Abstract

Purpose: This study investigated the relationship between travel demands and match loads on perceptual recovery, fatigue and sleep following post-match travel in national football teams. Additionally, the influence of travel demands and the time between match kick-off and travel departure on post-match recovery was examined.

Methods: Match-running load (via GPS) and travel data was obtained from 79 male national team footballers. Post-match travel duration, direction, context, time zone difference, and time between kick-off and travel departure was collated. Athletes provided perceptual ratings of fatigue, soreness, sleep, stress, and recovery from 1 day pre-match through to 3 days after post-match travel. Linear mixed models assessed the influence of match load and travel on perceptual ratings for 3 days post-travel. Additional models assessed a standardised post-match timepoint of MD+3 to determine whether timing and extent of travel influenced recovery. *Results*: Higher match-loads were associated with poorer recovery, fatigue, soreness, and sleep (p=0.001-0.032). Athletes reported poorer fatigue, soreness and recovery when travelling from national teams back to clubs compared to between national team matches ($p<0.001$). Travelling eastward was associated with poorer sleep (p=0.004). Longer periods between kick-off and travel departure were associated with poorer sleep on MD+3 (p=0.003).

Conclusions: Perceptual recovery, fatigue, sleep, and soreness following post-match travel were affected by both match load and travel demands. Greater match loads and eastward post-match travel may impair recovery. Additionally, departing later after a match was associated with poorer sleep on MD+3 due to arrival closer that timepoint, without any effect on other recovery measures.

Key Words: Travel, Jet lag, Match Recovery, Fatigue, National Team, Football

Introduction

National football (soccer) team athletes are often required to travel back to their clubs shortly after the completion of a national team match, and then be prepared to compete again for their club team within 3 days[1]. Hence, post-match travel is a concern for national football teams due to the physiological and physical stresses of travel, combined with the need to recover from match-play[1-3]. Further, travel stressors and the time required for travel may restrict time available to undertake post-match recovery and affect recovery status. The combined effects of both match load and travel requirements are likely to have significant implications on fatigue, sleep, and recovery, potentially also impacting selection for their next club match[3,4]. Understanding how match load and post-match travel influence perceived recovery, fatigue, sleep, and soreness can assist practitioners to plan for travel after both international and club matches.

International football windows are typically 9-day periods in which club football teams must release their athletes to national teams to compete in up to 2 international matches. Within these 9-day windows, players travel from clubs to national teams (often immediately after club matches), compete in 2 international matches with transition travel in between, and then return for their next club team fixture within a few days. Due to the condensed nature of these windows, athletes are often afforded only a few days to recover from both match loads and subsequent travel demands. Currently, very little research explores the combined effects of these two stresses on post-match recovery to guide subsequent player availability in any sport, but particularly for football. Kraemer, et al. [5] observed elevated blood recovery markers following a simulated team-sport match and 5h eastward trip in physically trained individuals; however, as both the travel and match load was the same for all participants, the influence of variations in these variables is unknown. Studies examining short-haul travel in Australian domestic football have reported no difference in post-match recovery [6] or perceptual wellness[7] between home and away matches, though only incorporated short-haul travel in a single club team. Further, the aforementioned studies address only a fraction of the possible travel demands a national team footballer may experience, and no studies compare the recovery responses of athletes across a broad range of travel demands. Whilst evidence exists that national team footballers report poorer perceptual fatigue, sleep, and soreness following travel out of a national team compared to travel into or between matches [8], the specific effects of different match loads and post-match travel demands on recovery are unknown. Detailed understanding of player responses to combined match and travel loads, is therefore needed to better inform player availability and recovery when travelling between national team matches and when returning to club teams.

The need to travel to subsequent national team matches or return to club teams shortly after demanding national team matches may be suboptimal conditions for recovery, which may influence preparation and selection in subsequent matches. While the timeline of recovery from a professional football match is reported to range from 5-96h[9], the conditions of travel are often suggested to interfere with the recovery of athletes following matches and prolong this timeline. Whilst a common occurrence in modern fixtures, this is not ideal when only 3-5 days separate matches and include extensive travel. Despite this major concern, no research has investigated how player recovery differs based on post-match travel demands. A recent review on post-match recovery strategies highlighted sleep and nutrition as being particularly important for match-recovery[10]. Post-match travel, however, has been previously observed to reduce total sleep in Rugby 7's players[11], while reductions in sleep during and after travel have frequently been reported by travelling athletes[12-15]. As such, it is possible that the post-match recovery of athletes may be impaired by travel-induced sleep loss. Additionally, travel demands may also reduce time available for other recovery strategies ie., nutrition, cold-water immersion or massage, which have also been suggested to have beneficial effects on perceptual recovery[10]. Due to the potential impacts of travel on post-match recovery, practitioners of national teams are also left to consider the best time to travel after a match. However, it is unclear whether travelling later and spending time recovering prior to travel, will eventuate in better outcomes than travelling immediately post-match and recovering after travel. Given an athlete may be required to compete again within 3 days of their previous match, understanding how the timing and extent of travel influence post-match recovery will help inform the planning of travel schedules (e.g. when to depart), and guide post-travel recovery plans.

