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2		responses of national footballers
3		during and following long-haul
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5		
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ABSTRACT

Purpose: The present study examined the sleep, travel and recovery responses of elite footballers during and following long-haul international air travel, with a further description of these responses over the ensuing competitive tour (including two matches). *Methods:* In an observational design, 15 elite male football players undertook 18 h of predominately westward international air travel from the United Kingdom to South America (-4 h time-zone shift) for a 10-day tour. Objective sleep parameters, external and internal training loads, subjective player match performance, technical match data and perceptual jet-lag and recovery measures were collected. *Results:* Significant differences were evident between outbound travel and recovery night 1 (night of arrival; *P*<0.001) for sleep duration. Sleep efficiency was also significantly reduced during outbound travel compared to recovery nights 1 *(P*=0.001) and 2 *(P*=0.004). Furthermore, both match nights (5 and 10), showed significantly less sleep than non-match nights 2-4 and 7-9 (all *P*<0.001). No significant differences were evident between baseline and any time point for all perceptual measures of jet-lag and recovery (*P*>0.05); although large effects were evident for jet-lag on Day 2 (two days after arrival). *Conclusions:* Sleep duration is truncated during long-haul international travel and following night matches in elite footballers. These results suggest although sleep quantity is lost during long-haul travel with a 4 h time-zone delay, there is a significant increase in these values on the night of arrival. However this poor sleep appeared to have a limited effect on perceptual recovery, which may be explained by a westbound flight and a relatively small change in time zones, in addition to the substantial sleep following the long-haul flight.

KEYWORDS: Soccer, fatigue, match performance, regeneration, team sport

Introduction

Sleep has been recognised by players, coaches and practitioners as critical to both optimal physiological and psychological recovery.[1,2] Unfortunately, professional footballers currently face numerous situations throughout a season where disrupted sleeping patterns can exist.[2] Such scenarios could include compromised recovery during and following short- and long-haul domestic or international travel, late-night matches and congested competition scheduling.[2,3] Of these, long-haul international air travel (LHIT) is a necessity for some national and club football teams who are required to play away matches in different continents due to international competitions. When LHIT is endured across multiple time-zones, numerous physiological variables are disrupted including the sleep-wake cycle,[4] body temperature and hormonal circadian rhythms.[5] Sleep is perhaps the more critical given sleep loss can affect athletic performance[6] and has been shown to reduce physiological and cognitive recovery in rugby-league footballers.[7] In addition, travelling across time zones can cause disruption to circadian rhythms and give rise to jet lag, further disrupting sleep and increasing residual fatigue – particularly in eastward compared to westward directions.[4] However, to date, the interaction between these aforementioned situational disturbances and objective measurements of sleep in team sports is relatively unknown. Given the upcoming 2016 Olympic Games in Brazil, further knowledge of the objective sleep and perceptual responses to LHIT in elite team-sport athletes would be welcomed to assist the planning of travel and training schedules.

Previous research has described the sleeping patterns of elite junior football players following LHIT.[8-10] For instance, Lastella et al[10] reported reductions in sleep duration (6.6±1.3 h per night compared to baseline 7.5±1.3 h) and quality immediately following travel from Sydney to Denver with an 8-h eastward time-zone change. However, Lastella et al[10] focused on the effects of altitude at the destination on ensuing sleep. Additionally, insights provided by Roach et al[8] and Sargent et al[9] into the influence of international travel on sleep are further compounded by the lack of sleep measurement during the flight, most likely due to understandable logistical issues.[8,9] Thus, further research is required to confirm the assumption that LHIT disrupts sleep, let alone aspects of team-sport performance. To date there is only one previous study that has attempted to investigate the effects of LHIT on sleep with relation to the physical and psychological demands of team sports. Fowler et al[11] reported 24 h simulated LHIT significantly reduced sleep quality and quantity in trained participants.[11] However, this study only focussed on the acute, 24 h post-travel recovery timeline.[11] Thus, recovery responses following this initial 24 h arrival period remain unclear, which

