Title: The Influence of Travel in the Home Advantage Effect.

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Travel is suggested to be an important factor within the Home Advantage effect. For away teams, the need to travel can often be disruptive to routines and results in a number of potential negative effects on preparation and performance. However, the extent to which travel is an issue for teams will differ based on the travel required, as the effects of travel result from combined effects of multiple different factors. In order to understand the potential effects of a bout of travel, it is important to understand each of the issues of circadian misalignment, jet lag, travel fatigue, and sleep loss, as all may play a role in post-travel physical and mental performance responses. Understanding the nature of these factors as well as their potential effects, may allow support staff, coaches, and athletes to limit the influence of travel on the home advantage effect. Therefore, this chapter firstly discusses the mechanisms behind circadian misalignment, jet lag, travel fatigue and sleep loss within the context of travel. Following, this chapter will report current lab and field-based research using athletic populations to identify the potential effects that travel that may contribute to the home advantage effect.

Introduction

Home Advantage (HA) represents the greater winning percentage and performance often experienced by teams at their home ground (Nevill & Holder, 1999). Understanding the factors contributing to this effect can reduce the disadvantage of competing in away environments or enhance the home advantage for home teams. Within HA, an important consideration is the effect of travel requirements on away teams, since the interrelated effects of travel fatigue, sleep disruption and jet lag may potentially impact performance (Waterhouse et al., 2004) and contribute to the HA.

Travel for athletes varies between competitions and teams, with particular concerns for international away match travel. For example, previous research on national football teams has reported travel durations of 15 h (Fullagar et al., 2016) and 19 h (Fowler, McCall, et al., 2017) across 4 and 11 time zones respectively. Conversely, teams competing in domestic competitions, have shorter but potentially more frequent travel. For example, domestic competitions often require travel durations of ≈ 2-6 h across 0-3 time zones (Fowler et al., 2014a; Fowler, Duffield, Waterson, et al., 2015; McGuckin et al., 2014). In addition, the frequent travel demands for domestic teams may result in the accumulation of travel fatigue across the season (Samuels, 2012). Thus, the extent of travel for different teams or competitions is an important influence on HA in professional sport.

The ensuing travel-induced effects on performance are dependent on the interaction between symptoms of jet lag, travel fatigue and sleep loss (Reilly et al., 2009). Rapid transition across time zones results in the misalignment between the circadian system and the new local time, negatively influencing performance (Reilly & Waterhouse, 2009). Jet lag symptoms can also indirectly affect performance through decrements in sleep, fatigue and mood (Forbes-Robertson et al., 2012). Prolonged journeys, regardless of time zone transition, may also cause travel fatigue and disrupt sleep (Waterhouse et al., 2004). Sleep loss during and after travel can add further stress and may exacerbate performance and health implications (Leatherwood & Dragoo, 2013). To understand the contribution of travel-related factors to HA, it is important to understand the mechanisms that underpin travel-induced effects on fatigue, sleep, health, and performance. This chapter will firstly discuss the mechanisms of circadian misalignment, jet lag, travel fatigue, and sleep loss. Following this, evidence for travel related reductions in physical performance, sleep and wellbeing measures will be explored through assessing current observational and experimental research.

Conditions Associated with Air Travel

Circadian Misalignment and Jet Lag

When time zone transitions are required, desynchrony occurs between the athlete's circadian rhythms and the new local time. This misalignment may cause reduced performance depending on the time of training or competition, while the symptoms of jet lag may also indirectly affect performance (Reilly et al., 2009). Circadian rhythms ensure a number of important biological functions occur in a timed manner and regulate aspects of life, such as the sleep-wake cycle (Reilly et al., 2009) and influence the timing of physical performance peaks (Reilly & Waterhouse, 2009). The body's circadian rhythms are synchronised to the external environment via a number of external cues, particularly the light-dark cycle (Reilly et al., 2009). Effects on performance and symptoms of jet lag are likely to remain until the athletes circadian rhythm has synchronised to the new local time zone; however, the time required for this to occur will vary based on the number of time zones crossed and the direction of travel, with eastward travel requiring a longer amount of time to adjust than westward (Reilly et al., 2009).

