Abstract:

Purpose: This study investigated the association between i) time zone difference and ii) travel direction (east vs west) with post-travel changes in perceptual responses of national team footballers.

Methods: Travel schedules from 355 national team trips (50 elite soccer players) were verified using an online flight database. All players provided perceptual ratings of fatigue, sleep quality, soreness, and stress to calculate changes in scores up to 2 days after travel. Trips were categorised as <3, 3-6, 6-9 or 9^+ time zone change, along with travel direction (eastward or westward). The pre- to post-travel change in perceptual ratings at both day 1 and 2 post-arrival were compared between time zone change and travel direction with linear mixed models.

Results: For every time zone crossed poorer ratings of perceptual fatigue (β=0.068, $p<0.001$), sleep (β=0.095, $p<0.001$), soreness (β=0.0049, $p<0.001$) and total wellness (β=0.214, $p<0.001$) were observed. However, the models explained only small proportions of the variation in post-flight perceptual responses (7–18%). Regardless, travel across 9^+ time zones resulted in significantly worse perceived fatigue, sleep and total wellness for Day 1 and 2 post-arrival compared to travel with <6 time zones ($p<0.05$). Additionally, fatigue, sleep and total scores were worse on Day 2 following trips of 9^+ time zones. Eastward travel resulted in poorer ratings sleep (β=0.52, $p<0.001$) than westwards travel within time zone groupings.

Conclusions: Perceptual ratings of fatigue and sleep become progressively worse as travel increases in national team soccer players, especially after travel across 9+ time zones and eastward travel.

Key Words: Jet lag, travel fatigue, time zone transition, soccer, international tournaments

Introduction:

Travel remains a concern for national team footballers (soccer) due to the effects of jet lag and travel fatigue on camp and tournament preparation [1]. The physiological and psychological stresses associated with prolonged air travel and rapid time zone change can negatively influence fatigue and sleep [2,3], potentially resulting in poorer physical and mental performance [4-6]. For a national football team, concerns surrounding travel are further complicated as athletes are located at different clubs around the world and thus significant variation in travel requirements exist for any single camp or tournament. As such, when planning for the potential effects of jet lag and travel fatigue, various flight related factors need to be considered including the travel distance, duration, time zone change and direction, as these are likely to influence the extent of symptoms[7]. However, limited data exists for any measure comparing athletes across a large number of trips with varying distances, directions and time zone changes, let alone data in elite football contexts. Hence, it is difficult to determine the specific variation in athlete responses based on the diversity of travel demands and factors [8]. Measures of physical performance or detailed jet lag scales are difficult to obtain when athletes travel for camp or competition, and often only simple perceptual measures (ie. fatigue, sleep, soreness, stress) exist for practitioner use. Regardless, comparisons between varying travel durations, directions and time zone changes on athlete perceptual responses are yet to be reported, especially in national team footballers.

The effects of specific travel durations on athlete responses remain ambiguous, though common responses to long-haul include altered sleep and fatigue responses[8]. Travel durations of >5h caused greater reductions in lower-body power of professional rugby 7s players compared to travel <5h [9], though the trips >5h actually ranged from 9.5 to >24 hr. Similarly, greater reductions in intermittent sprint performance, sleep duration, mood and perceptual fatigue were observed following 24h of simulated travel compared to 5h in physically-trained individuals [3]. Further, Thornton, et al. [10] observed poorer ratings of jet lag, fatigue and vigour following a 6h time zone change compared to a 1h time zone change in wheelchair basketball athletes. These studies highlight that longer travel demands are likely to induce more detrimental symptoms of jet lag and/or travel fatigue. However, monitoring of athlete responses to national team travel is difficult as often only limited perceptual ratings are available, and thus understanding responses of these measures to different travel demands is important. Furthermore, these studies represent only extreme comparisons of short vs long haul flights from singular travel bouts, and thus do not provide sufficient detail to differentiate between the full range of travel demands encountered by a national football team. Therefore, further exploration using larger data sets from elite athletes across broader ranges of travel duration, time zone change and direction are required.

