The effect of an acute sleep hygiene strategy following a late-night soccer match on recovery of players

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Abstract

Elite soccer players are at risk of reduced recovery following periods of sleep disruption, particularly following late-night matches. It remains unknown whether improving sleep quality or quantity in such scenarios can improve post-match recovery. Therefore, the aim of this study was to investigate the effect of an acute sleep hygiene strategy (SHS) on physical and perceptual recovery of players following a late-night soccer match. In a randomised cross-over design, two highly-trained amateur teams (20 players) played two late-night (20:45) friendly matches against each other seven days apart. Players completed a SHS after the match or proceeded with their normal post-game routine (NSHS). Over the ensuing 48 h, objective sleep parameters (sleep duration, onset latency, efficiency, wake episodes), countermovement jump (CMJ; height, force production), YoYo Intermittent Recovery test (YYIR2; distance, maximum heart rate, lactate), venous blood (creatine kinase, urea and *c*-reactive protein) and perceived recovery and stress markers were collected. Sleep duration was significantly greater in SHS compared to NSHS on match night ($P=0.002$, $d=1.50$), with NSHS significantly less than baseline ($P<0.001$, $d=1.95$). Significant greater wake episodes occurred on match night for SHS ($P=0.04$, $d=1.01$), without significant differences between- or within-conditions for sleep onset latency ($P=0.12$), efficiency ($P=0.39$) or wake episode duration ($P=0.07$). No significant differences were observed between conditions for any physical performance or venous blood marker (all $P>0.05$); although maximum heart rate during the YYIR2 was significantly higher in NSHS than SHS at 36 h post-match ($P=0.01$; $d=0.81$). There were no significant differences between conditions for perceptual 'overall recovery' ($P=0.47$) or 'overall stress' ($P=0.17$). Overall, an acute SHS improved sleep quantity following a late-night soccer match; albeit without any improvement in physical performance, perceptual recovery or blood-borne markers of muscle damage and inflammation.

Introduction

In professional soccer it is important to achieve an adequate balance between the stress of training/games and recovery to ensure optimal physical preparation, particularly during the competitive season (Nédélec et al., 2013; Meyer et al., 2014). Though matches are expected to cause increased strain on players, factors that prolong or result in inadequate post-match recovery can potentially induce greater symptoms of fatigue and reduced performance (Nédélec et al., 2013). Sleep is often postulated as an essential component of recovery (Halson, 2008; Samuels, 2008), and given the regularity of late-night matches, is particularly applicable to elite soccer players (Nédélec et al., 2013; Meyer et al., 2014; Fullagar, 2015). However, despite the widely held assumption that sleep aids the recovery process, to date there is limited evidence to support the notion that the improvement of sleep indices (e.g. sleep duration and/or quality) can aid the recovery of physical or perceptual function in athletes, let alone soccer players. This is most likely due to the complexity of sleep function, contrasting sporting environments and the variability in the individual requirements for sleep (Fullagar et al., 2015b). Accordingly, the interaction between the improvement of sleep quality/quantity and recovery in soccer, especially following late-night matches, is an issue that remains to be fully addressed.

Although limited evidence supports elite soccer players as healthy sleepers in 'normal' situations i.e. rest days and training (Meyer et al., 2014; Fullagar, 2015), there are instances whereby sleep may be disrupted. For example, regular early training session start times can lead to desynchronization during off days in athletes i.e. in swimmers (Sargent et al , 2014), although such evidence in association in soccer players is lacking. It is generally accepted that elite players are sensitive to disruptions to their natural sleep environment (Drust et al., 2005; Nédélec et al., 2013; Fullagar et al., 2015a). For example, late-night matches are often scheduled during periods of congested fixtures (i.e. multiple games in seven days, such as UEFA Champions League and national team matches). These later kick-off times (20:45) invariably result in late-night finishes to matches and in turn, players reporting a loss of sleep compared to normal (Meyer et al., 2014). This reduction in sleep quantity and quality, particularly when training or travel demands are fixed the next day, is proposed to result in inadequate physical and perceptual recovery (Nédélec et al., 2013; Skein et al., 2013).

