Title: Effects of northbound long-haul international air travel on sleep quantity and subjective jet-lag and wellness in professional Australian soccer players.

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Abstract

The present study examined the effects of 10 h northbound air travel across one time-zone on sleep quantity, together with subjective jet-lag and wellness ratings in sixteen male professional Australian football (soccer) players. Player wellness was obtained throughout the week prior to (home training week) and the week of (away travel week) travel from Australia to Japan for a pre-season tour. Sleep quantity and subjective jet-lag were measured two days prior to (Pre 1 and 2), the day of and for five days following travel (Post 1-5). Sleep duration was significantly reduced during the night prior to travel (Pre 1; 4.9 (4.2-5.6) h) and night of competition (Post 2; 4.2 (3.7-4.7) h) compared to every other night ($P<0.01$, $d>0.90$). Moreover, compared to the day prior to travel, subjective jet-lag was significantly greater for the five days following travel ($P<0.05$, $d>0.90$), and player wellness was significantly lower one day post-match (Post 3) compared to all other time points ($P<0.05$, $d>0.90$). Results from the present study suggest that sleep disruption, as a result of an early travel departure time (08:00) and evening match (19:30), and fatigue induced by competition had a greater effect on wellness ratings than long-haul air travel with a minimal time zone change. Furthermore, subjective jet-lag may have been misinterpreted as fatigue from sleep disruption and competition, especially by the less experienced players. Therefore, northbound air travel across one time-zone from Australia to Asia appears to have negligible effects on player preparedness for subsequent training and competition.

Keywords: Football, international travel, jet-lag, travel fatigue, sleep, wellness.

Introduction

Teams that finish first and second in Australia's highest national football (soccer) competition (A-League) qualify for the Asian Champions League (ACL), which commences towards the end of the A-League season. Consequently, these teams are required to undertake international air travel of up to 11 h, 9000 km, across 1-2 time-zones to South-East Asia, in between the final matches of the A-League. Reduced physical performance, sleep disruption and negative mood states have been reported in response to long-haul transmeridian air travel of varying distance and direction[1-3]. Therefore, long-haul air travel between Australia and Asia may affect preparation for ACL and A-League matches. However, no studies have investigated the effects of Australian football teams travelling to Asia on player preparedness for subsequent training and competition.

Jet-lag symptoms result from the loss of synchrony between internal circadian rhythms and the external environment, which occurs after rapidly crossing multiple time-zones during air travel[3-5]. Conversely, travel fatigue symptoms are induced by the demands of air travel, including the travel schedule (departure, stop-over and arrival times), mild hypoxia and cramped conditions. Whilst several studies have reported the detrimental effects of long-haul air travel east and west across multiple time-zones on performance, physiological and perceptual responses[6-8], few studies have assessed the impact of long-haul air travel north and south with minimal time-zone changes. Due to minimal time-zone changes, it is presumed that travel fatigue symptoms are more likely to be present than jet-lag symptoms following air travel north and south between Australia and Asia. However, the impact of such travel is yet to be reported in football players. Results from previous research suggest that due to the travel schedule, cramped conditions and associated sleep disruption, 24 h simulated international air travel exacerbated physiological and perceptual fatigue, and suppressed intermittent-sprint performance[1]. Consequently, it is plausible that travel between Australia and Asia may negatively affect players sleep and wellness, which could compromise preparation for subsequent training and competition. Furthermore, inter-individual variation in responses to travel have been reported due to differences in age[9], suggesting travel may have a greater impact on younger, less experienced players, though this is currently unknown.

Physical performance decrements can be present up to 72 h following competitive football matches[10]. However, competition schedules often require travel to occur the day of or day after away matches, and therefore, due to the time lost, disruption of normal routines and fatigue induced by travel, the recovery process may be prolonged[11]. In addition, the prescription of training loads in the days leading into subsequent competition may be congested in order to maintain the weekly training dose, which in conjunction with impeded recovery, could reduce player preparedness. Whilst domestic air travel (~ 5 h) did not impede player recovery following A-League matches[12], the greater duration of international air travel following ACL competition (~ 10 h) could mean it has a larger impact[1]. Consequently, research investigating the effects of international air travel on player preparedness for subsequent training and competition is warranted.