National football teams require travel from clubs that are located in range of geographical locations, involving a multitude of trips with differing directions and durations. Chronobiological principles suggest eastward travel will be more disruptive to performance than westward travel [11]. In support, worse sleep duration, perceived fatigue, motivation and jet lag existed following eastward travel in sub-elite populations following a 21 h flight across 8 time zones when compared to an equivalent westward flight [6]. Further, poorer subjective jet lag ratings were reported in Olympic gymnasts following eastward compared to westward travel [12], though the number of time zones crossed and the population used differed between these acute travel bouts. While detrimental effects of travel on sleep and recovery have previously been observed in both professional football[13] and rugby athletes[14], no comparisons exist between travel directions and comparisons between time zone differences/durations are limited to only a small number of flights. As such, better understanding of the effects of travel direction, duration, and time zone change, on perceptual responses of fatigue, sleep, soreness and stress can assist planning for national team travel schedules.

Given different players within a national team are often located across a variety of clubs around the world, it is important for national federations to have further insight on the effects of travel demands to inform player recovery and preparation strategies. Therefore, this study investigated the association between i) time zone difference and ii) travel direction (east vs west) on the post-travel changes in perceptual responses of national team footballers.

Methods:

Subjects

Participants included 62 elite senior male national footballers (soccer) (age 25.6 ± 4.1y) from a national football team inside FIFA's top 50 ranked teams. All players travelled for national team duties between March 2018 and November 2021. Players within this national team were based across various clubs around the world including those in Europe, Asia, and Australia. Through individual contracts with the national football federation, participants consented to the use of their anonymous data for research. Consent was obtained from the national football federation for the use of data, whilst Human Ethics approval was provided by the institutional Human Ethics Committee (ETH20-5080).

Design

Data was collated for all trips between March 2018 and November 2021 (n=679 flights). Travel details and perceptual measures were collated and anonymised using numeric codes. Baseline perceptual measures as part of normal team monitoring were obtained the day prior to departure (or 2 days before if unavailable). Post-flight perceptual data was obtained in the morning on day 1 (D1) and 2 (D2) following arrival to calculate the change from pre-flight outcomes at each day. In total, 355 trips with relevant pre- and post-flight data were included in the study. Of these 355 trips, 50 players were included with 7.1 (±5.1) trips per player.

Methodology

Using flight bookings obtained from the Federation, details of each trip were verified using an online flight database (Flightera.net). The following details were obtained: arrival and departure locations, arrival time, departure time and flight duration. Based on these details, the total travel duration of the trip was calculated as the total time between aircraft departure and aircraft arrival at the final destination's airport, including the duration of stopovers. Time zone difference was defined as the difference in time zone between departure and arrival locations. Travel direction was labelled as either westward or eastward based on the initial departure location and final arrival destination. To allow further comparisons between travel bouts, trips were grouped by travel duration and time zone difference. Prior studies have compared travel bouts of 5h and 24h [3], <5h and >5h [9], and 1 time zone compared to >6 time zones [10]. As such, smaller travel duration and time zone difference groupings were used in this study. Categories of travel duration included <5 h, 5-10 h, 10-15 h, 15-20 h and 20^+ h. Categories of time zone difference included <3 h, 3-6 h, 6-9 h and 9^+ h.

Players completed an online perceptual "wellness" questionnaire every morning (09:00 – 10:00) as part of national team commitments. This questionnaire comprised of 4 items requiring players to rate their current perceived fatigue, soreness, stress, and sleep quality.