The effects of sleep disturbance encountered after night soccer matches may be long-lasting and thus altering the sleep in the ensuing days after the match. Despite the lack of explicit evidence in footballers, it is known that reductions in non-rapid eye movement (NREM) sleep can disrupt energy conservation and nervous system recuperation (Stickgold, 2005). Furthermore, reductions in rapid eye movement (REM) sleep can affect periodic brain activation, localized recuperative processes and emotional regulation (Stickgold, 2005; Vyazovskiy & Delogu, 2014). However, it remains unknown whether an improvement in sleep duration or quality can improve the rate of perceived or physical recovery following compromised sleep (i.e. late-night matches). Even then, recovery may incorporate numerous dimensions, including: physical performance (e.g. countermovement jump), physiological (e.g. blood-borne damage markers) and perceptual (wellness/mood) (Rattray et al., 2015). Thus, with players at risk of hindered recovery following sleep disrupted periods, further research is required to examine the relationship between sleep as a post-match intervention and the recovery of physical performance, physiological state and perceptual wellness (Rattray et al., 2015).

To help counter situations of compromised sleep, the use of sleep hygiene strategies (SHS) has recently been proposed for athletes (Halson, 2014; Fullagar et al., 2015a; Fullagar et al., 2015b). SHS were first introduced by medical physicians in an attempt to provide recommendations for patients with sleep disorders i.e. insomnia; (Hauri, 1977). In general, these strategies are aimed at avoiding behaviour that might compromise normal sleep or at supporting/initiating the behaviour that promotes good sleep (Nédélec et al., 2013). For example, various techniques including turning off all technological devices at least 30 min before bedtime, abstinence from watching TV/using laptops while in bed, creating cool, dark quiet rooms and wearing eye masks have been proposed (Malone, 2011). SHS have been shown to improve sleep quality and onset latency in university students and reduced sleep irregularity in adolescents (Stepanski & Wyatt, 2003). Further, SHS often represent ongoing habits that promote improved sleep behaviours. However, from a football perspective, little is known about either the chronic or acute effects of SHS and post-exercise recovery as related to performance.

Given the absence of evidence, it could be hypothesised that increasing sleep duration/quality may alleviate the decrements in physiological and cognitive performance caused by sleep loss. For instance, sleep extension has been shown to improve vigour, mood and athletic performance; including sprint speed, basketball shooting accuracy and reaction time (Mah et al., 2011). Further preliminary evidence indicates adhering to some of the previous SHS recommendations improves sleep quantity, resulting in a reduction in perceived soreness and fatigue in tennis players (Duffield et al., 2014). However, given the regularity of late-night matches and the proposed benefits of sleep, the effects of SHS on performance recovery following late-night soccer matches remain unknown. Accordingly, the aim of this study was to investigate the effect of an acute sleep hygiene strategy on physical, physiological and psychological recovery of soccer players following a late-night match.

Materials and methods

Subjects:

Twenty highly-trained amateur soccer players volunteered to participate in the study, providing written and verbal informed consent following full disclosure of all procedures. Additionally, participants underwent a medical check-up consisting of medical history, physical examination, 12-lead resting electrocardiogram and blood pressure measurement. Participants were also screened with a medical questionnaire (local institute Erholungs-Beanspruchungs-Fragebogen), and if necessary, excluded if they had past sleep related disorders, or were currently on medications possibly affecting sleep. All players were deemed eligible following this process and thus partook in the investigation. This study abided with the Declaration of Helsinki and was approved by the local Human Research Ethics Committee.

Experimental design

In a randomised cross-over design, two semi-professional teams (5th and 6th division of the German Football Federation) played two (friendly) matches against each other during the mid-season preparation period of the German 2014/15 soccer year. Matches were separated by seven days and played on the same ground at the same late-night kick-off time of 20:45 (to simulate kick-off time in the UEFA Champions League or national team home games). Both matches were officiated by a German Football Federation accredited referee and followed official FIFA™ rules and regulations. The same players played during both games, with all players playing at least 70 min in each match (excluding goalkeepers). Following each match, players completed two days of structured testing and training. Specifically, testing times and procedures were standardised by the researchers each morning, while each training session was set at the discretion of the coaches but replicated for volume and intensity on both weeks. Consuming alcohol/caffeine was prevented over the duration of the testing periods. To retain inclusion for data analysis, all data points were required from for all measurement variables (unless otherwise stated).

