

Effects of a sleep hygiene period on the match-loads and performance indicators of male university-level soccer players during a tournament

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DECLARATION

The co-authors of the two articles which form part of this dissertation (NWU-00299-21-A1-02), Dr A. Broodryk (supervisor) and Dr Mark Kramer (co-supervisor), hereby give permission to the candidate Mr Michael Prevoo to include the two articles as part of his master's dissertation. The contribution (i.e. supportive and advisory) of the co-authors was kept within limits of reason and, in this regard, allowed the student to submit this dissertation for the November 2023 examination in order to qualify for the June / July winter graduation ceremony.

Furthermore, this dissertation serves as a partial fulfilment of the requirements for the Magister Arts degree in Sports Science within PhASRec (Physical Activity in Sport and Recreation Research Focus Area – Faculty of Health Sciences) at the North-West University, Potchefstroom Campus, South Africa.



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PREFACE

The master thesis in front of you, “Effects of a sleep hygiene period on the match-loads and performance indicators of male university-level soccer players during a tournament”, has been written to fulfil the requirements of the degree in Human Movement Science at the North-West University. I devoted myself to researching and writing this thesis from January 2021 to February 2024.

I wanted to broaden my knowledge about the physical demands of another sports code that I am not accustomed to, as well as how to prepare myself to the best of my ability to perform on match days. I chose an area in the sporting world that will require me to develop new skills I did not have yet. I worked with GPS devices and HR monitors and did match analysis of games. I learnt how to manage my workload during busy times at work and deadlines during my studies. This has maximised the learning opportunities, for which I am grateful.

I would like to thank everyone who was part of the study. I would like to express gratitude to you, my reader, and I hope you find enjoyment in your reading.

Michael Prevoo

Pretoria, February, 2023

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ABSTRACT

Effects of a sleep hygiene period on the match-loads and performance indicators of male university-level soccer players during a tournament.

With soccer being one of the most popular sports worldwide and players training harder and competing in more competitions, a greater physiological demand is placed on their bodies. Recovery strategies are used to help athletes recover between training sessions, matches, and competitions. Athletes are advised to obtain eight hours of sleep per night to improve their mood, cognitive performance and decrease daytime sleepiness. Over the years, sleep hygiene principles have been implemented to aid in the quality and quantity of sleep obtained. Despite numerous publications, a gap still exists on what effect a Sleep Hygiene Intervention Period (SHP) has on real-life match Performance Indicators (PIs). Therefore, the main objectives of this study were to determine the effects of an SHP on the physical performance indicators of male university-level soccer players during a soccer tournament. Secondly, to determine the effect of an SHP on the internal [HR] and external (GPS) match demands of male university-level soccer players during a soccer tournament.

Sixteen soccer players from the North-West University participated in the study. Internal- and external match demands (rate of perceived exertion - RPE, heartrate - HR and global positioning systems - GPS), as well as numerous (PIs), were analysed over an entire tournament. For objective one, 14 matches (five matches: no-SHP, four matches consisting of SHP, and five matches: no-SHP), and for objective two, eight matches (two matches: no-SHP, four matches consisting of SHP, and two matches of no-SHP) were analysed. During the no-SHP, players continued with their own, normal sleep routines. For the SHP, players were required to adhere to at least 10 of a possible 16 sleep hygiene principles daily in their own home setting for at least a week prior to the match.

Comparing the different halves between the no-intervention and post-intervention conditions, the minimum HR ($p = 0.006$) and time spent in the medium HR zone ($p = 0.040$) were significantly higher during the SHP period compared to the second half. Following the intervention period total distance ($p = 0.003$), distance covered while running ($p = 0.006$), and jogging ($p = 0.001$) was higher than the no-SHP. Distances covered at different intensities showed significantly higher values for moderate ($p = 0.018$) and low intensities ($p = 0.009$). There were significantly more decelerations below -4 m/s^2 ($p = 0.033$) and between -3 to -4 m/s^2 ($p = 0.047$), as well as more accelerations between $3 - 4 \text{ m/s}^2$ ($p = 0.001$), and above four m/s^2 ($p = 0.005$).

A higher number of connections ($p = 0.05$) and dribbles ($p = 0.01$) were reported during the SHP. The number of passes ($p = 0.09$, $ES = 1.1$) and crosses ($p = 0.20$, $ES = 0.8$) demonstrated a large

and moderate effect size, respectively. Successful passes (24.9%), connections (38%), dribbles (47.3%), crosses (28.6%), successful passes in opposition half (10.2%), and shots taken in the penalty area (24.7%) improved during the SHP.