151 is of particular relevance as matches are routinely conducted
152 after this initial 24 h arrival period. Since sleep reportedly
153 assists in memory consolidation, motor learning, cognitive
154 growth and physical regeneration,[12] poor sleep during or
155 following LHIT may limit athletes' post-exercise recovery
156 timeline, which could also be especially pertinent to subsequent
157 training sessions performed close to arrival. Therefore, further
158 research is required to assess the sleep and recovery responses
159 to LHIT in field-based team-sport settings.
160   Moreover, whilst there is evidence supporting the loss
161 of sleep prior to competition in athletes,[13] research evaluating
162 sleep following matches is lacking.[14] Considering that playing
163 at night could promote arousal and prolong wakefulness,[2]
164 playing at night might potentially cause sleep disturbances.
165 Additionally, the physical demands of the actual game could
166 inflict pain and increase perceived soreness and thus, combined
167 with sleep disruption, may hinder physiological and/or
168 psychological recovery.[7,12] Thus, there could be potential for
169 players to sleep differently to those who do not play.
170 Accordingly, the purpose of this study was to examine the
171 sleep, travel and recovery responses of elite footballers during
172 and following international air travel, with a further description
173 of these responses on an ensuing competitive tour. Within this
174 overall purpose, two secondary aims were investigated. Firstly,
175 a comparison of sleep responses on outbound travel and
176 recovery nights (nights following arrival), and secondly given
177 this tour included two respective night matches we aimed to
178 provide a comparison of sleep responses between players and
179 non-players for both match nights and non-match nights.
180
181 **Methods**
182 *Subjects*
183   Fifteen elite male football players voluntarily agreed to
184 participate in the investigation (mean±SD; age 25.5±4.9 y,
185 body mass 74.3±7.3 kg and height 180.0±10.0 cm). The players
186 were national representatives for their country with 5.1±4.8 y
187 and 19.4±24.7 matches of playing experience. All players
188 provided written informed consent prior to data collection.
189 Participants were excluded if they experienced a prolonged
190 injury or illness during the data collection period. One
191 participant was excluded in accordance with these criteria. In
192 addition, from an original pool of twenty-one players, all of
193 whom partook in the study, a further five were excluded due to
194 lack of complete data sets. Thus, data of fifteen participants
195 were included for final analysis. This study was approved by
196 the local Human Research Ethics Committee and conducted in
197 accordance with the Declaration of Helsinki.
198
199 *Design*
200   This study had a descriptive-observational design. Data

was obtained from all players over a 10-day period during a pre-FIFA™ World Cup friendlies 2014 trip to South America, which included a trip from Europe to South America and a similar return trip (Fig. 1). All players were familiarised with the experimental procedures prior to the commencement of the investigation. Data was collected from the players prior to the tour (baseline), during each flight (outbound and return travel) as well as during the 10-day tour (day 1-10). During this tour, two matches were played against Uruguay (day 5; 20:00 local time) and Chile (day 10; 20:40 local time). The outbound flight from London, United Kingdom (GMT+1 h) to Montevideo, Uruguay (GMT–3 h; an overall time-zone shift of 4 h) consisted of late-afternoon departure from London to Paris, France (eastbound travel; 1 h; 341 km travelled), a 3-h stopover in Paris then an evening departure from Paris to Montevideo for a final arrival at 10:00am (westbound travel; 14 h; 10931km). The return trip was from Santiago, Chile to London, United Kingdom, consisting of a late-afternoon departure from Santiago to Paris (15 h; 11627 km travelled), a 2-h stopover in Paris then a midday departure from Paris to London. The afternoon trip from Montevideo to Santiago on day 6 required a 2-h journey with no time-zone change. Modes of travel were in premium economy class, meaning players were restricted from lying in a pure supine position for all flights. During both flights players were left to their own travel routines and were not monitored. No sleep or travel recommendations were given to the players. Training schedules were continuously monitored and conducted at the discretion of coaches (days 1-4 and 8).

