together with melatonin administration are recognised as ecological valid occurrences in travelling professional athletes, it is recognised as a limitation of the present study that there was no control group, since these interventions may have blunted travel responses.

**Practical Implications**

* Early waking was evident following long-haul westward travel, thus practitioners may consider utilising sleep hygiene interventions, particularly eye masks to block out light, to assist with re-initiating sleep onset.
* In order to reduce the risk of URTI following long-haul travel, practitioners may consider the use of interventions to enhance immune function.
* Future research may focus on the development of an athlete specific jet-lag questionnaire that takes into account the impact of training demands on subjective jet-lag symptoms.

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