Players answered each question on a seven-point Likert scale with values between 1 and 7 in increments of 1. Each scale included descriptive anchors at scores of 1, and 7, with a midpoint anchor at 4. For the fatigue, soreness, and stress scales, these anchors included "No Fatigue/Soreness/Stress", "Moderate Fatigue/Soreness/Stress", or "Maximal Fatigue/Soreness/Stress". The sleep scale required players to rate their perceived sleep quality from the previous night with scores of 1 described as "Outstanding Sleep", scores of 4 described as "Average Sleep" and scores of 7 described as "Horrible Sleep". A player's total score was calculated as the sum of the 4 items. Each score was assigned as either day 1 (D1) or day 2 (D2) in relation to their arrival from travel. Players completed the questionnaire through their smartphone via the online athlete monitoring system (SMARTABASE, Fusion Sport, Brisbane, Australia). The questionnaire had previously been used by all participants for regular monitoring and all participants had high familiarity. Whilst it is recognised that a specific jet lag scale may have provided more valid measurements of travel stress, such data collection was unavailable.

The use of single item perceptual "wellness" measures has been debated recently due to a lack of an underpinning conceptual framework and absence of validation studies [15]. However, these measures represent a practical tool that is likely to achieve high compliance due to the low burden placed on elite athletes. These measures have also been observed to be responsive to acute training load in professional footballers both at the club [16] and national team level [17], although questions still remain in their ability to differentiate between levels of training load [17]. Further, several studies have observed changes in perceptual sleep and fatigue following travel bouts [3,18] highlighting potential for these measures to infer the impact of travel related stress.

Statistical Analysis

Travel details were collated into a single excel spreadsheet and perceptual response scores before and after travel were aligned. All perceptual rating scales were converted into a change score by subtracting the pre-travel score from scores at D1 and D2. For all statistical tests, alpha was set at 0.05 for statistical significance.

To analyse the effects of travel variables on perceptual responses, linear mixed models were built using the 'lme4' package [19] in the R statistical software [20]. The presence of multi-collinearity was checked prior to modelling using Pearson's r correlation coefficient. Travel duration was excluded from the model due to strong correlation with time zone difference ($r=0.84$, $p<0.001$). To account for non-independence between observations, the anonymous player code was included as a random effect. Models were built using a stepwise approach with the introduction of a new variable assessed at each stage through examining the model's Aikake information criterion (AIC), R^2 values and the significance of the fixed effects. The significance of fixed effects were calculated using an F-test with Satterthwaite degrees of freedom approximation, implemented using the 'lmertest' software package [21]. Assumptions of normality and homogeneity of variance were assessed using final model residual QQ-plots and residual plots respectively. Cooks Distance was calculated to identify influential points, though no points were deemed to have a major effect on the model.

Linear mixed models were also created using time zone difference as a factored variable consisting of groups of <3h, 3-6h, 6-9h and 9^{+}h. While measurement day (D1, D2) was also included as a fixed effect. To control for non-independence of observations, the anonymous player code was included as a random effect. For the total wellness variable, the direction of travel (East or West) was also entered as a fixed effect to assess the influence of travel direction on subjective wellness. Pairwise comparisons were made within each variable (i.e.

holding other variables constant) using estimated marginal means calculated by the "emmeans" package in R [22]. Normality and homogeneity of variance was again assessed using model residual QQ-plots and residual plots respectively.

Results:

Relationships between travel variables and perceptual responses

The stepwise approach used for the linear mixed models and the regression coefficients are shown in Table 1. Time zone difference had a significant effect on total wellness (p<0.001), fatigue (p<0.001), sleep (p=<0.001), and soreness (p<0.001). Direction of travel had a significant effect on sleep (p<0.001) and stress (p<0.001). Lastly, the day since arrival had a significant effect on total wellness (p<0.001), fatigue (p<0.001), sleep (p<0.001), and soreness (p=0.027).

Total Wellness Grouped Time Zone Difference and Direction

The mean change in total wellness for each time zone grouping and direction is shown in Figure 1. On both D1 and D2, the change in total wellness was significantly worse (ie. increased) after 9^+ h time difference compared to both <3h (D1: p<0.001; D2: p<0.001) and 3-6h (D1: p=0.005; D2: p=0.013). Total wellness was also significantly worse after 9^+h time difference compared to 6-9h on D1 only (p=0.012). Similarly, a significant increase (worse value) was observed at 6-9 h time zone difference compared to <3 h on D2 only (p=0.035). Total wellness significantly improved between D1 and D2 for time zone changes of <3h (p=0.001) and 3-6h (p=0.042).