Methodology
Sleep measures

The assessment of sleep duration (total amount of sleep obtained; min), sleep onset latency (time at which bed was entered to when the individual first fell asleep; min), sleep efficiency (sleep time expressed as a % of time in bed), wake episodes and wake episode duration (min) were collected using wrist-watch actigraphy (Readiband™, Fatigue Science, Vancouver, Canada). Data were analysed using the manufacturer's software (Fatigue Avoidance Scheduling Tool™ software). The use of these actimetry measures is based upon a previously validated fatigue model[15] and have also been validated in flight crew and attendants during both work and rest patterns, making them suitable for sleep measurements on commercial aircraft[16]. In addition, within-industry tests revealed Readibands showed good agreement (93%) with polysomnographic measurements[15]. These actigraphs were utilised during outbound and return travel, and every night on the tour (worn continuously except during training and matches).

250 As with previous research,[17] logistical reasons
251 prevented the allocation of wrist actigraphs until just prior to
252 outbound travel. Accordingly, mean baseline sleep data was
253 subjectively recorded over a three-day period prior to the
254 outbound flight via the completion of an online sleep and
255 sporting activity questionnaire (SosciSurvey©). The
256 questionnaire was completed in the morning after awakening,
257 and at night prior to sleeping. However, recent research
258 suggests the majority of sleep parameters related to duration,
259 latency and efficiency within this questionnaire correlate poorly
260 with objective methods of actigraphy (ICC=0.22-0.70[18]).
261 Consequently, sleep parameters during the tour were excluded
262 from comparative analyses to baseline given such different
263 methods of collection. Thus, baseline measures of sleep would
264 be presented herewith purely to provide some descriptive
265 context of pre-tour sleeping patterns.

266
267 *Perceptual measures*
268 The Liverpool John Moore's Jet-lag Questionnaire
269 (LJMJQ)[19] was completed both prior to boarding on the day of
270 outbound travel (baseline) and before training (same time each
271 day) on days 2, 4, 6 and 10. The questionnaire assessed
272 participants' subjective ratings of jet-lag on a visual analogue
273 scale (VAS) of 0 (no jet-lag) to 10 (very bad jet-lag), and sleep
274 (latency, onset time, quality, wake time, inertia), function
275 (fatigue, concentration, motivation, irritability), diet and bowel
276 movement ratings on a VAS of -5 to +5, with 0 representing
277 habitual ratings prior to travel. At the same time points,
278 subjective mental, emotional, and physical well-being (total
279 stress-recovery score) were assessed using the Recovery-Stress
280 Questionnaire for Athletes (RESTQ-Sport)[20] and a Likert scale
281 (1=very restful to 5=not at all restful) was used to assess sleep
282 restfulness.

283
284 *Training load and match performance*
285 For each training session mean total distance (m), high
286 intensity running distance (>19.9 km/h), mean speed (m/min),
287 mean heart rate (HR; beats per min) and time spent above 85%
288 of HR_{max} (min) were recorded using 10 Hz Global Positioning
289 Satellite (GPS) devices (STATSports™ Viper, STATSports
290 Technologies, Dundalk, Ireland) and Polar heart rate monitors.
291 In addition, rating of perceived exertion (RPE) was collected
292 approximately 30 min following each training session using
293 Borg's CR-10 scale to calculate training load (session-RPE x
294 min).[21] Additionally, subjective match performance for each
295 player was assessed from the same member of coaching staff
296 for both matches using a scale ranging from 0=very poor to
297 10=excellent. In addition, technical match data (possession
298 percentage, passes attempted, passes completed, pass
299 completion rates, and attacks in the final third) were collected