In a randomised order (both within- and between-teams), players then either completed a SHS after the match or proceeded with their normal post-game routine without any assistance or recommendations for sleep (NSHS). The SHS group proceeded to their bedrooms at 23:45 in preparation for sleep. The SHS included ensuring players were in bed rooms as soon as possible with lights dimmed, and provided (optionally) with ear plugs and eye-masks in cool temperature rooms (~17°C). Further, no technological or light stimulation was allowed ~15-30 min prior to bedtime. To ensure this mobile phones and TV remotes were collected for the night. Finally, lights were turned off at 00:00 which was deemed the earliest manageable bedtime given the end of the match. In contrast, players in the control condition (NSHS) were permitted to undertake normal activities (but onsite under the supervision of the research team within the common room at the training centre) following each match. These players remained awake until they were allowed to go to bed at 02:00 am. The time was chosen both because of previous anecdotal reports and researcher experience of players' usual bedtime at this time following night matches (Meyer et al., 2014; Fullagar, 2015). The NSHS group was allowed to use their mobile phones/TV as they saw fit. All protocols were adhered to and the research team monitored all rooms until bedtime (including personally turning off the lights at bedtime). All players from both conditions were woken by the research team at 07:30 the next morning in preparation for breakfast and measurements.

Experimental procedures

All players were familiarised with procedures and measures in the two weeks prior to commencement. Players resided at the onsite Olympic Training Centre for the night of and the night following each match. During both the control and intervention phase, players slept in the same bedding conditions in single beds, double rooms and paired with the same player over both conditions, whilst they provided their own pillows from home for comfort. The match itself was played at a local stadium of a semi-professional team on an artificial turf surface, 5 min drive from the training centre. Environmental conditions were similar during both matches (range 2-6^{o}C, floodlights emitting 200 lux (within official German FA sub-elite division requirements) and 74-82% relative humidity)). Players finished playing both games at ~ 22:30, commenced a standardised light active recovery and stretching session while listening to their respective coaches (22:30-22:40), and showered at approximately 22:40-23:00, before returning directly to the training centre and commencing dinner at ~ 23:10. On the day of and for the two days following the match, players were provided meals. Meals were offered in a buffet form and although not identical, consisted of similar nutritional content of a serving of meat (chicken), vegetables (potatoes and mixed green salad) and pasta/rice. Moreover, players took photographs on mobile phones of their meals each week to attempt to match portioning over both conditions. Players' personal liquid intake immediately post-match was not controlled; although the consumption of protein or recovery shakes, caffeine or alcohol was prevented and intake was similarly asked to be replicated over the span of the study.

Measurements:

Sleep measures

Each of the three days prior to each game (mean baseline), the night of (match night) and the night following (match night + 1), objective (SenseWear actigraphy; BodyMedia, Pittsburgh, Pennsylvania) and subjective sleep data (subjective sleep diary) were collected. All data points were required for data to be retained (six players excluded for either lack of baseline measure or equipment failure; 14 players included for final analyses). Objective data was downloaded via relevant software and generated using manufacturers' algorithms (SenseWear 7.0 Professional, BodyMedia, Pittsburgh, Pennsylvania). Objective measures included sleep duration, time in bed, sleep onset latency, sleep efficiency, wake episodes (including wake episode duration). It is recognised polysomnography (PSG) is the most accurate method to quantify sleep, however given the field-based nature of this study, actigraphy was used in this investigation. Subjective measures included perceived sleep restfulness (very restful, pretty restful, average, hardly restful and not at all restful) and general recovery state upon waking (Likert scale 0 (not at all recovered) to 6 (absolutely recovered)) (Kölling et al., 2014). Players refrained from napping on the day following the match but were allowed to engage in napping activity on the second day following the match. In addition, sleep chronotype was evaluated using the Morningness-Eveningness Questionnaire (MEQ) (Horne & Ostberg, 1976) to determine if sleep chronotype influenced sleep variables. This questionnaire uses 19 questions regarding to sleep behaviour, with a cumulative score used to categorise individuals as 'morning' types (scores 59-86), 'evening' types (14-41) and neither types ('intermediate'; 42-58) (Horne & Ostberg, 1976; Lastella et al., 2011).