Therefore, the purpose of the present study was to examine the effects of international air travel from Australia to Asia on training loads and sleep quantity, together with subjective jet-lag and wellness ratings in professional football players. In addition, the present study aimed to identify whether inter-individual variation in travel responses occurred and if so, whether player age and/or experience were determining factors.

Methods

Participants

Sixteen male professional Australian football players representing a team competing in the A-League participated in the present study; mean (95 % confidence intervals [CI]); age 27.0 (25.0-29.0) y, height 179.1 (176.2-182.0) cm and body mass 74.13 (71.49-76.77) kg. At the time of data collection, players were participating in 3-5 football-specific field-based training sessions, 1-2 recovery sessions, and 1-2 competitive matches per week. All players volunteered to participate and prior to the commencement of the study, were informed of any associated risks and provided verbal and written informed consent. The study was approved by the institutional Human Research Ethics Committee.

Experimental Design

Following familiarisation with all experimental measures and procedures, data was collected from players around international travel from Australia to Japan for a pre-season tour in preparation for ACL competition. Specifically, training load and wellness measures were obtained in the week prior to (home training week) and the week of (away travel week) travel, whilst sleep and subjective jet-lag measures were collected prior to (Pre 1 and 2), the day of and following travel (Post 1 - 5). A competitive match was played at 19:30 Japan Standard Time (JST) two days following travel (Post 2). Table 1 provides a general description of the training schedule, along with mean (95% CI) training loads for both weeks. The departure and arrival time for travel was 08:00 Australian Eastern Standard Time (AEST) and 17:00 JST, respectively. The flight was 10 h, 7800 km north, across one time-zone.

Insert Table 1 here

Experimental Procedures

Internal and External Training Load

Training loads (arbitrary units, [AU]) were calculated by multiplying each players training session or match duration (min) by their session rating of perceived exertion (sRPE) provided approximately 30 min following each training session and match[13]. During each training session and match, total distance covered (m), mean speed (m/min) and the distance covered (m) in three pre-defined categories[14], low-intensity activity (<14.4 $km.h^{-1}$); high-intensity running (>14.5 $km.h^{-1}$); and very-high intensity running (>20 $km.h^{-1}$) were determined via 5-Hz Global Positioning Satellite (GPS) devices (SPI Pro, GPSports, Canberra, Australia). For each training session and match, players wore the same individually assigned device between the scapulae in a customized harness and data was subsequently analyzed using device specific software (Team AMS, GPSports, Canberra, Australia).

Sleep

Players' sleep was monitored using self-report diaries and wrist activity monitors (Philips Respironics, Bend, OR) worn on the same wrist two days prior to, the day of and five days following travel. According to methods previously described[15], data from the diaries and activity monitors was used to determine when players were awake and asleep. Sleep duration (h), specified as the amount of time spent in bed asleep[15], was the only dependent variable derived from the data.

Jet-lag and Wellness

The Liverpool John Moore's University (LJMU) jet-lag questionnaire[8], which is based on a series of visual analogue scale questions, was completed at a standardized time (09:00) on the day of and five days following travel. Though participants were familiarized with the questionnaire prior to the study, similar to previous research[8], specific advice about the meaning of jet-lag or any of the other questions was not given. Following a method previously outlined[16], the data was subsequently pooled and summed into five categories (jet-lag and sleep, function, diet and bowel movement ratings). Furthermore, a wellness questionnaire[17] was completed approximately 60 min prior to each training session at home and away (including the away match) to assess players' fatigue, sleep quality, muscle soreness, stress levels and mood on a Likert scale from 1 to 5, in 0.5 point increments. Overall wellness was determined by summing the five scores[17]. Player wellness has been reported to be sensitive to changes in training load in an applied setting[17,18] and a useful indicator of athlete recovery and fatigue[17].