Directional analyses revealed significantly worse change in total wellness following eastward travel compared to westward travel on D1 after a <3h time zone change (p=0.006) and on D2 following a 3-6h time zone change (p=0.016). In contrast, total wellness was significantly better on D2 after eastward travel of 6-9h time difference when compared to westward travel (p=0.003). Significant improvements in total wellness were observed on D2 compared to D1 for westward time zone changes of 3-6h (p=0.010) and eastward time zone changes of <3h (p<0.001).

Perceptual response Subscales across Grouped Time Zones

The mean change in each perceptual subscale across time zone groups is shown in Figure 2. Fatigue scores were significantly worse following 9^+ h time difference on both days when compared to <3 h (D1: p=0.015; D2: p=0.004) and 3-6 h (D1: p=0.022; D2: p=0.004). Fatigue ratings improved from D1 to D2 for time zone changes of <3h (p=0.008), 3-6h (p=0.012), and 6-9h (p=0.007). Sleep ratings were significantly worse after 9^+ h time difference on both D1 and D2 compared to <3h (D1: p<0.001; D2: p<0.001), 3-6 h (D1: p<0.001; D2: p<0.001) and 6-9h (D1: p<0.001; D2 p=0.002). Sleep ratings significantly improved between D1 and D2 for trips of <3h (p=0.001) and 9^+h (p=0.012) time difference. Soreness ratings were significantly worse on both days after 6-9 h time difference compared to <3 h (D1: p=0.038; D2: p=0.007). Stress rating changes were significantly better after 9^+h time difference on D2 compared to 3-6h time difference (p=0.034).

Discussion

This study examined the influence of travel direction and time zone change on subjective ratings of fatigue, sleep, soreness and stress in national team footballers. Larger time zone changes resulted in worse perceptual fatigue, sleep, soreness and total wellness scores. Additionally, eastward travel resulted in poorer perceptual ratings of sleep and improved perceptual ratings of stress. Further, fatigue, sleep, and total scores improved on D2 compared to D1, and whilst total scores returned to baseline by D2 on trips of <9h time zones, they remained elevated for trips >9^+ time zones. Importantly, the models explained only a small portion of the variation in post-flight perceptual responses (7 – 18%), indicating that these perceptual scales may not provide a sensitive measure of travel stress in footballers until the time zone change is large. Regardless, if such scales are used by practitioners for travel, poorer fatigue and sleep ratings may be expected for travel bouts across 9^+ time zones, while trips <6 time zones may warrant less concern.

This study reports a change in total (wellness) score of 0.21AU for each time zone crossed in national team players, while trips >9 time zones produced significantly poorer scores than trips across <9 time zones. Our work supports previous observations on poorer wellness scores in professional footballers following a singular trip across 11 time zones [2], while negligible effects were observed following shorter domestic trips across <2 time zones [23,24]. It is likely that the impact of the larger time zone change results in increased jet lag and travel fatigue symptoms [11] that manifest in the wellness scales. Further, for trips of 9^+ time zones, total wellness scores remained above baseline on D2, with longer time required to adjust to the greater time zone change [11]. However, minimal (or improved) changes following trips <6 and especially <3 time zones suggest such travel demands may not have substantial implications for the athlete's perceived wellness, perhaps even acting as periods of reduced load [25]. Travel across 9^+ time zones may require additional support, including scheduled naps, sleep hygiene or circadian realignment interventions [26-28]. Importantly, despite the association between time zone difference and total wellness, only a small amount of wellness variance (R^2 = 0.07) was explained by the fixed travel effects. Hence, other influences such as training or match loads [17], team selection and match outcomes [29] may be co-founders and mask the effects of travel. This highlights the limitations of using subjective wellness scales to infer travel related stress and future use of more specific jet lag and travel fatigue scales are required.