Match and training measures

External (global positioning systems [GPS]) and internal (heart rate [HR]) load markers, along with rating of perceived exertion (RPE; CR-10 scale) (Borg, 1998) to calculate training load (session-RPE x min) (Foster et al., 2001), were collected following each match. In addition, load responses to one standardised training session the day following the match (16:00: ~19 h post-match; Match+ 1 PM) and two sessions two days after the match (10:30; ~37.5 h post-match; Match+2 AM and 16:00: ~ 43 h post-match; Match+2 PM) were collected. Whilst each training session was composed separately by the respective team coaches, they were replicated for drill type and duration and basic skill composition across both weeks. Players also completed a short 'recovery run' on the morning after the match (~ 13 h post-match); however load responses to this run were not collected. Rather than scheduled for research *per se*, these sessions were requested by the teams to form part of their mid-season preparation phase. GPS variables included total distance (m), mean speed (m/min), peak speed (m/s), high intensity running distance (distance (m) covered above each player's previously determined speed at individual anaerobic threshold (Stegmann et al., 1981)), mean HR (bpm) and number of very high intensity bouts (defined as the number of bouts performed above 19.8 km/h for more than 1 s (Carling et al., 2008)). During both training and match play players wore localised 2-Hz GPS systems (Adidas miCoach elite©, Adidas©, Nurumberg, Germany) on the back between scapulae within a customised undergarment (Adidas Climalite©). In addition, HR monitors were positioned within the customised undergarment allowing for the collection of average and peak HR data. Data was retained from players who completed at least five of the six available sessions (13 players retained for analyses). All data was extracted using the miCoach© software, processed in MatLab™ (where raw data was derived from the miCoach© system and analysed for each individual player by a trained analyst) and stored in Microsoft Excel 2007™.

Recovery measures

Recovery of exercise performance

Counter movement jump's (CMJ) were performed three days prior to the first match week (baseline) and 12 h and 36 h post-match to determine jump height (cm) and force production (N). CMJ were performed using a calibrated force platform (Quattro Jump, Type 9290AD, Kistler Instrument AG, Winterthur, Switzerland) and analysed using professional motion analysis software (Contemplas Bewegungs analyse, Contemplas Gmbh, Kempten, Germany). Jump height was determined as the height of centre of mass displacement, calculated from the recorded force and body mass. The CMJ began from an upright position, making a downward movement to a knee angle of approximately 90° and simultaneously beginning to push-off, whilst hands were placed upon hips. Thirty s of rest was allowed between 5 trials of each test, the maximum being used in subsequent analyses. A standardised 10-min warm-up preceded the jumps.

The YoYo Intermittent recovery test level two (YYIR2; (Bangsbo et al., 2008)) was performed indoors on a hard wooden floor (basketball court). The test was performed immediately after the CMJ and consisted of repeated 2x20-m runs at a progressively increased speed controlled by audio beeps from a laptop and speakers (Bangsbo et al., 2008). When a player had failed twice to reach the finish line in time, the distance covered was recorded as the test result. In addition, maximum HR (Polar RS 400, Polar Electro, Kempele, Finnland) and RPE (Borg, 1998) were also recorded. Capillary whole blood samples from the ear were also collected prior to the test, immediately after finishing the test and 1, 3 and 5 min post to determine maximum lactate concentration to ensure comparable exhaustion in both conditions (18 players included for final analyses).

Physiological recovery responses to training

In addition to baseline measures (3 d prior to first match week, NB: performed only once), prior to both afternoon training sessions (18 h and 42 h post-match, respectively) all subjects completed a submaximal interval-based running test (Heart Rate Interval Monitoring System (HIMS) (Lamberts & Lambert, 2009). These tests were performed under similar environmental conditions on the artificial turf where training and match play took place. The full protocol for the HIMS is available elsewhere (Lamberts & Lambert, 2009); however, it comprises 4x2-min stages (S1, S2, S3 and S4) repeated 2x20-m runs with increasing speeds from 8.4, 9.6, 10.8, and 12.0 km/h, respectively as controlled by audio signals. After each 2-min stage, players rest and stand upright for 1 min. After the final stage (S4) there is a 2-min recovery period. Mean HR (derived from the HR monitors within the Adidas© vests and miCoach© system) for each exercise stage and each recovery period was calculated from the last final 15 s of each period to produce a final value of absolute decrease in HR during recovery (HRR) and recovery HR expressed as a percentage of the mean HR during the last minute of the stage (HRr%) for each stage (Lamberts & Lambert, 2009).

Blood-borne markers of muscle damage and inflammation

Venous blood samples were obtained at 2 h prior to each match (venous blood baseline) and 10 h, 20 h, 34 h and 44 h post-match from the antecubital vein by standard protocol, following 5 min of seated rest. Serum tubes were centrifuged at 4000 revolutions per minute for five min, aliquoted, then measured for c-reactive protein (CRP), creatine kinase (CK) and urea (U) using a Unicel DxC600 synchronised clinical system (Beckmann Coulter GmbH, Krefeld, Germany). Remaining serum samples were then stored frozen at -20°C until analysis. Blood count was determined automatically by an ACT 5 Diff AL (Beckmann Coulter GmbH, Krefeld, Germany). Given the high physical demands and noted skeletal muscle damage following matches, these parameters were chosen as representative markers of recovery due to their known response to exercise-induced stress and their prevalent use in the fatigue and recovery literature. For all blood recovery parameters, all data points were required for data to be retained (20 players included for final analyses).