Playing Experience

To identify whether playing experience was a determining factor for inter-individual variation in responses to travel, player age, together with the number of professional first team and international appearances was obtained from the football club's official records.

Statistical Analysis

Data for each player was only included in analyses if they participated in all training sessions and playing duration was ≥45 min for the away match. Data are presented as mean (95% CI). Differences between the home and away travel weeks were assessed using a two-tailed, paired samples t-test. One-way analysis of variance (ANOVA) was used to determine the effects of time on sleep duration, subjective jet-lag ratings and player wellness during the away travel week. Where a significant effect was observed ($P<0.05$), a post-hoc test (Tukey HSD) was used to determine differences between means. Lastly, players were divided into two groups of eight based on whether they were in the upper or lower half of the team for their subjective jet-lag rating one day post travel and mean subjective jet-lag rating during the away travel week. A two-tailed, two-sample (unequal variance) t-test was subsequently used to determine whether there were any differences in age or experience between the two groups. Analysis was performed using the Statistical Package for Social Sciences (SPSS v 16.0, Chicago, IL). Furthermore, standardized effect size (Cohen's *d*) analysis was used to interpret the magnitude of differences between the home training and away travel weeks, and high and low subjective jet-lag rating groups, along with differences over time for the away travel week. Due to the amount of statistical analyses performed, only large effect sizes (ES; $d>0.90$) are reported.

Results

Total training duration and load, low-intensity activity, high-intensity running and very-high intensity running, along with mean speed were significantly greater during the home training compared to the away travel week (*P*<0.01; Table 2). Furthermore, a trend was evident for a reduction in mean daily wellness during the away travel week compared to the home training week (*P*=0.07, *d*=0.50; Table 2).

Insert Table 2 here

Sleep duration was significantly reduced on Pre 1 (day off) (4.9 (4.2-5.6) h) and Post 2 (match) (4.2 (3.7-4.7) h) compared to every other night, including the night of arrival in Japan (*P*<0.01; Figure 1). Compared to Pre 1, subjective jet-lag was significantly greater on all subsequent days (*P*<0.05; Table 3), and sleep was rated significantly worse on Pre 1 and Post 2 compared to every other night (*P*<0.05; Table 3). Function ratings were significantly worse on the day of travel compared to Post 2 and 4 (*P*<0.05; Table 3), and on Post 3 (recovery) compared to Post 2 (*P*=0.003). Diet ratings were significantly worse on the day of travel compared to Post 2, 4 and 5 (*P*<0.05; Table 3). Lastly, bowel movement ratings were significantly worse on Post 3 compared to the day of travel (*P*=0.01; Table 3).

Insert Figure 1 here

Insert Table 3 here

During the away travel week, wellness was significantly lower on Post 3 compared to all other time points, and on Post 5 compared to Post 2 (*P*<0.05; Table 3). As part of the wellness scale, sleep was rated significantly worse on Post 2 compared to all other time points (*P*<0.05; Table 3) and fatigue ratings were significantly worse on Post 3 compared to Post 2 (*P*=0.003; Table 3). Moreover, compared to Post 1 and 2, muscle soreness ratings were significantly worse on Post 3, 4 and 5 (*P*<0.05; Table 3). No significant effects of time were observed for stress or mood (*P*>0.05; Table 3).

No significant differences in age or experience were evident between players reporting a high or low subjective jet-lag rating one day post travel or mean subjective jet-lag rating for the away travel week (*P*>0.05; Figure 2). However, large ES suggested that the number of professional first team appearances was lower for players whose mean subjective jet-lag rating for the away travel week were high compared to those that were low (105 (46-164) vs. 178 (106-250); *P*=0.15, *d*=1.08).