Based on the lack of research surrounding the relationships between match-load and travel, this study has two aims. Firstly, to describe the relationship of match load and travel duration, time zone change, and direction on the perceptual fatigue, sleep, soreness, and recovery status of national team footballers upon arrival from post-match travel. Secondly to describe the influence of travel duration, time zone change, direction and time between match and travel departure, on match recovery status 3 days after a match in national team footballers. By addressing these two aims, this study will provide staff of club and national teams better insight on the expected recovery response of players as related to their match load and travel demands.

Methods

Subjects

Participants included 79 male international footballers (age= 25.00±3.67) competing for a national football team between October 2018 and November 2023. Data was collected from each trip the players undertook for either the senior or under 23's national teams (n=258). Through contracts with the national football federation, all players provided consent for their data to be used anonymously for research purposes. Ethics approval was obtained from the institutional human ethics committee (ETH22-7708).

Methodology

Data was collected from each national team player travelling after a national team match (including travel both between national team matches and back to clubs). Participants were required to complete a perceptual questionnaire every day when in the national team camp and up to 3 days following return to their club. Players were also required to provide a perceived recovery status rating from the day prior to each match, through to 3 days after the match. Each player's perceptual scores were aligned with their match loads and post-match travel details. To accomplish aim 2, perceptual outcome scores were collated from a standardised post-match time point of match day +3 (MD+3). This time point was selected as all players had completed post-match travel requirements by this point, but allowed for a standardised time point for comparison that could align with the earliest possible club match. Baseline scores for both aim 1 and 2 were obtained the morning before a match (MD). Perceptual outcomes were converted to change scores by subtracting the baseline score from the raw value.

Travel Details

Travel details for each post-match flight were obtained from booked travel schedules provided by national team managers. Actual departure and arrival times for each flight were verified via an online flight database (Flightera.com). Travel duration (Mean: 14.51h ± 4.10, Range: 1.08h - 32.98h) was calculated as the total time between airport departure and arrival at the final destination airport (including the duration of stopovers but not travel to and from airport). The recovery time between matches and travel was calculated as the length of time in hours between match kick-off and aircraft departure due to the availability of match start time (Mean: 24.34h ± 12.11, Range: 4.83h - 76.33h). The number of time zones crossed during travel was measured as the difference in time zone between departure and destination locations at the time of travel (Mean: 5.56 ± 2.25, Range: 0 – 14). The direction of the flight was labelled as either eastward or westward based on the flight path. The travel context was categorised as being either transition (travel between two national team matches), or return (travel out of national team back to club team). The travel variables used have been explored in prior works where they have shown to have a relationship with post-travel perceptual fatigue and sleep measures[8,16]. Athletes stayed in team hotels during camp periods (i.e. after transition travel), while following return travel athletes typically stayed in their own accommodation at their respective club teams.

Match Load

Global positioning system (GPS) devices measured the running loads of players during each match. Players wore a GPS unit (STATSports, Apex, Northern Ireland) worn between the players scapulae using a customised vest. Each unit includes a gyroscope (10Hz), tri-axial accelerometer (100Hz) and magnetometer (10Hz). Satellite quality was filtered for using HDOP values of <1. These devices have previously been validated for the measurement of speed and distance variables in team sports [17,18]. The following measures were obtained for each player from each match: Total distance (TD), total high-speed distance (HSD) (19.8 – 25.2 $km \cdot h^{-1}$), total very high-speed distance (VHSD) (>25.2$km \cdot h^{-1}$), number of accelerations (>3$m \cdot s^{2}$), and number of decelerations (>3$m \cdot s^{2}$).