Psychological recovery

Players completed a perceptual fatigue and recovery questionnaire (Short version of the Acute Recovery and Stress Questionnaire; SRSS (Kölling et al., 2014)) at baseline (2 h prior to each match), the morning after the match (12 h post) and after each training session (24 h post, 36 h post and 48 h post). The SRSS consists of eight adjectives describing physical, emotional, mental, and overall aspects of recovery and stress (recovery: 'Physical Performance Capability', 'Mental Performance Capability', 'Emotional Balance', 'Overall Recovery' and stress: 'Muscular Stress', 'Lack of Activation, 'Emotional Imbalance', and 'Overall Stress' (Kölling et al., 2014). These items were assessed with a seven-point Likert-type scale ranging from 0 (not at all) to 6 (absolutely) and are designed to be analysed and interpreted separately. Items 'overall recovery' and 'overall stress' are reported herein. In addition, morning subjective measures (diary completed upon waking) including perceived sleep restfulness and general recovery state, as mentioned previously were collected (14 players included for final analyses).

Statistical Analysis

Data are presented as means±SD. A two-way repeated measures ANOVA (time x condition) was used to compare differences between all time-points for both conditions (SHS and NSHS) for sleep parameters and all recovery markers (physical, physiological responses to training, blood-borne and psychological). A two-way repeated measures ANOVA was also used to compare differences between time points for both conditions (SHS and NSHS) for all physical and perceptual training variables. Where significant effects were observed, a Scheffé post-hoc test was performed. Independent *t*-tests were used to i) determine differences between matches for all physical and perceptual match variables and ii) determine differences between sleep chronotypes for all measures of sleep variables. Dependant t-tests were used to determine whether an order effect was observed from the first to the second weekend. $P<0.05$

for the α-error was accepted as significance for all statistical comparisons. All statistical procedures were performed using the statistical package Statistica© Version 7 (StatSoft Inc©, Tulsa, OK). Furthermore, standardised effect size (Cohen's d; ES) analyses were used to interpret the magnitude of the mean differences between conditions for all sleep and recovery parameters with $d<0.20$ (trivial), $d=0.20$-0.49 (small), $d=0.50$-0.79 (medium), $d\geq0.80$ (large) (Cohen, 1988). Due to the multitude of analyses only large ES are reported herein.

Results

Sleep measures

All sleep variables for both conditions are presented in Table 1. Individual cases for sleep duration are additionally illustrated in Figure 1. No significant differences were evident between any baseline measures prior to both conditions (all $P>0.05$). Sleep duration was significantly reduced on match night from baseline in the NSHS condition ($P<0.001$, $d=1.95$) but not in the SHS condition ($d=0.73$). On match night, sleep duration was significantly greater in SHS compared to NSHS ($P=0.002$, $d=1.50$), whilst there were also significant within-condition differences apparent for NSHS between match night and match night +1 ($P<0.001$, $d=2.22$). Large ES were also present in the SHS condition where sleep duration improved on match night + 1 compared to match night ($d=0.82$). A significant difference was evident between conditions for wake episodes on match night, with more wake episodes present for SHS ($P=0.04$, $d=1.01$). There were no significant differences between- or within-conditions for sleep onset latency ($P=0.12$), sleep efficiency ($P=0.39$) or wake episode duration ($P=0.07$); although large ES were evident between conditions for wake episode duration (longer in the SHS condition; $d=0.90$). Mean MEQ score was 49 ± 6 (range: 36-58). Four participants were classified as 'evening types' (14-41) and the remaining 16 as 'neither' types (42-58); thus the analysis of the difference between 'evening' and 'morning' chronotypes was abandoned. There was a significant order effect present on the second weekend compared to the first for both sleep onset latency and sleep efficiency (improvement; $P<0.05$); however no other order effects were present for any other match, training or recovery measure.

Match and training measures

There were no significant differences between matches for either condition for any match-based physical or perceptual variable, or any physical performance or perceptual response data from training sessions performed following the match between either condition (all $P>0.05$; Table 2).