Respective subscales of fatigue and sleep showed the strongest association with worse outcomes for greater time zone changes in national team footballers. However, the regression models for perceived fatigue and sleep still showed low associations (R^2 = 0.12 and 0.18). Simulated long-haul travel bouts (>24h) have reported higher fatigue ratings in physically-trained subjects [3], as well as in wheelchair basketball athletes travelling across 6-11 time zones compared to 1 time zone. In the current study, athletes reported significantly worse changes in fatigue and sleep quality after travel across >9 time zones compared to <9 time zones. Similar to total wellness, fatigue and sleep scores also remained above baseline on D2 for trips of 9^+h time difference, with prolonged sleep loss and fatigue likely symptoms of jet lag from the time zone change [30]. For time zone changes <9h, fatigue and sleep scales were largely unchanged, suggesting such trips are unlikely to cause major impairment to player wellness. Negligible effects of time zone difference existed on stress and soreness, which may not be sensitive to travel related influences. In support, unchanged muscular soreness was observed in physically trained individuals after 24h of simulated travel [31], and in professional rugby players travelling for 25h across 11 time zones [32]. Therefore, practitioners should be aware of current recommendations regarding jet lag/travel fatigue interventions [28], and should consider interventions targeted at improving sleep and reducing fatigue in the first 48h after travel, particularly when athletes are required to travel across 9 or more time zones.

Regression models used in this study found the direction of travel to be significantly related to sleep and stress responses. Eastward travel is expected to invoke more detrimental jet lag effects than westward due to the body's circadian rhythms taking longer to advance than delay [11]. While no effect of travel direction was found on overall wellness or fatigue scores, travelling eastward resulted in 0.522 AU increase in worse perceived sleep quality. Eastward travel is expected to delay getting to sleep as arousal is likely high at night-time in the new environment based on circadian phase [33]. Similar findings have been observed in a physically trained population, with later sleep onset and reduced mean time in bed and sleep duration observed following eastward travel compared to westward [6]. The lack of direction effect on fatigue and total wellness measures may be due to the lack of specificity of these measures to travel-related stress. It is possible that any effect of direction was masked by other factors such as training load [17], and thus jet-lag specific scales may be more appropriate. For athletes travelling eastward, sleep promoting interventions in the first 48h after travel are recommended. Future research should seek to expand on these findings by analysing more objective sleep measurements before and after travel bouts.

Whilst recognising the novelty of the current findings, certain limitations are also acknowledged when interpreting the results. Although data was collected in a systematic manner by national team staff, there was no control over what athletes did before, during or after travel i.e. training, matches or travel interventions. Furthermore, perceptual wellness measures are likely influenced by other external factors and may not represent a true measure of travel stress, hence, a specific jet lag or travel fatigue scale may provide a more valid measurement. While perceptual measures may provide some insight into how an athlete is coping with the stress associated with air travel, the lack of physical performance measures mean no inferences can be made relating to athlete performance. Additionally, using only a single value as the baseline measure should also be recognised as a potential limitation as external factors were not controlled and thus may have influence on the baseline score. Lastly, perceptual wellness measures were only obtained at a single time point each day and hence alterations in scores may have been reported if taken at other times throughout the day[30].

Practical Applications

- In professional footballers, ratings of perceptual fatigue and sleep appear more responsive to travel stress than other perceptual wellness ratings
- Interventions to promote sleep and reduce fatigue may be especially important for footballers travelling across 9 or more time zones
- Footballers travelling eastward are likely to experience poorer perceived sleep and thus additional focus on sleep promoting interventions is required

Conclusion

Perceptual ratings of fatigue, sleep and soreness from national team footballers in the first 48h after travel are worse when required to travel across a greater number of time zones. Particularly, travel across 9 or more time zones is likely to have greater and longer lasting effects on an athletes sleep and fatigue ratings than travel across <6 time zones. Poorer perceived sleep was also observed when players were required to travel eastward. Therefore, focus on interventions to maintain sleep and potentially hasten the adaptation to the new time zones are especially important. This study highlights the greatest concern for national team footballers should be with athletes travelling across 9 or more time zones in an eastward direction.