In conclusion, an SHP can lead to significantly better physical output measures as well as improvements in PIs during a soccer match of university-level soccer players when comparing an SHP to a no-SHP. Therefore, emphasising the importance of implementing sleep as a recovery tool for athletes and coaching staff to implement over a competitive season.

Keywords: *performance indicators, sleep hygiene, match loads, soccer, GPS, heart rate, video analysis*

OPSOMMING

Die effekte van 'n slaaphigiëne-periode op die wedstrydbeladings en prestasie-aanwysers van manlike universiteitsvlak-sokkerspelers gedurende 'n toernooi.

Met sokker as een van die mees gewilde sportsoorte wêreldwyd en spelers wat harder oefen en aan meer kompetisies deelneem, word 'n groter fisieke ladings op hul liggame geplaas. Herstelstrategieë word gebruik om atlete te help herstel tussen oefensessies, wedstryde en tussen kompetisies deur. Dit word aanbeveel dat atlete agt uur slaap per nag kry om hul gemoedstoestand, kognitiewe prestasie te verbeter, en dagtydse slaapheid te verminder. Oor die jare was daar al verskeie slaap higiëne beginsels geïmplementeer om die kwaliteit en kwantiteit slaap aan te help. Ten spyte van talle publikasies bestaan daar steeds 'n gaping oor die effek van 'n Slaap Higiëne Intervensie Periode (SHP) op regstreekse wedstrydprestasie-aanwysers. Die hoofdoelwitte van hierdie studie was om die effek van 'n slaap Higiëne-periode op die fisiese prestasie-aanwysers van manlike universiteitsvlak-sokkerspelers gedurende 'n sokkertoernooi te bepaal. Tweedens, om die effek van 'n slaaphigiëne-periode op die interne (harttempo) en eksterne (globale posisioneringsstelsel) wedstrydvereistes van manlike universiteitsvlak-sokkerspelers gedurende 'n sokkertoernooi te bepaal. Sestien sokkerspelers van die Noordwes-Universiteit het aan die studie deelgeneem.

Sestien sokkerspelers van die Noord-Wes Universiteit het deelgeneem aan die studie. Interne en eksterne wedstrydvereistes (persepsie van aangewende inspanning - RPE, globale posisioneringsstelsel - GPS, en harttempo - HT), sowel as verskeie prestasie-aanwysers, is geanaliseer gedurende 'n hele sokker toernooi. Vir doelwit een, was 14 wedstryde (vyf wedstryde: geen-SHP, vier wedstryde wat bestaan uit SHP, en vyf: geen-SHP), en vir doelwit twee, was agt wedstryde (twee wedstryde: geen-SHP, vier wedstryde wat bestaan uit SHP, en twee wedstryde van geen-SHP) geanaliseer. Gedurende die geen-SHP, kon spelers voortgaan met hul eie, normale slaap roetines. Gedurende die SHP, was spelers vereis om ten minste 10 van 'n moontlike 16 slaap higiëne beginsels daagliks te voltooi in hul eie huistoestande vir ten minste 'n week voor die aanvang van 'n wedstryd.

Met die vergelyking van die verskillende helftes tussen die geen-SHP en na-SHP, was die minimum harttempo ($p = 0,006$) en tyd spandeer in die medium harttempo-sone ($p = 0,040$) beduidend hoër gedurende die SHP in vergelyking met die tweede helfte. Na die SHP was die totale afstand ($p = 0,003$), afstand afgelê tydens hardloop ($p = 0,006$), en draf ($p = 0,001$) hoër as die geen-SHP. Afstande afgelê by verskillende intensiteite het beduidend hoër waardes getoon vir matige ($p = 0,018$) en lae intensiteite ($p = 0,009$). Daar was beduidend meer vertraging onder -4 m/s^2 ($p = 0,033$) en tussen -3 tot -4 m/s^2 ($p = 0,047$), sowel as meer versnellings tussen $3 - 4 \text{ m/s}^2$ ($p = 0,001$) en bo 4 m/s^2 ($p = 0,005$). 'n Hoër aantal konneksies ($p = 0,05$) en dribbels ($p =$

0,01) is gerapporteer tydens die SHP. Die aantal bal aangeë ($p = 0,09$, $ES = 1,1$) en oorsteekskoppe ($p = 0,20$, $ES = 0,8$) het onderskeidelik 'n groot en matige effekgrootte getoon. Suksesvolle bal aangeë (24,9%), konneksies (38%), dribbels (47,3%), oorsteekskoppe (28,6%), suksesvolle bal aangeë in die teenstander se helfte (10,2%), en doelskoppe geneem in die strafgebied (24,7%) het verbeter gedurende die SHP.