Recovery measures

Recovery of exercise performance

Mean and individual recovery responses of the primary exercise performance parameters for both conditions at 12 h post following the late-night match are presented in Figure 2. There were no significant differences between conditions for CMJ height (P=0.53) or force production (P=0.49) at either 12 h post or 36 h post; although, CMJ height was significantly less at 12 h post in the NSHS condition compared to baseline (P=0.04; *d*=0.81). Within conditions, CMJ height was significantly greater 12 h post than 36 h post for SHS (P=0.03; *d*=0.22). There were no significant differences between conditions for YYIR2 distance (P=0.50), RPE (P=0.70) or maximal lactate (P=0.75) for 12 h post or 36 h post; although, there were significant reductions in YYIR2 distance in the NSHS condition (P=0.04; *d*=0.51) at 12 h post and in the SHS condition 12 h post (P=0.01; *d*=0.71) and 36 h post (P=0.01; *d*=0.69) compared to baseline. No significant between-condition differences were evident for max HR during the YYIR2 at 12 h post (P=0.71); however max HR was significantly higher in NSHS than SHS at 36 h post (P=0.01; *d*=0.69).

Physiological recovery responses to training (HIMS)

Physiological HR responses to the HIMS are presented in Table 3. There were no significant differences in HRR recovery or HRr% between conditions at any stage for either training session performed at 18 h and 42 h post-match respectively (all P>0.05).

Blood-based variables

No significant differences were evident between conditions for any blood parameter at any time point (P>0.05; Table 3). The only large ES present between conditions was for CK at baseline (*d*=1.29).

Psychological recovery

Mean SRSS scores are presented in Figure 3. Following the late-night match 'overall recovery' showed no significant differences between SHS and NSHS (P=0.47), nor were there any significant differences between conditions for 'overall stress' (P=0.17). No large ES were present between conditions for either marker at any time point. There were no significant differences between conditions (all P>0.05) for recovery states upon waking in the morning following the match (SHS: 2.7 ± 0.9; NSHS: 2.8 ± 0.7) or for the percentage of answers for restfulness (sleep quality) for SHS (very restful: 0%, pretty restful: 24%, average 57%, hardly restful: 14% and not all restful: 5%) compared to NSHS (very restful: 0%, pretty restful: 19%, average 52%, hardly restful: 17% and not all restful: 12%).

Discussion

The present study investigated the effect of an acute SHS on the recovery of players following a late-night soccer match. The SHS increased sleep duration compared to NSHS, despite significantly more wake episodes and large ES to suggest longer wake episode durations. Regardless, players subjectively reported no difference in sleep quality between conditions. Of novel interest, no significant improvements in perceived stress and recovery, the recovery of exercise performance, or blood-borne markers of damage and inflammation were present. SHS appeared to have no effect on overall training loads, with players covering similar distances and intensities during the standardised training sessions following both conditions on the two days following the match. The present findings suggest soccer players may consider acute SHS strategies where possible following a late-night match to ensure sufficient volume of sleep; however there appears to be no additional benefit for the recovery of performance.

The effect of SHS on sleep quality and quantity has previously been studied in certain populations, with SHS shown to improve sleep quality and onset latency in university students (Stepanski & Wyatt, 2003). Comparatively, the effect of SHS in normal sleepers is equivocal (Stepanski & Wyatt, 2003). Interestingly, there is limited data from athletes, with little known about the interaction between SHS and sleep, let alone ensuing improved recovery (Halson, 2014). Recently, (Duffield et al., 2014) investigated the effect of a SHS (21:00 bed time; low-light (8 ± 5 lux), cool (19 ± 2^{o}C) environment, no technology 30 min prior to bedtime)) on sleep duration/quality and recovery of elite tennis players following simulated match play. SHS was shown to improve sleep quantity (increased time in bed and min asleep;)), which is comparable to the present study, with SHS significantly improving sleep duration. Such findings are likely given the enforced earlier bedtime as part of the SHS and was a primary aim of the SHS strategy. Consequently, ; players were in bed as soon as possible to maximise exposure to sleeping environments and then assisted them within this environment. Although speculative, it is also possible the removal of technology prior to bedtime aided the subsequent improvement in sleep duration, especially given the enforced earlier bed time. For example, bright light emitted from portable technological devices can suppress melatonin and disrupt ensuing subsequent sleeping quantity and quality (ENETR REF) – though this currently unsubstantiated here. Regardless of the mechanisms responsible, given elite soccer players report large reductions in sleep quantity following night matches (Meyer et al., 2014), this improvement in sleep duration in our study is a both a novel and practical outcome for soccer players.