Perceptual Measures

Players completed a perceptual monitoring questionnaire every morning during the national team camp and for 3 days after the completion of the camp. The questionnaire included 4 subjective rating scales on a 7-point Likert scale. Players were asked to rate their current level of fatigue, soreness, sleep quality, and stress as used in prior works [16,19]. A “Total Wellness” score was calculated from the sum of each of the individual scales. Athletes were also asked to complete the Perceived Recovery Status Scale (PRSS)[20] each day from the day before a match through to 3 days after the match. This scale is a 10-point scale requiring players to rate their current perception of their recovery status with scores of 10 relating to being very well recovered and scores of 0 relating to being very poorly recovered. Athletes completed all perceptual monitoring scales via the federation’s athlete monitoring software (Smartabase Athlete, Fusion Sport Pty Ltd) installed on their own smartphone.

While the authors acknowledge the validity of perceptual wellness scales to monitor athletes can be questioned[21], these scales have previously been observed to be responsive to variations in match load[22-24]. Additionally, these scales have been found to be responsive to variations in travel demands including travel duration, time zone difference and travel direction[8,16]. Given the challenges associated with athlete monitoring in national football teams[25], these tools represent a practical way to monitor athlete responses to both match and travel stresses.

Statistical Analysis

All perceptual monitoring scales were aligned with the prior travel details and match GPS measures in an excel spreadsheet. For aim 1, perceptual scores were labelled as either Day (D) 1, D2 or D3, based on the timing of the score relative to arrival from travel. All data was imported into R Studio (version: 2023.6.0.421) for analysis. Linear mixed models were created for each perceptual outcome variable[26]. Models were built using a forward step-wise approach with the inclusion of each fixed effect determined by statistical significance ($p<0.05$), measured via F-tests with Satterthwaite degrees of freedom approximations using the lmertest package[27]. Where multiple effects were deemed statistically significant, the AIC value and the R^2 values of the model were used to determine order. Where fixed effects were correlated (i.e. all match load variables and travel duration/time zone difference), only one of the strongest of the two variables was included to control for multicollinearity within models. The following fixed effects were tested for each model: day, travel duration, time zone difference, travel direction, travel context, match total distance (m), match HSD, match VHSD, match ACC, and match DEC. All players were assigned an anonymous identification number, which was included as a random effect within the model to account for variation between participants. The national team camp that the data came from was also coded in as a random effect.

For aim 2, perceptual measures taken on MD+3 were used as outcomes for separate linear mixed models. Models were built using the same methods described for aim 1. Models were built using the same fixed and random effects as those listed above, with the additional included fixed effect of the recovery time.

Results

Model Outcomes

Details of the final selected models for each outcome are presented in Table 1. Overall, the model R^2 values showed fatigue (R^2 Marginal=0.21) and recovery (R^2 Marginal=0.22) scales to be the most responsive to combined travel and match stresses.

Post-Travel Perceptual Outcomes

Athletes reported poorer ratings of fatigue (0.491AU increase; $p<0.001$), soreness (0.297AU increase; $p<0.001$), total wellness (0.529AU increase; $p=0.007$), and recovery (0.629AU decrease; $p<0.001$), following return travel than when they travelled between national team matches (Figure 1). Travelling eastward resulted in significantly poorer sleep responses than travelling westward (0.429AU increase; $p=0.004$), while, regardless of travel context, travelling later after the match also had a negative effect on sleep ratings 3 days following arrival (0.014AU increase per hour later; $p=0.003$) (Figure 2). No significant effects existed for any other travel variable on perceptual makers ($p>0.05$).

The strongest associated match load measure differed between perceptual outcome variables. Increases in match VHSD had a negative effect on sleep (0.003AU increase per metre VHSD; $p<0.001$) and recovery (0.002AU decrease per metre VHSD; $p=0.032$) scores. A greater number of decelerations in matches resulted in poorer ratings of fatigue (0.002AU increase per deceleration; $p=0.031$), soreness (0.002AU increase per deceleration; $p=0.023$), and total wellness (0.012AU increase per deceleration; $p<0.001$). Greater match accelerations were also associated with poorer stress ratings (0.002AU increase per acceleration; $p=0.008$).

[Table 1 Here]

Table 1. Model outputs for changes in wellness and recovery scales from baseline (MD or MD-1) and post-travel (arrival +1,+2,+3). Coefficient values represent change in outcome variable per one unit increase in explanatory variable (1 for categorical variables).

[Figure 1 Here]

Figure 1. Change in A) Fatigue, B) Soreness, and C) Recovery scores between pre-match to post-travel based on travel type, match decelerations and match very-high-speed distance. Shaded areas represent the 95% confidence intervals.

[Figure 2 Here]

Figure 2. Change in sleep scores from pre-match to post-travel based on the time between match kick-off and travel departure, and the travel direction. Shaded areas represent the 95% confidence intervals.