In samevatting, 'n SHP kan lei tot beduidende beter fisieke uitsetmaatstawwe asook verbeterings in prestasie-aanwysers gedurende 'n sokkerwedstryd van universiteitsvlak-sokkerspelers wanneer 'n SHP vergelyk word met 'n geen-SHP. Dus, beklemtoon SHP die belangrikheid van die implementering van slaap as 'n herstel metode deur atlete en die afrigtingsspan oor 'n kompeterende seisoen.

Sleutelwoorde: *Prestasie indikators, slaap higiene, wedstrydladings, sokker, GPS, harttempo, video analise*

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CHAPTER 1

INTRODUCTION

INTRODUCTION

1. INTRODUCTION

The purpose of this study is to determine the effects of a sleep hygiene period (SHP) on the internal and external match demands as well as match performance indicators (PIs) of male university-level soccer players over an entire competitive tournament. For the international readers, it is important to note that in this study, we will use the term “soccer” as it is the standard name in a South African context. It is well known within the literature how vital sleep is for full recovery and thereby enhancing performance. Soccer players are frequently exposed to various situations and conditions that can interfere with sleep, potentially leading to sleep deprivation and having an adverse effect on their playing performance. Previous studies indicated that athletes’ sleep is influenced by various factors, with traveling, late-night training and competitions and specific sleeping conditions among others. This has led researchers in developing various sleep hygiene recommendations to aid athletes in their quality and quantity of sleep. Therefore, the aim of this study is to determine the effects of a SHP on internal (heart rate), external (match and running demands) and match PIs of 15 male university-level soccer players. This may serve as an integral tool in the monitoring of university-level soccer players’ recovery during the ABC Motsepe League, therefore improving both their physical and match performance. A repeated measure, quantitative research design over an intervention period is anticipated to measure the set outcomes over an entire competitive period comprising of multiple matches.

2. PROBLEM STATEMENT

Soccer is considered the most viewed and most played sport globally, with up to 270 million male and female participants (Asken & Rabinovici, 2021:1049). The United States National University Athletic Association noted a high increase in soccer participation over the past decade, with 37 000 American university level soccer players, this resulted in a similar increase in the amount of match fixtures, and subsequently training sessions (Grooms *et al.*, 2013:782). Therefore, recovery is deemed vital for optimal performance, with sleep the most prevalent recovery modality that aids with physiological- and psychological recovery (Bonnar *et al.*, 2018:683; Vitale *et al.*, 2019:542). Unfortunately, up to 70% of soccer players experience insufficient sleep before the competition, largely attributed to anxiety and mood disturbances before competition (West, 2018:2).

Sleep deprivation (reducing sleep by 2.5 hours per night or total sleep deprivation over several days) in soccer players can be caused by various reasons, with noise and light exposure, congested schedules, late-night matches with the start time of the matches between 8:00 and

9:00 pm (which is adversely associated with exposure to bright light, caffeine, alcohol consumption, and travel fatigue), resulting in later bedtimes (Nèdèlèc *et al.*, 2015:1552; Vitale *et al.*, 2019:3). This, in turn, can lead to reduced sleep duration, resulting in increased melatonin secretion later on, thereby delaying the sleep onset (Fullagar *et al.*, 2015:12). Soccer players often have to travel for competitions, arriving a day before the match and spending a night in a hotel room, thereby experiencing the "*first night effect*" (Fullagar *et al.*, 2016:1337). Soccer players may struggle to adapt to unfamiliar sleeping environments, decreasing sleeping efficiency and total sleep time (Nèdèlèc *et al.*, 2015:1394-1397). This can lead to performance decrements, as Abbott *et al.* (2022:330) reported a decrease in total match distance of $\pm 700\text{m}$ during a soccer match following a night of sleep restriction. However, Abbott *et al.* (2018:285) found that there were no significant differences between GPS metrics and different match outcomes ($p > 0.05$). Sleep deprivation can cause lower arousal and decreased motivational levels, poor competition performance, concentration and attention, and higher pain perception and perceived exertion (West, 2018:2-6). To minimise the negative effects of any external distractions, as mentioned above, SHP have been developed to aid in sleep quality and -quantity.