Insert Figure 2 here

Discussion

This study examined the effects of 10 h northbound air travel across one time-zone on training loads and sleep quantity, together with subjective jet-lag and wellness ratings in professional football players. Both training load and wellness were reduced during the away travel week, which is likely due to differences in the training schedule compared to the home training week rather than the effects of travel. Furthermore, sleep duration was reduced the night before travel and following competition, which is probably a result of the early departure time and late match finish, respectively. Compared to pre-travel, subjective jet-lag was greater and player wellness was worse throughout the away travel week, which could be a result of the aforementioned sleep disruption, along with fatigue induced by competition, instead of the effects of long-haul air travel. This is feasible given only one time-zone was crossed during travel, and therefore, subjective jet-lag may have been misinterpreted as fatigue from sleep disruption and competition. Consequently, northbound long-haul air travel across one time-zone from Australia to Asia appears to have negligible effects on player preparedness for subsequent training and competition.

Total training duration and load, together with mean wellness were reduced during the away travel compared to the home training week. However, rather than an effect of travel, it is likely that these findings are due to the greater training duration at home and difference in training schedule compared to away, as a result of the competitive match. Reductions in wellness were reported up to 72 h post-match in the present study, which is similar to previous research in team sports[17,19]. Whilst the demands of air travel, particularly the mild hypoxia and cramped conditions, may temporarily augment perceptual fatigue[20], no differences in wellness were evident following home compared to away matches in the A-League[12], where domestic air travel is often required the day following away matches. Whilst travel demands for ACL matches are greater, collectively these results suggest that in the present study, instead of travel, the competitive match is more likely to explain the reduced wellness away, particularly since wellness was lower one day post-match compared to all other time points during both the home training and away travel weeks. Moreover, given a reduction in wellness following competition also requires training loads to be adjusted accordingly, the combination of a day lost to travel and recovery from competition may explain the reduced training loads away compared to at home in the present study. However, it is acknowledged as a limitation that return travel to Australia, which is typically scheduled for the day following ACL matches, didn't occur during the present study. Consequently, whether an exacerbated reduction in wellness following a match occurs due to return international travel requires further investigation.

Sleep duration was reduced the night before travel in the present study, which is likely due to an early travel departure time (08:00), as this meant the team had to arrive at the airport at ~06:00 and therefore, players were required to wake-up at ~04:00. However, sleep was unaffected the night following travel, which is contrary to the reductions in sleep quantity and quality observed for up to five days following 10 - 14 h of eastward transmeridian air travel across 7 - 11 time-zones[7,21]. These findings indicate that the loss of synchrony between the body's internal circadian rhythms and the external environment following long-haul air travel east and west across multiple time-zones has a greater impact on sleep than the demands of air travel *per se*, during long-haul air travel northbound with minimal time-zone changes. Previous research has also reported reduced sleep quantity during actual[9] and simulated[1] long-haul (24 h) air travel between Sydney, Australia and London, England. Travel between Australia and Europe often involves an evening departure time (18:00 AEST) and early morning arrival (08:00 Greenwich Mean Time), and therefore, overnight travel and stopover's (04:00 - 06:00 AEST). Thus, certain commercial flight schedules may disrupt sleep, as the timing of stopovers, meals and cabin lighting changes can enforce waking during the sleep phase of the sleep-wake cycle. Consequently, it is not surprising that sleep disruption wasn't observed during travel in the present study, as travel occurred during the day (08:00 AEST - 17:00 JST). Regardless, these results imply that the travel schedule is important, especially when travelling a few days before competition. If possible, travel early in the morning or late at night should be avoided, as travel during the day (i.e. 08:00/09:00 - 17:00/18:00) would be considered preferable, though this may not always be feasible and depends on the duration of travel together with the availability, cost and timing of flights.