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References

1. McCall A, Davison M, Andersen TE, et al. Injury prevention strategies at the FIFA 2014 World Cup: perceptions and practices of the physicians from the 32 participating national teams. *Br J Sports Med*. 2015;49(9):603-608. doi:10.1136/bjsports-2015-094747
2. Fowler P, McCall A, Jones M, Duffield R. Effects of long-haul transmeridian travel on player preparedness: Case study of a national team at the 2014 FIFA World Cup. *J Sci Med Sport*. 2017;20(4):322-327. doi:10.1016/j.jsams.2016.08.021
3. Fowler P, Duffield R, Vaile J. Effects of simulated domestic and international air travel on sleep, performance, and recovery for team sports. *Scandinavian Journal of Medicine & Science in Sports*. 2014;25(3):441-451.
4. Fowler P, Duffield R, Morrow I, Roach G, Vaile J. Effects of sleep hygiene and artificial bright light interventions on recovery from simulated international air travel. *Eur J Appl Physiol*. 2015;115(3):541-553.
5. Chapman D, Bullock N, Ross A, Rosemond D, Martin D. Detrimental effects of West to East transmeridian flight on jump performance. *Eur J Appl Physiol*. 2012;112(5):1663-1669.
6. Fowler P, Knez W, Crowcroft S, et al. Greater Effect of East versus West Travel on Jet Lag, Sleep, and Team Sport Performance. *Med Sci Sports Exerc*. 2017;49(12):2548-2561.
7. Janse Van Rensburg DC, Jansen Van Rensburg A, Fowler PM, et al. Managing Travel Fatigue and Jet Lag in Athletes: A Review and Consensus Statement. *Sports Med*. 2021;doi:10.1007/s40279-021-01502-0
8. Rossiter A, Warrington GD, Comyns TM. Effects of Long-Haul Travel on Recovery and Performance in Elite Athletes: A Systematic Review. *J Strength Cond Res*. 2021;Publish Ahead of Printdoi:10.1519/JSC.0000000000004021
9. Mitchell JA, Pumpa KL, Pyne DB. Responses of Lower-Body Power and Match Running Demands Following Long-Haul Travel in International Rugby Sevens Players. *Journal of Strength & Conditioning Research*. 2017;31(3):686-695.
10. Thornton HR, Miller J, Taylor L, Sargent C, Lastella M, Fowler PM. Impact of short- compared to long-haul international travel on the sleep and wellbeing of national wheelchair basketball athletes. *J Sports Sci*. 2018;36(13):1476-1484. doi:10.1080/02640414.2017.1398883
11. Reilly T, Waterhouse J, Edwards B. Some chronobiological and physiological problems associated with long-distance journeys. *Travel Med Infect Dis*. 2009;7(2):88-101. doi:10.1016/j.tmaid.2008.05.002
12. Lemmer B, Kern RI, Nold G, Lohrer H. Jet lag in athletes after eastward and westward time-zone transition. *Chronobiol Int*. 2002;19(4):743-764. doi:10.1081/CBI-120005391
13. Fullagar HHK, Duffield R, Skorski S, et al. Sleep, Travel, and Recovery Responses of National Footballers During and After Long-Haul International Air Travel. *Int J Sports Physiol Perform*. 2016;11(1):86-95.
14. Smithies TD, Eastwood PR, Walsh J, Murray K, Markwick W, Dunican IC. Around the world in 16 days: the effect of long-distance transmeridian travel on the sleep habits and behaviours of a professional Super Rugby team. *J Sports Sci*. 2021;39(22):2596-2602. doi:10.1080/02640414.2021.1947617
15. Jeffries AC, Wallace L, Coutts AJ, McLaren SJ, McCall A, Impellizzeri FM. Athlete-Reported Outcome Measures for Monitoring Training Responses: A Systematic Review of Risk of Bias and Measurement Property Quality According to the COSMIN Guidelines. *International Journal of Sports Physiology & Performance*. 2020;15(9):1203-1215.
16. Thorpe RT, Strudwick AJ, Buchheit M, Atkinson G, Drust B, Gregson W. Monitoring Fatigue During the In-Season Competitive Phase in Elite Soccer Players. *Int J Sports Physiol Perform*. 2015;10(8):958-964. doi:10.1123/ijspp.2015-0004