Implementing an SHP can entail creating a cool ($19 \pm 2^\circ\text{C}$) and dark (8 ± 5 lux) environment, minimising noise and distraction, creating a comfortable place without any electronic devices, appropriate napping (five to 30 minutes), and a 30- to 60-minutes period of quite a relaxation before bedtime among others (Watson, 2017:416). Furthermore, active daytime behaviours (massages, stretching, electrical stimulation, and active recovery), consistent sleep patterns, using red-light treatment to improve subjective sleep, dawn-simulation (to slightly increase the illuminance before waking up in the morning of low-intensity light) can be used to create a SHP environment (Nèdèlèc *et al.*, 2015:1547). Research on the effectiveness of an SHP (5- to 7-week sleep extension phase) reported on cognitive-related tasks and the execution of specific-sport related skills such as shooting accuracy and reaction time improved when players increased their amount of sleep either through napping or nocturnal sleep (sleep period dictated by the circadian rhythm of sleep) (Bonnar *et al.*, 2018:695-696).

As soccer is a physically demanding sport, scientists implement various strategies to monitor performance and/or playing load. Two monitoring systems generally implemented are examining match performance indicators and internal- and external match demands by monitoring heart rate and movement analysis (using global positioning systems - GPS) (Strauss *et al.*, 2019:73).

A typical match comprises of various physical- (i.e., running speeds and direction alterations, sprinting, tackles, jumps among others) and technical actions (i.e., shooting, passing, and dribbling among others) (Nèdèlèc *et al.*, 2015:1547-1548). PIs in soccer are defined as "*the selection and combination of variables that define some aspect of performance*" (Harrop & Nevill,

2014:907). These variables specific to soccer are classified as total shots, shots on target, shots inside the penalty area, passes, successful passes, passes in the opposition half, fouls received, dribbled, crosses, corners, offsides committed, and yellow and red cards. Concerning match outcome, during the 2017 African Cup of Nations tournament, the winning teams executed more total shots, shots on target, offsides, overall fouls, red cards and yellow cards, whilst losing teams had more corners, total passes, accurate passes, and ball possession (Kubayi & Toriola, 2020:217). Yang *et al.* (2018:163) reported how successful teams demonstrated more ball possession in the opponent half, penalty area, and entries in the final third. Internal and external match demand such as work-to-rest ratio, average heart rate (HR), sprinting performance, and relative distance covered is impacted by the soccer player's position (Arrones *et al.*, 2014:7).

Rendering the internal- and external match demands, research indicates that a soccer player spent at least 65% of the duration of the match at intensities of 70-90% maximal heart rate (HR_{max}) and rarely went below 65% of HR_{max} ; furthermore, the exercise intensity during competitive matches varies between 70-80% of maximum oxygen consumption (VO_{2max}) or 80-90% of HR_{max} (Alexandre *et al.*, 2012:2890). Furthermore, central midfielders typically cover a mean distance of 12 027m, forwards about 11 254m. In contrast, central defenders cover the least distance (10 627m) per match (Di Salvo *et al.*, 2017:224-225). During 90-minute soccer match external midfielders cover the most distance whilst having ball possession (286m) and central defenders the least distance (119m) (Di Salvo *et al.*, 2017:224-225). A simple tool that can be used to evaluate the load regarding the volume and intensity of a training session or match is rating of perceived exertion (RPE) (Radziminski, 2021:1669). Using RPE to estimate internal load is beneficial for team sport bearing in mind its practical applicability and low cost (Marinho *et al.*, 2021:2).

Upon examining sleep duration on match days, Fullagar *et al.* (2016:6) reported how implementing an SHP (proceeded to their bedrooms at 23:45 after the game, lights in the bedroom are dimmed and the temperature at $\pm 17^{\circ}C$, and 15-30 min before bedtime no technological or light stimulation was allowed) significantly improved sleep duration as measured by actigraphy and questionnaires on match nights compared to normal post-game routine ($p = 0.002$). Research has shown that a basketball player's reaction time, endurance performance, sprint times and shooting accuracy improved with an increase in sleep duration ($p < 0.05 - 0.001$) (Mah *et al.*, 2011:946; West, 2018:5). Furthermore, the basketball player's mood and daytime sleepiness improved as measured by Epworth Sleepiness Scale scores and Profile of Mood States in basketball players following a five-to-seven-week period of extended sleep (Mah *et al.*, 2011:946).