300 and analysed using Prozone™ software for both matches
301 (VideoPro, Amisco Sports Analysis Services).
302
303 *Statistical Analysis*
304   Data are presented as means±SD. Recovery nights
305 (those following outbound travel) were classified as nights 1-4.
306 Non-match nights were classified as nights 2-4 and 7-9, whilst
307 matches were played on nights 5 and 10. A one-way repeated
308 measures ANOVA was used to compare differences between
309 time points of the away trip including and following
310 international travel (outbound travel, night 1-10, return travel)
311 for all sleep parameters. A one-way repeated measures
312 ANOVA was also used to compare differences in perceptual
313 recovery and jet-lag parameters between baseline measures
314 (pre-travel), and time points of the away trip including both
315 directions of travel. Where significant effects were observed, a
316 Scheffé post-hoc test was performed. $P<0.05$ was accepted as
317 significance for statistical comparisons. Furthermore,
318 standardised effect size (Cohen's *d*; ES) analyses were used to
319 interpret the magnitude of the mean differences between pre-
320 and post- outbound and return travel for sleep, jet-lag and
321 recovery parameters with $d<0.20$ (trivial), $d=0.20$ (small),
322 $d=0.50$ (medium), $d=0.80$ (large)[22]; NB: only large ES reported
323 for sleep parameters). ES analyses were also used to assess pre-
324 and post-match differences for objective sleep indices for both
325 players (played more than 60 min in each game) and non-
326 players.
327
328 **Results**
329 *Sleep measures*
330   A summary of variables related to sleep quantity and
331 quality is presented in Table 1. In addition, individual subject
332 cases for sleep duration are illustrated in Fig. 2.
333
334 *The effect of travel on sleep parameters*
335 Significant differences were evident between outbound travel
336 and night 1 ($P<0.001$; $d=1.86$) for sleep duration, with large ES
337 evident on nights 2-4 ($d=1.20-1.41$). Significant differences
338 were evident for sleep efficiency between outbound travel and
339 recovery nights 1 *($P=0.001$; $d=1.05$)* and 2 *($P=0.004$; $d=1.00$)*.
340 There were no significant differences between outbound travel
341 and recovery nights (1-4 all $P>0.05$) for either sleep onset
342 latency or wake episodes, nor were any large ES present. Large
343 ES were present between outbound travel and recovery night 2
344 ($d=0.90$), and 3 ($d=0.80$) for wake episode duration.
345 Significant differences were also evident between the return
346 flight and the preceding nights 7 ($P<0.001$; $d=1.54$), 8
347 ($P=0.002$; $d=1.35$) and 9 ($P=0.01$; $d=1.30$) for sleep duration.
348 In addition, significant differences were present between return

349   travel and nights 7 *(P=0.03; d=0.92)* for sleep efficiency, with
350   large ES also present on night 9 *(d=0.86)*.

351

352   *The effect of match play on sleep parameters*
353   Match 1 (night 5) showed significantly less sleep than non-
354   match nights 2-4 (all *P<0.001; d=1.79-2.00)* and 7-9 (all
355   *P<0.001; d=1.95-2.18)*. Match 2 (night 10) also showed
356   significantly less sleep than non-match nights 2-4 (all *P<0.001;*
357   *d=1.46-1.60)* and 7-9 (all *P<0.001; d=1.56-1.72)*. No
358   significant differences were evident for sleep onset latency
359   *(P=0.75)*, although large ES were present between Match 2 and
360   non-match night 8 *(d=1.20)*. Match 1 showed large ES with
361   non-match nights 7 *(d=0.93)* and 9 *(d=0.85)* for sleep
362   efficiency, although no significant differences or large ES were
363   present between Match 2 and non-match nights 2-4 or 7-9. A
364   significant difference was present for wake episodes between
365   both match nights (5 and 10) and non-match night 3 *(P=0.02;*
366   *d=1.78* and *P=0.007; d=2.08*, respectively). Large ES were
367   also present between Match 1 and non-match nights 2-4
368   *(d=1.17-1.78)* and non-match night 8 *(d=0.86)*. No significant
369   differences were evident for wake episode duration for all
370   comparisons, although large ES were also evident between
371   Match 2 and non-match night 3 and 4 *(d=0.80* and *d=1.02,*
372   respectively).
373   Participants mainly napped on three specific days: day
374   of arrival (Day 1; number of nappers=6, mean start time:
375   14:27±1:29, mean end time: 15:32±1:19, mean duration: 65±15
376   min), day of match 1 (Day 5; n=7; 14:54±1:28; 16:34±1:06;
377   100±35 min) and day of match 2 (Day 10; n=11; 14:53±0:14;
378   16:30±0:32; 91±38 min). Outside of these days no more than
379   two participants each day napped during the daylight hours.