Match Day +3 Perceptual Outcomes

Final model outcomes for MD+3 perceptual measures are shown in Table 2. Travelling eastward after matches was associated with poorer fatigue (0.432AU increase; p=0.002), sleep (0.502AU increase; p=0.032), total wellness (1.030AU increase; p=0.015), and recovery (0.853AU decrease; p<0.001) ratings when compared to travelling westward. Athletes also reported poorer sleep (0.024AU increase per hour later; p=0.003) and total wellness scores (0.032AU increase per hour later; p=0.023) the later after the match they travelled. Perceptual recovery ratings were worse when travelling for longer durations (0.065AU decrease per hour travelled; p=0.003). At MD+3, greater VHSD in matches was associated with poorer sleep (0.003AU increase per metre VHSD; p=0.019) and total wellness scores (0.005AU increase per metre VHSD; p=0.030). No other effects of match load were observed at MD+3.

[Table 2 Here]

Table 2. Model outputs for the difference in wellness and recovery scales from baseline (MD or MD-1) and 3 days post-match (MD+3). Coefficient values represent change in outcome variable per one unit increase in explanatory variable (1 for categorical variables).

[Figure 3 Here]

Figure 3. Change in Sleep and Recovery scores from MD to MD+3 based on travel direction, the time between match kick off and travel departure, and the duration of travel. Shaded areas represent the 95% confidence intervals.

Discussion

The current study explored the relationship of match load and travel demands on perceptual fatigue, sleep and recovery responses of professional footballers following national team matches. Perceptual ratings of recovery, fatigue, soreness, and sleep were influenced by both match external load and the post-match travel demands. Greater match acceleration, deceleration and high speed running load was associated with poorer recovery, fatigue, soreness, and sleep, with these measures also reported to be worse following travel back to club compared to travel between national team matches. Additionally, players who travelled eastward after matches reported poorer sleep and recovery than those travelling westward. Further, players with longer travel durations reported poorer perceptual recovery on MD+3, and players who travelled later after a match reported poorer sleep on MD+3 than those who travelled earlier.

The findings of this study indicate that the perceptual fatigue, sleep, and recovery state of national team footballers upon arrival from post-match travel showed small associations (R^2=0.02-0.22, as context an R^2 of 1.0 represents all variation in the outcome value is explained by the model and its fixed effects) with high-speed running loads undertaken in the prior match and the travel demands after matches. Greater high-speed loads (measured as either high speed distance, very high-speed distance or acceleration/deceleration counts), were negatively associated with all perceptual recovery measures. These findings concur with recent works in both senior [22] and junior[23] professional footballers reporting negative associations between increased high-intensity running and perceptual fatigue, soreness, energy, and sleep on MD+1[22] and MD+2[23] respectively. However, similar to the findings in a recent systematic review on perceptual responses to training and match load[28], the variation in scores explained by these models was relatively low (R^2conditional = 0.04-0.22) indicating that other factors are likely to also have influence on perceptual scores. Regardless, this study is the first to show that pre-travel match loads, specifically high-speed loads, continue to influence an athlete's perceptual recovery status following arrival from post-match travel. As such, high speed match loads should be considered when planning for the expected arrival status of athletes. Further, these findings emphasise the importance of sharing match load information between clubs and national teams to better inform athlete status and availability upon return to clubs.

In addition to the influence of match-load, both post-match travel direction and the context of travel appeared to influence an athlete's post-arrival state. Athlete's travelling eastward after a match reported poorer sleep scores (0.429AU increase)post-arrival compared to those travelling westward. This finding concurs with Fowler, et al. [15] who identified reductions in sleep duration and time in bed following eastward travel across 8 time zones compared to westward travel of the same extent. The reduction in sleep quality in this study may be explained by delayed sleep onset as a result of jet lag, with morning commitments potentially limiting the capability to make up for the delayed onset of sleep; though we recognise neither sleep onset or wake time was recorded in this study. As such, athletes with prolonged travel eastwards, especially overnight after a national team match, may require additional time to sleep or strategies to improve sleep quality following arrival. Travel context, as either transition between national team matches or returning to club, also appeared to influence perceptual state upon arrival. Perceptual status was poorer following travel back to club teams with an increase in fatigue ratings (0.491AU), increase in soreness ratings (0.297AU) and decrease in recovery ratings (0.629AU) observed in athletes returning to clubs compared to those travelling between national team matches. This finding has previously been reported in the same population group using a smaller sample size, showing perceptual fatigue, sleep, soreness and total wellness scores up to 3 days post-travel were lower following travel out of national teams compared to travel into national teams or between national team matches[8].