17. Noor D, McCall A, Jones M, et al. Perceived load, fatigue and recovery responses during congested and non-congested micro-cycles in international football tournaments. *J Sci Med Sport*. 2021;doi:10.1016/j.jsams.2021.07.001

18. Stevens CJ, Thornton HR, Fowler PM, Esh C, Taylor L. Long-Haul Northeast Travel Disrupts Sleep and Induces Perceived Fatigue in Endurance Athletes. *Front Physiol*. 2018;9doi:10.3389/fphys.2018.01826

19. Bates D, Mächler M, Bolker B, Walker S. Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software*. 2015;doi:10.3929/ethz-b-000105397

20. *R: A language and environment for statistical computing*. Version 4.1.1. R Foundation for Statistical Computing; 2021. https://www.R-project.org/

21. Kuznetsova A, Brockhoff PB, Christensen RH. lmerTest package: tests in linear mixed effects models. *Journal of statistical software*. 2017;82(1):1-26.

22. *emmeans: Estimated Marginal Means, aka Least-Squares Means*. 2021. https://CRAN.R-project.org/package=emmeans

23. Fowler P, Duffield R, Waterson A, Vaile J. Effects of Regular Away Travel on Training Loads, Recovery, and Injury Rates in Professional Australian Soccer Players. *Int J Sports Physiol Perform*. 2015;10(5):546-552.

24. Fowler P, Duffield R, Vaile J. Effects of domestic air travel on technical and tactical performance and recovery in soccer. Article. *International Journal of Sports Physiology and Performance*. 2014;9(3):378-386. doi:10.1123/IJSPP.2013-0484

25. Everett KL, Chapman DW, Mitchell JA, Ball N. Effects of Westbound Trans-meridian Travel on Countermovement Jump Performance in International-Level Rowers. *J Strength Cond Res*. 2020;

26. Fowler PM, Knez W, Thornton HR, et al. Sleep Hygiene and Light Exposure Can Improve Performance Following Long-Haul Air Travel. *International Journal of Sports Physiology and Performance*. 2021;16(4):517-526. doi:10.1123/ijspp.2019-0931

27. Petit E, Bourdin H, Tio G, Yenil O, Haffen E, Mougin F. Effects of a 20-Min Nap Post Normal and Jet Lag Conditions on P300 Components in Athletes. Article. *Int J Sports Med*. 2018;39(7):508-516. doi:10.1055/a-0599-0888

28. Janse Van Rensburg DC, Jansen Van Rensburg A, Fowler P, et al. How to manage travel fatigue and jet lag in athletes? A systematic review of interventions. *Br J Sports Med*. 2020;54(16):960-968. doi:10.1136/bjsports-2019-101635

29. Fessi MS, Moalla W. Postmatch Perceived Exertion, Feeling, and Wellness in Professional Soccer Players. *International journal of sports physiology and performance*. 2018;13(5):631-637. doi:10.1123/ijspp.2017-0725

30. Waterhouse J, Edwards B, Nevill A, et al. Do subjective symptoms predict our perception of jet-lag? *Ergonomics*. 2000;43(10):1514-1527. doi:10.1080/001401300750003943

31. Fowler P, Duffield R, Vaile J. Effects of simulated domestic and international air travel on sleep, performance, and recovery for team sports. *Scand J Med Sci Sports*. 2015;25(3):441-451.