The loss of synchrony between internal rhythms and the external environment may have direct implications for human performance as circadian rhythms exist in both mental and physical performance measures (Reilly & Waterhouse, 2009). Physical performance generally peaks during the early evening and is reduced during the night and early morning (Reilly & Waterhouse, 2009).

Cognitive performance appears to follow a similar rhythm, however, more complex measures are affected by fatigue accrued from time spent awake, and as such show an earlier peak (Reilly et al., 2009). When desynchrony occurs, the internal component of a rhythm will exist at a different time relative to the new external environment; hence creating desynchrony between required behaviour patterns and the physiological/cognitive state (Reilly et al., 2009). Circadian misalignment should raise particular concern if the time of competition occurs at a low point in performance, such as the biological night or early morning (Reilly et al., 2009). Therefore, when considering the impact of time zone transition on HA it is important to be aware of the nature of circadian desynchrony at the time of performance.

While the misalignment of circadian rhythms may have direct effects on performance, the symptoms of jet lag may have their own discreet effect on the athlete's preparation and performance. Following rapid time zone transitions after long-haul air travel, symptoms of jet lag can include, sleep disruption, exacerbated daytime fatigue, reduced alertness and motivation, irritability, headaches, and gastrointestinal upset (Forbes-Robertson et al., 2012; Leatherwood & Dragoo, 2013). Such symptoms are likely to impair an athlete's mental wellbeing and preparation for competition, which could therefore affect physical and mental performance (Duffield & Fowler, 2017). Given the symptoms of jet lag may further contribute to the disadvantage experienced during an away match, focus should be on treating the symptoms of jet lag in addition to the realignment of circadian rhythms.

Travel Fatigue

Travel fatigue relates to any form of prolonged transport and involves feelings of fatigue, disorientation, headaches and weariness that occur as a result of the journey itself (Weingarten & Collop, 2013). Unlike jet lag, symptoms of travel fatigue are expected to be overcome quickly once the traveller has settled into their new environment (Waterhouse et al., 2004). The causes of travel fatigue can involve a number of factors, including disruption to sleep, stresses associated with the journey and the conditions of travel (Waterhouse et al., 2004). Furthermore, travel may disrupt an athlete's normal sleep routine (Weingarten & Collop, 2013) or restrict an athlete's time to train or undergo recovery sessions. As such, long-haul travel requirements may disrupt sleep and preparation and therefore reduce performance when playing away from home.

While travel fatigue is not specific to air travel (Reilly et al., 2009), commercial air travel poses its own unique concerns. Due to the pressurisation of cabin air, time spent on aircraft can be likened to time spent at altitude with hypoxic conditions, which can place additional physiological stress on the athlete (Leatherwood & Dragoo, 2013). Further, the dry cabin air and close contact with other passengers may also contribute to greater illness rates post-flight (Schwellnus et al., 2012), although, evidence suggests this may be more closely linked to changes in environmental conditions (Schwellnus et al., 2012). Seating arrangements on aircraft can also add to feelings of discomfort and the prolonged periods in cramped conditions may cause stiffness and increase the risk of thromboembolism (Reilly et al., 2009). Accordingly, the conditions associated with air travel may impair the wellbeing and preparation of athletes travelling to away matches and thus place them at greater disadvantage.

Sleep Loss

When travelling, sleep quantity and quality can be impaired both during and after the journey which may have implications for performance (Weingarten & Collop, 2013). During travel, the uncomfortable conditions of aircraft seating, bright cabin lights, exposure to mild hypoxia, and noise levels are all likely to make sleep difficult during the journey (Weingarten & Collop, 2013). Therefore, journeys that occur during normal sleep periods are likely to impact the amount and quality of sleep an athlete attains on the day of travel. Sleep may also be disrupted on the days surrounding each trip if early departures or late arrivals are required. When time zone transitions occur during travel, the misalignment of circadian rhythms may impair sleep for several days following arrival. For example, for sleep to be consolidated, a reduction in body temperature and an increase in melatonin levels are required (Reilly et al., 2009). Such events normally occur prior to sleep onset, though, following a time zone transition, the timing of these events becomes misaligned resulting in difficulty initiating sleep in the evening following eastward travel and early awakening following westward travel (Waterhouse et al., 2004). Such effects on sleep may remain until the athlete has fully adjusted to the new time zone. Overall, for teams travelling short distances for away matches, travel should be planned to minimise the disruption to sleep periods where possible. However, if long distance travel is required, teams should focus on interventions that can improve sleep during travel and limit the effects of jet lag on sleep upon arrival.