380

381   *Players vs. non-players*
382   As presented in Table 2, small ES were found for the
383   within-player change in sleep duration when comparing players
384   to non-players for match 1 *(d=0.25)*. This was determined as
385   the relative change following a match compared to the
386   individual mean of the previous three nights. For the second
387   match, non-players presented overall poorer absolute means
388   and within-player changes, including sleep duration and
389   efficiency (Table 2). For the first match, five starters played the
390   full game and a further four played at least 80 min (overall
391   starting mean 87 min). In the second match five starters played
392   the full game, with a further three playing at least 80 min (mean
393   85 min).

394

395   **Perceptual measures**
396   There were no significant differences between baseline
397   and any day of the tour for any perceptual measure *(P>0.05;*
398   Fig. 3). However, large ES were evident for jet-lag on day 2

399 (*d*=1.47; two days after outbound travel) and moderate (*d*=0.76
400 on day 6. Moderate ES were present for sleep restfulness on
401 day 6 following match 1 (*d*=0.52).
402
403 ***Training load and match performance***
404   The physical performance data for the five training
405 sessions are presented in Table 3. The results of both matches
406 were similar (0-1 in match 1 and 0-2 in match 2), along with
407 coaches' ratings of player performance (match 1=7.5±1.0,
408 match 2=7.4±0.9). Match technical data included 46% and 32%
409 possession, 451 and 175 passes attempted, 368 and 122 passes
410 completed (pass completion rates of 82% and 70%), and 44 and
411 21 attacks in the final third of the pitch, per game in match 1
412 and 2 respectively.
413
414 **Discussion**
415   This study describes the sleep, travel and recovery
416 responses of professional footballers during and following
417 LHIT from the United Kingdom to South America, including a
418 comparison of sleep responses during travel and nights
419 following arrival, and a comparison of sleep responses between
420 players and non-players for both match nights and non-match
421 nights. The main finding was the truncated sleep durations
422 during outbound and return travel. That said, a 'rebound' effect
423 (significant increase in sleep duration) was evident on the first
424 night of arrival. Furthermore, both match nights (5 and 10)
425 showed significantly less sleep than non-match nights 2-4 and
426 7-9. Interestingly, there were no significant differences in
427 perceptual recovery between baseline and any day of the tour,
428 nor were players any worse in sleep than non-players. Thus, it
429 would appear further analysis of the relationship between the
430 nuances of sleep loss and recovery in elite football players is
431 required to confirm sleep loss impedes athletic recovery.
432   Sleep duration is reported to be reduced during
433 simulated LHIT,[11] and following actual transmeridian travel.[10]
434 Although we were unable to provide direct comparisons of
435 sleep parameters to baseline in the present study, the mean of
436 5.5 and 5.7 h during outbound and return travel respectively is
437 both far below the recommended 7-9 h for healthy adults[23] and
438 the mean 8.5 h players subjectively reported prior to travel.
439 Moreover, mean sleep efficiency during outbound travel was
440 approximately 20% worse than average values for young
441 adults who sleep for 8 h a night (~90% with
442 polsomnography)[24], indicating poor sleep quality. Previous
443 research suggests this poor duration and quality of sleep during
444 travel could be due to hydration or cabin air pressure.[4]
445 Additionally, the non-supine position experienced in economy
446 class may have hindered melatonin secretion thus perhaps
447 preventing the inducement of sleep[25]. Within the present study,
448 noise within the cabin, comfort and the extensive travel

449   schedule and timing of meals may also have played a role.
450   Notwithstanding, there was a significant increase in players'
451   sleep durations on the first night of arrival. This acute increase
452   in sleep duration on night 1, followed by some stability on
453   nights 2-4, suggests alterations to the sleep-wake cycle due to
454   travel. The 4 h time zone shift is likely to have had only minor
455   effects compared to more extensive time-zone shifts (i.e. 8-10
456   h).[4] In addition, it is suggested that body clocks are better adept
457   at extending the day, and thus westbound flights such as the
458   one experienced in this study are more likely to elicit reduced
459   severity of jet lag symptoms (such as reduced sleep) than
460   eastward travel.[4] Alternatively, the significantly greater sleep
461   duration observed on the night following travel may be
462   explained by an increased homeostatic pressure (drive) for
463   sleep caused by the poor sleep incurred during outbound
464   travel.[26]