Compared to pre-travel, subjective jet-lag was significantly elevated throughout the away travel week in the present study. The values reported are lower than those previously observed following long-haul eastward[16] and westward[24] air travel across five time-zones, which is likely due to the reduced number of time-zones crossed during travel in the present study, and further emphasises the greater disruption caused by long-haul air travel east and west. Considering jet-lag symptoms result from the loss of synchrony between internal circadian rhythms and the external environment, which only occurs after crossing multiple time-zones, the results of the present study are surprising, given only one time-zone was crossed during travel. Though it is presumed circadian rhythm disruption is unlikely to have occurred in the present study, it is acknowledged as a limitation that no physiological markers of circadian rhythms were measured. One of the main reported symptoms of jet-lag is poor sleep, which can subsequently induce negative perceptual changes, such as increased daytime fatigue[7,9]. Though sleep disruption occurred in the present study, as previously discussed, it is likely that this was a result of the travel and match times rather than a symptom of jet-lag. Furthermore, whilst participants were familiarized with the LJMU jet-lag questionnaire prior to the study, similar to previous research[8], specific advice about the meaning of jet-lag was not given. Therefore, it is plausible that subjective jet-lag was misinterpreted as increased fatigue caused by sleep disruption, especially by the less experienced players, which will be discussed later.

Previous research suggests that conditions during air travel, particularly the prolonged exposure to mild hypoxia and cramped conditions, may temporarily augment perceptual fatigue[12,20,25]. Whilst this should not be discounted in the present study, results indicate that the aforementioned sleep disruption may have had a greater impact on perceptual responses and masked any temporary travel fatigue. Indeed, sleep was perceived to be worse the night prior to travel and following competition, which corresponds with the aforementioned objective sleep measures, and as a result, function ratings (fatigue, concentration, motivation and irritability) were worse on the day of travel and the day following competition. Furthermore, players' wellness responses followed a similar pattern, with overall wellness, fatigue and muscle soreness still worse 72 h post- compared to pre-match. Again, these results suggest that sleep disruption and competition had a greater detrimental impact on perceptual responses than long-haul air travel in the present study.

Lastly, a trend existed for the number of professional first team appearances to be greater for players whose mean subjective jet-lag for the away travel week was low compared to those that was high. Similarly, older males and females, have previously reported lower perceptions of jet-lag and fatigue following 24 h eastward international air travel across 10 time-zones[9]. However, no differences in age were detected between players with high and low mean subjective jet-lag in the present study. Neither were the number of international appearances, which is surprising given that frequent international travel is a necessity for players who regularly represent their country and suggests greater travel experience may not reduce the impact of long-haul travel. Regardless, given the limited information available, further research is required to confirm whether any significant predictors of travel responses exist, including age and/or playing experience.

In conclusion, results from the present study suggest that northbound long-haul air travel across minimal time-zones between Australia and Asia is unlikely to affect player preparedness for subsequent training and competition. Instead, the findings suggest that sleep disruption, as a result of an early travel departure time and evening match, together with fatigue induced by competition had a greater effect on player wellness. Therefore, whilst it would be beneficial to avoid scheduling long-haul travel either early in the morning or late at night to minimize sleep disruption, it is appreciated how difficult this may be and depends on the duration of travel together with the availability, cost and timing of flights. Furthermore, results from the present study could suggest that players with greater experience were less affected by travel. However, given the limited information available, further research is required to substantiate these findings, since it could allow practitioners to highlight players with certain characteristics that indicate they may require greater support around travel. Lastly, it should be taken into consideration that the results from the present study are only a case study of one team and one travel scenario, and therefore, further research involving multiple trips and/or teams is required.

Practical Implications

- Northbound long-haul air travel during the day across minimal time-zones between Australia and Asia is unlikely to affect player preparedness for subsequent competition.
- Sleep duration was reduced the night prior to travel as a result of an early wake and departure time. Therefore, if feasible, it

would be beneficial to avoid scheduling long-haul travel early in the morning to minimize sleep disruption.

- Players with greater experience could be less affected by travel and therefore, practitioners may consider providing greater sports medicine/science support to less experienced players around travel.

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