Despite the increased sleep duration with SHS, significantly greater wake episodes and a trend towards increased wake episode duration (38.9 ± 27.5 v 20.0 ± 18.1 for SHS and NSHS) and sleep onset latency (21.1 ± 16.9 min v 8.8 ± 7.1 min for SHS and NSHS) existed. The inverse responses of these sleep variables is likely due to the context of the players attempting sleep. Specifically, the homeostatic drive for sleep in the NSHS condition, given the prolonged duration of wakefulness, likely resulted in faster sleep onset times and reduced awakening (Vyazovskiy & Delogu, 2014). Conversely, in the SHS condition, players were likely to still be highly aroused when attempting to fall asleep following the night match; hence resulting in longer sleep onset latency (Vyazovsky and Delogu, 2014). That is, enforcing an earlier bedtime may have led to a delayed sleep onset as this went against players' sleep, and consequentially a low sleep propensity. In one sense, this likely further justifies the need to use behavioural interventions to aid sleep at a time where players may still be reluctant to attempt sleep, thereby by providing conditions which are conducive to assisting the drive for sleep to override the drive for wakefulness. That said, it should be noted that other reasons for the inverse response of sleep variables could also include the unfamiliar sleeping environment of the training centre or the evening exposure to light (Malone, 2011), even though these factors were standardised. Thus, whilst sleep duration can be extended in a SHS following a late-night match it should be acknowledged that players may face difficulties initiating sleep when enforced with earlier bed times post-match.

The acute SHS showed limited to no effect on markers of physical recovery. These results concur with previous research which has investigated the effect of sleep on recovery-post exercise (Duffield et al., 2014), and are not unexpected considering a meta-analysis revealed that psychological mood and fatigue states are more affected by sleep deprivation than both cognitive and motor performance (Pilcher & Huffcutt, 1996; Rattray et al., 2015). It should be noted that some physiological effects were present, with maximum HR significantly higher during the YYIR2 in the NSHS condition 36 h post-match. This could suggest that SHS may reduce the sympathetic capacity during intermittent-sprint performance; although a lack of an effect 12 h post likely limits such an assumption. Similarly, whilst the reduction in CMJ height from 12 h post to 36 h post in SHS could lead to the postulation of SHS enhancing training output (and thus leading to increased fatigue and a reduction in lower body power), the lack of any differences between conditions for any training variable likely negates such theories. Indeed, outside these findings the majority of effects on the recovery of exercise performance and physiological recovery were non-existent.

Further explanation The restricted napping in the 24 h post-match could hinder improvements in the 24-48 h post-match recovery via prevention of the ‘repayment’ of any sleep debt due to the late-night finish. Indeed, the timing, duration and performance benefits of napping have been well documented (WATERHOUSE REF). However, it should be noted that naps were avoided in the day following the match in our study to ensure that any effects on recovery were a result of the SHS rather than naps.

The SHS also showed no effect on blood-borne markers of recovery and inflammation. Although the physical demands of the match and subsequent training sessions led to an increase in inflammatory markers in this study (e.g. CK), the observed increase sleep duration was not sufficient to alter these responses. This is in line with our previous knowledge of sleep deprivation studies where nights of complete sleep loss (e.g. 0 h), rather than partial sleep deprivation (e.g. 3-5 h) and a night of normal sleep (~8 h), are more likely to affect measures of post-exercise recovery (Skein et al., 2013; Fullagar et al., 2015a; Fullagar et al., 2015b). Therefore, it may be speculated that a larger sleep difference between conditions during the night (from both a duration and quality perspective) is required to affect the majority of physical and physiological measures of recovery.

Similar to the lack of an improvement in performance recovery there were no significant improvements in measures of psychological stress and recovery in the sleep hygiene condition. These findings differ with previous results from the aforementioned work by Duffield et al. (2014) with large effect sizes evident for perceived soreness and feelings of fatigue the following morning after the sleep hygiene intervention in their study. Indeed, our results are surprising given almost all forms of extensive sleep deprivation result in increased negative psychological mood states (e.g. fatigue, loss of vigour, sleepiness, and confusion (Fullagar, Skorski, et al., 2015; S. Halson, 2014; Pilcher & Huffcutt, 1996;),. It has been shown that sleep disturbances lead to feelings of waking unrefreshed and greater perceptual fatigue (Koutedakis Y, Budgett R, Faulmann L), It would appear a greater sleep differential between conditions is required to improve perceptual recovery and stress. It should be further noted that the effect of the SHS was also only acutely assessed in the present study (i.e. after one late-night soccer match). Elite soccer players who regularly play late-night matches may consequently enjoy greater benefit from the SHS if it were applied regularly throughout the season, i.e. after each night soccer match.