Effects of Air Travel on Sleep, Performance, and Wellbeing

There are a number of potential mechanisms whereby air travel may cause reductions in performance, wellbeing, and sleep and thus contribute to HA. Regardless of the cause, inferior outcomes have previously been observed across a number of sports when athletes are playing away from home (Nevill & Holder, 1999). However, it is often unclear whether such effects can be attributed to direct decrements in physical and mental performance from travel or resulting from other factors related to HA. As such, a number of studies have attempted to explore the direct effects of travel on individual measures of sleep, performance, wellbeing, and mood. Therefore, the next section of this chapter will summarise current key findings from experimental and observational research on the effects of travel on athletes and discuss the respective influence of jet lag, travel fatigue and sleep loss.

Sleep

Sleep loss during or following travel has the potential to negatively affect athlete wellbeing, recovery, and both mental and physical performance (Fullagar et al., 2015). Several studies have reported reduced sleep durations on the day of travel, likely related to the difficulties of attaining sleep in aircraft cabin conditions (Fowler et al., 2014b; Fowler, McCall, et al., 2017; Fullagar et al., 2016; Lastella et al., 2019; Stevens et al., 2018). However, travel that does not occur during normal sleep periods appears to have minimal effects on sleep. For example, Fowler, Duffield, Howle, et al. (2015) observed unchanged sleep upon arrival in football players undertaking a 10 h northbound journey that did not require overnight travel. Similarly, interstate travel by Australian Football Players had negligible effects on sleep measures in the evening following arrival (Richmond et al., 2004; Richmond et al., 2007). Thus, when considering the effects of travel on sleep, the timing of the flight relative to normal sleep periods should be considered, as teams may be disadvantaged by poorer sleep when travelling to away matches and strategies to improve sleep during the journey are essential.

Disruption to the sleep-wake cycle is a common symptom of jet lag and can last for several days after arrival (Weingarten & Collop, 2013). Sleep onset and wake times are expected to be earlier following westward travel and later following eastward travel (Weingarten & Collop, 2013). Field-based studies have found negligible effects of jet lag on sleep following westward shifts of 5 h in national team footballers (Fullagar et al., 2016) and 11 h in professional rugby league athletes (Fowler et al., 2016). However, a number of studies have observed effects of time zone transitions on sleep. For example, later sleep onset and reductions in sleep duration have been observed following eastward travel with an 8 h time difference (Fowler, Knez, et al., 2017). Reductions in sleep quantity and quality caused by early awakening were observed for 5 days following travel in national football players after an 11 h eastward time zone shift (Fowler, McCall, et al., 2017). This suggests that the manner in which time zone transitions impact the sleep-wake cycle is affected both by the direction of travel, and the number of time zones crossed. Accordingly, for teams that are required to travel across multiple time zones for away matches, changes in sleep patterns may be expected and may contribute to the HA effect.

Effects of Sleep Loss on Performance

Sleep loss from travel can have important implications for athlete wellbeing and performance (Fullagar et al., 2015), and thus contribute to poorer away team performance. Varying impacts of acute sleep loss have been reported across measures of both aerobic power and muscular strength, with separate studies reporting no changes or reductions, respectively (Fullagar et al., 2015). There appears to be a greater potential effect of sleep loss on prolonged bouts of exercise, (Fullagar et al., 2015; Watson, 2017), while maximal one-off efforts, particularly relating to maximal strength, appear less affected. It is also unclear as to the extent to which changes in performance following sleep loss can be attributed to losses of motivation caused by sleep deficits as opposed to direct physiological effects (Fullagar et al., 2015). In addition to the effects on physical performance, acute reductions in sleep will likely reduce cognitive function in areas such as decision making, memory, alertness and reaction time, all of which could impact training and performance in some sports (Fullagar et al., 2015). Considering these effects of sleep loss on sports performance, potential reductions in sleep caused by the travel requirements of away teams are likely to add to HA.