This may relate to athletes returning to clubs at the end of a national team camp having experienced multiple national team matches and travel bouts in a relatively short period of time. Accordingly, for players transitioning back to club teams from national teams additional strategies to maintain sleep during travel are highly recommended [29], while recovery interventions that can be implemented during periods of[10] may further benefit the athlete.

Due to the potential need to compete again within 3 days after national team matches, a secondary aim of this study explored how long after a match travel occurred and effects on post-match recovery 3 days after a national team match. Longer travel demands in this study appeared to affect perceptual recovery from matches, with athletes reporting a decrease in perceptual recovery scores on MD+3 (0.065AU) for every hour travelled after matches. This is a novel finding, as no other studies have compared an athlete's post-match recovery at a standardised time point based on differing post-match travel requirements, recognising players travel at different times following the match. Poorer recovery ratings when required to travel longer durations may in part be associated with reductions in sleep duration and quality that have been frequently reported during long-haul travel[12-15]. However, as sleep duration or quality during travel was not recorded in this study, further research is necessary. In addition to the duration of travel, athletes travelling eastward after matches reported on MD+3 an increase in fatigue (0.432AU), increase in sleep (0.502AU), and decrease in recovery ratings (0.853AU) compared to those who travelled westward. As discussed previously, eastward travel is likely to result in delayed sleep onset caused by jet lag, which has previously been observed to reduce sleep duration[15]. Reductions in sleep because of this may further exacerbate feelings of fatigue from matches and impair post-match perceived recovery status. Based on the findings of this study, it appears that longer post-match travel durations, particularly in an eastward direction, may impair recovery from national team match play, and result in poorer ratings of recovery 3 days after a match. This poses concern for athletes who are required to compete within 3 days after their national team match, and recovery tools that can be applied during travel are recommended.

A concern amongst practitioners of national football teams often revolves around whether it is better to travel immediately after a match or wait and allow athletes time to recover from the match prior to travelling. Athletes in this study reported an increase in sleep score (0.024) on MD+3 per hour later that they travelled after the match, while the timing of travel had no effect on any other perceptual recovery measures. Better sleep scores on MD+3 when departing earlier after a match may be related to having more time to adapt to the destination time zone and recover from sleep deficits associated with long-haul travel. As such, if athletes are required to compete again shortly after a match, travelling earlier may allow adaptation of sleep schedules to occur earlier. However, as this is the first study to explore the relationship between the timing of travel relative to a match and match recovery, further research is needed to support this finding.

While the findings of this study may inform practitioners of the travel and match load influence on perceptual recovery after national team matches, several limitations should be considered. The population used within this study represented only a single national team and thus variation may be expected from other national teams who are likely to have their own unique travel demands and strategies. Likewise, the speed and acceleration thresholds used for this research represent those employed by the studied national team and variations in outcomes may be expected where different thresholds are used. Additionally, as evidenced by low R^2 values, the variation in perceptual recovery measures used in this study are only explained to a small extent by travel and match related factors. Other influences on perceptual recovery from matches and travel are likely to exist and should be considered when monitoring athletes travelling post-match. Furthermore, this research only considers air travel requirements as data was not available for other forms of transport. Lastly, the design of this study meant that the research team had no control over what the athletes did before, during or after travel, nor over the use of recovery strategies post-match.

Practical Applications

- Elevated high-speed match-running demands are likely to affect perceptual fatigue, sleep and soreness ratings following travel after national team matches.
- Athletes may require additional support following travel back to clubs after national team matches due to poorer perceptual recovery, fatigue, and soreness than travel between national team matches.
- Perceptual recovery on MD+3 following travel is negatively impacted by longer post-match travel durations, while travelling later after the match may have negative impacts on sleep on MD+3.

Conclusions

In conclusion, this study was the first to determine the combined influence of travel and match demands on perceptual recovery, fatigue and sleep following post-match travel. Increased high-speed match running in the prior national team match was associated with poorer perceptual recovery, fatigue, sleep and soreness upon arrival from travel. Additionally, travelling from the national team back to the club was associated with poorer ratings of recovery, fatigue and soreness compared to travelling between national team matches, while travelling eastward was associated with poorer sleep ratings. In addition, the perceptual recovery status on day 3 after a national team match appeared to be negatively affected by longer post-match travel demands. Lastly, travelling later after a match was associated with poorer sleep ratings at MD+3. When monitoring the athletes travelling after national team matches, practitioners should be aware of both prior match loads and travel demands of their athletes. Additionally, for athletes who are required to compete again within 3 days of their prior national team match, travel-friendly recovery strategies are recommended to maximise post-match recovery.

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