Given this was a field-based study there are certain limitations that need to be acknowledged. Firstly, it is assumed late-night matches cause reductions in recovery, though the evidence to highlight this point seems lacking in the research literature. From an equipment perspective, the ‘gold standard’ of sleep quantity and quality monitoring is recognised as via PSG (Halson, 2008; Halson, 2014). Without the use of this technique in this investigation, we recognise the limitations of interpreting sleep data from actigraphy; however, for primarily for logistical reasons the use of PSG was not possible. Moreover, both actigraphy and subjective reports have been shown to not significantly differ to PSG data for total sleep time and sleep efficiency (Kushida et al., 2001). Secondly, the two matches played were ‘friendly’ fixtures. This limits the applicability of our results to actual matches, where numerous other extraneous disruptions to sleep can exist; including, post-match interviews, press conferences, anxiety and social/club demands (Fullagar et al., 2015a). However, by excluding such factors and attempting to control others (i.e. timing of the match, time of sleep, time of wake, sleeping conditions) our results possess some internal validity for a field-based study. Although post-match nutrition was comprised of similar nutritional content, nutrition was not individually monitored (e.g. weighing of meals and detailed ingredients). This may have affected our results as some nutritional compounds are known to affect sleep (i.e. protein and sleep onset; (Halson, 2014)). Nonetheless, every attempt in a field setting was made to match meals over both weeks, similar type of meals were served and photos of portions were recorded to attempt to match nutritional intake over both conditions. It could be argued that the primary component of our intervention was the pure extension of sleeping hours. However, from our perspective the enforced bedtime is *part* of an 'acute sleep hygiene strategy', but in recognizing this, we are attempting to make it easier with other factors i.e. no technology. Finally, due to the nature of the strategy imposed, blinding for the SHS intervention was not possible.

In summary, an acute SHS increased sleep duration compared to a NSHS following a late-night soccer match; although there were significantly more wake episodes in the SHS and players reported similar sleep qualities between conditions. The SHS did not improve measures of psychological stress and recovery, or the recovery of exercise performance. Furthermore, there were no significant differences between conditions for blood-borne markers of muscle damage and inflammation or physiological responses to training (HIMS). More research is required to assess whether a larger sleep differential (e.g. longer duration and higher quality sleep in the SHS condition) is required to affect the physical and physiological markers measured in this study. In addition, the effect of SHS on recovery in real-world elite environments requires further investigation, especially over the course of a season. For instance, there would an increased likelihood for potential benefits if sleep behaviour was modified for more than an acute period. Taken collectively, the present findings suggest soccer players might consider SHS strategies where possible following a late-night match to promote restorative sleep; however there appears to be no additional benefit for the recovery of acute performance or perceptual recovery outcomes.

Declaration of interest

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Figure captions

Figure 1: Individual cases (*n*=14) of sleep duration for either a non-sleep hygiene strategy (A) or a sleep hygiene strategy (B) following a late-night soccer match. B: baseline;

MN: match night; MN + 1: match night plus 1. * Significant difference between conditions (P<0.05). # Significant difference within conditions (P<0.05). Shaded bars represent condition. Horizontal black connected lines represent individual recovery responses.

Figure 2: Mean and individual recovery of exercise performance parameters in response to a either a non-sleep hygiene strategy (NSHS) or a sleep hygiene strategy (SHS) 12 h post following a late-night soccer match. A: Counter movement jump height (CMJ; cm), B: Countermovement jump force production (N); C: YoYo Intermittent recovery level two performance (YYIR2; distance in m), D: YoYo Intermittent recovery level two (YYIR2; max heart rate, beats per minute). * Significant difference between conditions. Shaded bars represent condition. Horizontal black connected lines represent individual recovery responses.

Figure 3: Subjective A) recovery and B) stress questionnaire responses ("Overall recovery and stress" ; 0 (not at all) to 6 (absolutely) (17)) at baseline (prior to the match), the morning after the match (12 h post-match) and after each training session (24 h, 36 h and 48 h post). Significant differences between conditions (P<0.05); Significant differences within conditions to baseline (SHP; P<0.05); # Significant differences within conditions to baseline (NSHP; P<0.05).