Physical Performance

Speed and Power

Following extensive travel demands, reductions in speed and power measures have been observed (Chapman et al., 2012; Fowler, Duffield, Morrow, et al., 2015; Fowler, Knez, et al., 2017). Reduced countermovement jump height was observed on the only the first day following arrival from a 24 h eastward trip across 8 time zones in national skeleton athletes (Chapman et al., 2012). While testing occurred at roughly 01:00 body clock time on that first day, more prolonged reductions in jump height would be expected if circadian misalignment was the sole cause. Instead, it may be that sleep disruption and prolonged inactivity incurred by the long duration flight may have influenced the results; though, as sleep was not measured in this study, the extent of its influence remains speculative. Similarly, reductions in countermovement jump height and maximal sprint speed were observed in physically trained males for two evenings following 24 h of simulated travel, while reduced sleep and elevated levels of perceptual strain and fatigue were also reported (Fowler, Duffield, Morrow, et al., 2015). In addition, Fowler, Knez, et al. (2017) found reductions in countermovement jump performance and maximal sprint performance to occur following both eastward and westward trips of 17 h across 8 time zones. As the authors noted, if circadian misalignment were expected to be the cause of such reductions, differences would exist between morning and evening testing times. Given such an effect was not present, it is likely that the reductions in speed and power resulted from other factors such as sleep loss and fatigue caused by the long duration flight. As many sports require fast and explosive actions, reductions in speed and power caused by travel to away matches may contribute to poorer performance when playing away from home.

In contrast to the above, several studies have identified a lack of effect of travel on speed and power measures (Broatch et al., 2019; Bullock et al., 2007; Everett et al., 2020; Fowler et al., 2014b). No changes in 30m sprint performance were reported by Bullock et al. (2007) in national skeleton athletes following 24 h of travel across 8 time zones. However, testing only occurred once per day and the first testing session occurred on the day after arrival, potentially allowing a full sleep before testing. It should also be noted, that in a separate study using the same population group, reductions in jump performance were observed. This may suggest that the effect of travel on speed and power may differ based on the specific measure used and the sensitivity of the testing protocol. In a study by Broatch et al. (2019), no changes in countermovement jump from baseline measures were reported in volleyball athletes travelling for 12 h across 2 time zones. It could be suggested that this lack of change may be related to the shorter 12 h travel duration and -2 h time zone change. However, as neither the timing of the flight nor the sleep of the athletes was reported, further research is required to confirm this. Furthermore, variation in outcome measures may also be expected based on the training and competition load before and after travel; as an example, Everett et al. (2020) suggested a 30 h journey across 9 time zones acted as a period of reduced load compared to pre-travel in elite rowers and thus caused a slight increase in countermovement jump height. In conclusion, reductions in speed and power that may occur in travelling athletes are likely to reduce performance when playing away from home and thus contribute to the HA effect. It is therefore important that travelling teams consider the use of interventions targeted towards improving sleep and accelerating circadian adaptation to limit reductions in speed and power.