32. Fowler PM, Duffield R, Lu D, Hickmans JA, Scott TJ. Effects of long-haul transmeridian travel on subjective jet-lag and self-reported sleep and upper respiratory symptoms in professional rugby league players. *Int J Sports Physiol Perform*. 2016;11(7):876-884. doi:10.1123/ijspp.2015-0542

33. Forbes-Robertson S, Dudley E, Vadgama P, Cook C, Drawer S, Kilduff L. Circadian Disruption and Remedial Interventions: Effects and Interventions for Jet Lag for Athletic Peak Performance. *Sports Med*. 2012;42(3):185-208.

Table 1. Model fit for each perceptual wellness scale

Model	AIC	R^2	R^2 Fixed
Total Wellness			
Total ~ (1|Player Code)	3411.6	0.08	
Total ~ Time Difference + (1|Player Code)	3381.9	0.11	0.05
Final Model: Total ~ Time Difference + Day + (1|Player Code)	**3364.2**	**0.13**	**0.07**
Time Difference $\beta = 0.214$ $p<0.001$			
DayD2 $\beta = -1.000$ $p<0.001$			
Total ~ Time Difference + Day + Direction + (1|Player Code)	3364.4	0.14	0.07
Fatigue			
Fatigue ~ (1|player_code)	2112.6	0.07	
Fatigue ~ Time Difference + (1|player_code)	2092.0	0.09	0.03
Final Model: Fatigue ~ Time Difference + Day + (1| Player Code)	**2073.0**	**0.12**	**0.06**
Time Difference $\beta = 0.068$ $p < 0.001$			
DayD2 $\beta = -0.394$ $p<0.001$			
Fatigue ~ Time Difference + Day + Direction + (1| Player Code)	2073.5	0.12	0.06
Sleep			
Sleep ~ (1|player_code)	2422.3	0.09	
Sleep ~ Time Difference + (1|Player Code)	2392.4	0.13	0.05
Sleep ~ Time Difference + Direction + (1|Player Code)	2372.2	0.15	0.07
Final Model: Sleep ~ Time Difference + Direction + Day + (1|Player Code)	**2357.8**	**0.18**	**0.09**
Time Difference $\beta = 0.095$ $p<0.001$			
DirectionEast $\beta = 0.522$ $p<0.001$			
DayD2 $\beta = -0.426$ $p<0.001$			
Soreness			
Soreness ~ (1|Player Code)	1978.1	0.05	
Soreness ~ Time Difference + (1|Player Code)	1966.2	0.07	0.02
Final Model: Soreness ~ Time Difference + Day + (1|Player Code)	**1963.2**	**0.07**	**0.03**
Time Difference $\beta = 0.049$ $p<0.001$			
DayD2 $\beta = -0.176$ $p=0.027$			
Soreness ~ Time Difference + Day + Direction + (1|Player Code)	1963.8	0.08	0.03
Stress			
Stress ~ (1|Player Code)	1190.1	0.06	0
Final Model: Stress ~ Direction + (1|Player Code)	**1166.9**	**0.11**	**0.04**
DirectionEast $\beta = -0.23$ $p<0.001$			
Stress ~ Direction + Day + (1|Player Code)	1168.8	0.11	0.04
Stress ~ Direction + Time Difference + (1|Player Code)	1168.8	0.11	0.04

Figure 1. Mean ± SD change in total wellness at D1 (circles) and D2 (triangles) post-travel across A) time zone change and B) time zone change and direction. Lower values indicate an improvement in wellness score.

a significantly different to <3 h within the same time point and direction

b significantly different to 3-6h within the same time point and direction

** significantly different to West for the same time difference and time point*

 # significantly different between D1 and D2 time points within time zone

Figure 2. Mean ± SD change on D1 (circles) and D2 (triangles) post-travel A) Fatigue, B) Sleep, C) Soreness and D) Stress by time zone change. Lower values indicate an improvement in wellness score.

a significantly different to <3 h within the same time point

b significantly different to 3-6h within the same time point

c significantly different to 6-9h within the same time point

 # significantly different between D1 and D2 within time zone