465   Although perceptual jet-lag was present during the early
466   stages of the trip, all other parameters relating to the LJMJQ,
467   perceived recovery and sleep restfulness were relatively
468   unchanged. These results may be explained by a westbound
469   flight and a relatively small change in time zones, in addition to
470   the substantial increase in sleep following the long-haul flight.[4]
471   The finding of no effect on perceptual recovery could also
472   possibly be explained by the elite playing experience of the
473   current players, who are accustomed to constant travel and
474   competition. Alternatively, athletes may have intentionally not
475   reported concerns through fears of not being chosen to play.[27]
476   Nonetheless, these results were somewhat surprising given
477   reductions in subjective sleep quality and perceptual responses
478   have been previously reported in athletes immediately
479   following LHIT.[5] The presence of perceived jet lag on day 2
480   was anticipated, with the players' adjusting to the new light-
481   dark cycle following travel. However, the dissipation of this
482   effect by day 4 suggests that the timing of arrival five days
483   prior to the first match was sufficient to alleviate symptoms of
484   jet-lag fatigue. This sufficient re-adjustment may have been
485   important given the effect circadian readjustment can have on
486   athletic performance.[17]

487   In addition, sleep duration was significantly less on both
488   match nights than non-match nights 2-4 and 7-9. These
489   reductions were likely due to excess arousal, post-match
490   commitments (i.e. press-conferences) and socialising.[2] These
491   observations of altered sleep in our investigation are supported
492   by evidence of post-competitive sleep disturbance in
493   professional Australian soccer players[14] and elite individual and
494   team-sport athletes.[13] It should be acknowledged that in our
495   study the nights of matches were not controlled, thus a range of
496   social-related factors were not controlled which may have
497   contributed to the poor sleep. Notwithstanding, a 'rebound'
498   effect was again evident in the majority of nights following

499 match one (7-9) during which sleep duration was significantly
500 greater. Thus, from a volume perspective, there appeared to be
501 no *ongoing* concerns for the players in terms of sleep quantity
502 for match preparation (for either match 1 or 2). However, sleep
503 efficiency, and thus perhaps quality, saw limited improvement.
504 Of further concern, a significant reduction in sleep duration
505 occurred following match 2 and during return travel compared
506 to the preceding nights 7 to 9. Given the congested scheduling
507 of club fixtures following international matches,[3] this return
508 journey represents perhaps the most demanding context for
509 sleep loss in elite football players.
510   Interestingly, sleep parameters did not differ extensively
511 between players and non-players following either match. It is
512 perhaps indicative that it is not so much the act of playing that
513 retards sleep duration and impairs quality, as has been
514 previously hypothesised based on increased arousal at onset of
515 sleep.[29] Indeed, the effect of exercising at night versus not is
516 presently unclear. Some report no significant sleep changes
517 following evening exercise,[30] whilst others have shown that
518 judo competitors performing maximal aerobic exercise in the
519 evening experienced greater elevated sleep-onset latency and
520 awakenings.[31] Since non-players reported poorer aspects of
521 sleep for the second match it is likely poor sleep induced from
522 later bedtimes (due to the timing of the match and post-match
523 functions) can be further attenuated from other sources (e.g.
524 socialising, psychological reasons).
525
526 ***Limitations***
527 Given the ecological nature of data collection, certain
528 limitations should be acknowledged. Unfortunately, due to
529 players being located in different countries it was not
530 logistically possible to obtain objective sleep and/or
531 performance data prior to departure. Hence, a subjective online
532 survey of sleep was used to collect baseline measures of sleep.
533 This method makes it difficult to estimate sleep quantity and
534 quality due to mood, memory bias and personality
535 characteristics.[32] Although it has also been shown that
536 respondents are capable of accurately estimating total sleep
537 duration,[33] the overall poor agreement between objective and
538 subjective measures[18] forced an exclusion of sleep parameters
539 from baseline comparisons. Thus, this weakens inferences
540 about the explicit effect of travel. In addition, the lack of a
541 sleep diary filled out during the trip (especially during both
542 directions of air travel, where subjects were sitting down for
543 extended periods), limits the comprehensiveness, and perhaps
544 accuracy, of sleep measurements. The lack of standardisation of
545 numerous variables, perhaps most notably the lack of control
546 for activities conducted post-match (i.e. socialising), weakens
547 the internal validity of the effect of various influences on sleep.
548 However, since those factors are usually not controlled for in