Endurance and Intermittent Sprint Performance

Athletes may be disadvantaged if travel to an away competition was to cause reductions in endurance or intermittent sprint ability. Currently, three studies have investigated the effects of travel on intermittent sprint performance (Fowler, Duffield, Morrow, et al., 2015; Fowler et al., 2014b; Fowler, Knez, et al., 2017). Reduced intermittent sprint performance was observed by Fowler, Knez, et al. (2017) for 2 days following 21 h of travel across 8 time zones in the eastward return trip; however, no reductions were observed following the westward outbound trip of the same study. This is despite the timing of testing occurring at a worse circadian time following the westward compared to the eastward trip. As sleep was reduced on the first 3 days following the eastward trip, it is likely that reductions in sleep and resulting increases in perceptual fatigue may explain this effect. Similarly, reduced intermittent-sprint performance was observed in the afternoon on the day following 24 h of simulated travel (Fowler et al., 2014b). Given that the time of testing was the same for baseline and post-travel measures, it is unlikely that this reduction is explained through natural circadian variation and may be a result of sleep loss and subsequent fatigue. Furthermore, as intermittent sprint performance was not affected during the morning testing session, the accumulation of sleep debt as a result of the morning arrival may have caused greater reductions in performance in the afternoon session. Interestingly, Fowler, Duffield, Morrow, et al. (2015) found intermittent sprint performance to remain unchanged following 24 h of simulated travel in physically trained males. While sleep was reduced during travel and perceptual fatigue and effort were elevated, these effects did not translate into reductions in intermittent sprint performance. This is despite similar simulated travel conditions and experimental protocols as those used in the earlier study that reported reduced intermittent sprint performance (Fowler et al., 2014b). These findings likely highlight the variation in response to travel and sleep loss that is expected between individuals and is of concern during away matches.

Jet Lag Symptoms

With the misalignment of circadian rhythms in many biological processes, athletes are likely to experience a collection of jet lag symptoms that may impair preparation and reduce overall wellbeing when travelling across multiple time zones. Therefore, in addition to the relative circadian phase, it is also important to consider the extent to which athletes experience the symptoms of jet lag. Subjective rating scales have often been used to determine the severity of jet lag symptoms an athlete experiences following travel. Studies have frequently reported elevated ratings of perceived jet lag following travel with time differences between 5-11 h (Bullock et al., 2007; Fowler, McCall, et al., 2017; Fowler et al., 2016; Fullagar et al., 2016; Kölling et al., 2017; Reilly et al., 2001; Thompson et al., 2013; Thornton et al., 2018). However, as the definition of jet lag is often not provided in these studies and increases in perceived jet lag have also been observed following travel with minimal time zone differences (Broatch et al., 2019; Fowler, Duffield, Howle, et al., 2015), it is difficult to separate whether such findings are truly related to circadian misalignment or result from misinterpretations of fatigue caused by sleep loss and the demands of travel (Fowler, Duffield, Howle, et al., 2015). In addition, the strength of the internal circadian drive can differ between rhythms and as such the severity of symptoms and rate of adaptation is likely to differ between symptoms (Waterhouse et al., 2005).

Based on chronobiological principles, jet lag ratings should last longer following a greater number of time zones crossed and following eastward compared to westward travel (Forbes-Robertson et al., 2012). However, comparing subjective jet lag responses to different travel bouts observed in different studies is difficult due to variation in the study methodology and participants. Currently, only two studies have sought to compare subjective jet lag ratings between different travel bouts. Thornton et al. (2018) compared the effects of short- (4.5 – 6.5 h duration; 1 time zone) and long-haul (10.7 – 31.0 h duration; 6 - 11 time zones) travel on perceived jetlag in wheelchair basketball athletes. As expected, athletes completing long-haul travel showed higher ratings of perceived jet lag than those in the short-haul travel group. While eastward travel is expected to produce longer-lasting jet lag symptoms than westward travel (Forbes-Robertson et al., 2012), currently only one study has provided comparisons between travel directions (Fowler, Knez, et al., 2017). The findings of this study support beliefs regarding the detrimental effects of eastward travel with more prominent and longer-lasting jet lag ratings observed following the eastward compared to the westward trip (Fowler, Knez, et al., 2017) and should be considered in treatments of jet lag symptoms contributing to HA.

Mood and Wellbeing

Perceptual Wellbeing

The combined symptoms of travel fatigue, jet lag and sleep disruption, are all likely to influence an athlete's subjective wellbeing and preparation for performance (Reilly et al., 2009). Despite some concerns, in an athletic context, wellbeing is used to define a loose collection of perceptual scales related to an athlete's fatigue, recovery, sleep, stress, soreness, and mood (Jeffries et al., 2020). Reduced wellbeing scores were observed in the week following 19 h of eastward travel across 11 time zones compared to the week prior to travel in national team footballers (Fowler, McCall, et al., 2017). Given the average training load was unchanged throughout the two weeks, it is likely that such effects may have been caused by jet lag and/or travel fatigue from the journey. Furthermore, poorer subjective sleep and elevated fatigue were present on the first day following arrival which is similar to the findings of Stevens et al. (2018), who observed elevated subjective fatigue in masters triathletes following 22.6 ± 2.4 h of travel across 2 time zones. Such findings suggest that sleep disruption caused by the long duration flight is likely to increase an athlete's perceived fatigue on the day following travel. Shorter duration travel of 10 h across 1 time zone has also been observed to reduce average wellbeing scores during an away travel week in professional footballers (Fowler, Duffield, Howle, et al., 2015). However, it was suggested that fatigue from a match may have influenced this finding rather than travel itself (Fowler, Duffield, Howle, et al., 2015).

Reductions in wellbeing ratings following travel have not been consistently reported, and a number of studies have observed a lack of change or even improvements in wellbeing measures. No changes in stress-recovery questionnaire scores were observed in national team footballers travelling westward 15 h across 4 time zones (Fullagar et al., 2016). Such findings may indicate that the 4 h westward time-zone transition was not enough to elicit symptoms of jet lag and thus affect perceptual wellbeing. Using the same stress-recovery questionnaire, Kölling et al. (2017) reported improved scores following an 11 h westward trip across 5 time zones, despite increases in perceptual jet lag ratings. While the effects of travel on wellbeing are likely influenced by numerous factors, there remains the potential for poorer wellness scores to occur following travel particularly if sleep is reduced as a result of the journey. This effect of travel may contribute to the HA effect by reducing preparedness and ability to perform.

Motivation and Mood

One of the proposed mechanisms through which jet lag, travel fatigue and sleep loss have been suggested to influence performance is through reductions in an athlete's motivation to perform (Reilly et al., 2007). Reductions in subjective motivation ratings have been observed following both eastward and westward travel of 17 h duration across 8 time zones in physically trained males (Fowler, Knez, et al., 2017), with greater reductions following the eastward trip in which reduced sleep quantity and quality were also observed. However, a sub-elite population was used and the effect of travel on motivation may not be as prominent in a motivated elite athlete population. Bullock et al. (2007) found subjective motivation to remain unchanged following 24 h of eastward travel across 8 time zones, with the authors of the study noting that a highly competitive testing environment was maintained in an ecologically valid environment. Thornton et al. (2018) reported lower vigour scores from wheelchair basketball athletes undertaking long- compared to short-haul travel. Such findings further support the view that long-haul travel is likely to cause poorer mood states in athletes. While short-haul travel appears unlikely to warrant concerns for athlete mood, teams having to travel for longer durations may be at risk of poorer mood states which could influence preparation for competition. Overall, through reductions in motivation to perform and general mood, travel may restrict the performance of away teams and thus contribute to HA.

Conclusions

While there is likely a number of additional factors that may contribute to HA, the potential negative effects of travel are an additional concern that need to be considered for away teams. For teams required to travel, circadian misalignment, jet lag, travel fatigue and sleep disruption may disrupt preparation and impair performance, thus contribute to the HA. It is important to note, that the extent to which these issues are likely to arise will differ based on the travel requirements of different competitions. Teams should therefore consider the extent and nature of travel for their own competition when assessing the need for travel related interventions when competing in away matches. If travel demands for competitions are significant, potential effects on physical performance measures such as intermittent and maximal sprint performance as well as jump performance may occur, and thus contribute to poorer performance away from home. Furthermore, symptoms of jet lag and the demands of travel itself may cause poorer sleep, mood and wellbeing, which can disrupt preparation and limit an athlete’s ability to optimise performance. Overall, the effects of travel that result from circadian misalignment, jet lag, travel fatigue and/or sleep disruption can reduce an athlete’s ability to perform and likely to contribute to HA effect.

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