549   real matches, external validity of our results is high. The low
550   frequency of jet-lag data collection could also possibly have
551   hindered perceptions of jet-lag.[34] In addition, having a stand-
552   alone question(s) related to perceived soreness or muscle pain,
553   outside that of the RESTQ-Sport, may have allowed for a
554   greater derivation of factors associated with poor sleep after a
555   match. Finally, no physiological measures of circadian rhythms
556   were able to be collected to confirm whether or not circadian
557   rhythms were disrupted. Indeed, it is difficult to differentiate
558   between the effects from a time-zone shift and that of long-haul
559   travelling in its own right.
560
561   **Practical Applications**
562   • Sleep duration is poor during LHIT and following
563   match play in elite footballers. Practitioners should be
564   aware this may have repercussions for subsequent
565   training sessions if performed closely after arrival or
566   following matches.
567   • Despite this hindrance to sleep, international travel of
568   more than 12 h (mostly westbound) together with a
569   time-zone shift of 4 h, appears to have a limited effect
570   on the perceptual recovery of elite footballers.
571
572   **Conclusion**
573   LHIT results in worsened sleep durations in elite
574   footballers than the recommended values for healthy adults.
575   However this poor sleep appeared to have a limited effect on
576   perceptual recovery, leaving the relationship between sleep loss
577   and recovery ambiguous. These results suggest although sleep
578   is initially poor during long-haul travel with a 4-h time-zone
579   delay, a strong 'rebound' effect (significantly increased sleep
580   duration) occurs upon arrival for the following night(s).
581   Furthermore, sleep duration was significantly less on both
582   match nights than non-match nights in elite footballers.
583   Interestingly, there were no longitudinal perceptual recovery
584   concerns for either playing or non-playing representatives
585   outside that of early effects on jet-lag, and moderate effects on
586   sleep restfulness following match 1. However, the hindrance to
587   sleep during travel and following match play would suggest the
588   future analysis of interventions which could potentially
589   improve sleep parameters in these scenarios (e.g. the use of
590   sleep hygiene protocols) is required, if not at least from a health
591   perspective. In addition, further research into the relationship
592   between sleep loss and recovery (i.e. physiological) of
593   footballers is required to confirm the popular belief that sleep
594   loss impedes athletic recovery.
595

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FIGURE CAPTIONS

Figure 1: Schematic representation of the study design. * represents when perceptual measures (Liverpool John Moores Jetlag Questionnaire, REST-Q-19 for Sport and sleep restfulness) were collected prior to training. During training, external (Global positioning systems) and internal load (ratings of perceived exertion, heart rate) monitoring were collected. OTN: Outbound travel night; RTN: Return travel night.

Figure 2: All fifteen subjects' sleep durations (minutes) for baseline, outbound travel (O-travel), each night on the trip (Night 1-10) and return travel (R-travel). The thick black boxes signify nights of long-haul travel (both directions) and night matches (Night 5 and 10).

Figure 3: Mean ± standard deviation of Liverpool John Moores questionnaire (Jet-lag (A), Sleep (B), Function (C), Diet (D), Bowel mvt (movement (E)), RESTQ-Sport (RESTQ total stress recovery score (REST-Q-TSRS); F) and a Likert scale (1-5) for sleep restfulness (G). ° represents a small effect size ($d = 0.20$-0.49) compared to baseline, ^ represents a moderate effect size ($d = 0.50$-0.79), # represents a large effect size ($d > 0.80$). B: Baseline; D2: day 2, and so forth.