According to West (2018:3), an increase in sleep quality and increased sleep duration can result in success in competition and training as various psychological- and physiological pathways are

affected by optimal sleep that range between eight to ten hours of sleep per night. Therefore, it is vital to educate a soccer player on the importance of effective sleep and ways to optimise it to ensure that they get quality sleep to regain performance levels and aid in the recovery process (Nèdèlèc *et al.*, 2015:1548).

In conclusion, the findings mentioned above indicate the high physical demands of an elite soccer player and how the successful execution of PIs in soccer will influence the match outcome (Russell & Kingsley, 2011:523). Elite soccer players have overall better performances in flexibility, strength, balance, and lower body explosive strength compared to the non-elite peers (Franca *et al.*, 2022:8). Most studies focus on how PIs influence the game outcome rather than the recovery process's effect on the PIs (Harrop & Nevill, 2014; Kubayi & Toriola, 2020). Very few research investigated the effects of a SHP on PIs and match demands (as measured by HR and global positioning systems) in soccer players. Therefore, the following research question is posed: what are the effects of a SHP on the internal- and external match demand and match PIs of university-level male soccer players? By answering this question, sports scientists and coaches can educate soccer players on their sleeping patterns and benefit their individual game and overall performance. Furthermore, this study may add valuable information to the current knowledge on how important sufficient sleep is for sports performance and the effectiveness of implementing a SHP.

3. OBJECTIVES

The objectives of this study are to determine:

- The effects of a sleep hygiene intervention period on the match performance indicators of male university-level soccer players during a soccer tournament (ABC Motsepe League).
- The effects of a sleep hygiene intervention period on the internal [HR] and external (GPS) match demands of male university-level soccer players across various matches and match halves during a soccer tournament (ABC Motsepe League).

4. HYPOTHESIS

The study is based on the following hypothesis:

- Due to a lack of scientific literature on the effects of an SHP on performance indicators, no set hypothesis could be established for the first aim of the study.
- A SHP will lead to significantly ($p < 0.05$) higher sprint velocities, time spent in high-intensity zones, player loads and lower HR_{max} values in male university-level soccer players compared to baseline values.

5. PROPOSED OUTPUTS

Chapter 1 – Introduction

Chapter 2 – Literature Overview: The importance of sleep on match performances in team sport athletes.

Chapter 3 – Research article 1: Effects of a sleep hygiene intervention period on the physical performance indicators of male university-level soccer players during a tournament (to be submitted to: *The Journal of Strength and Conditioning Research*).

Chapter 4 – Research article 2: The effects of a sleep hygiene intervention period on the internal and external, inter- and intra-match demands of male university-level soccer players during a tournament (to be submitted to: *The International Journal of Performance Analysis in Sport*).

Chapter 5 – Summary, conclusion, limitation, and recommendations.

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CHAPTER 2

**LITERATURE OVERVIEW: THE
IMPORTANCE OF SLEEP ON MATCH
PERFORMANCES IN TEAM SPORT
ATHLETES.**

1. INTRODUCTION

Invasion team-based sports such as soccer are physiologically and psychologically demanding; the magnitude of which can have appreciable effects on match performances (Spyrou *et al.*, 2020:1). To perform optimally throughout a competitive sports season, players should follow appropriate recovery interventions between tournaments, matches, and training (Strauss *et al.*, 2019:74). Recovery can be seen as a psychological and physiological healing process relative to time that follows physical fatigue induced by competition and/or training (Kellmann *et al.*, 2018:240). Appropriate recovery strategies are necessary for players to not just avoid health problems (e.g., injuries, overtraining, fatigue) but to perform at their best level during congested schedules (such as playing multiple matches within a short period of time whilst incorporating training sessions) (Doeven *et al.*, 2017:1). Therefore, the intrinsic balance between physiological and psychological stress and recovery is vital, especially when exposed to different organisational stressors such as team and cultural issues, personnel and leadership issues, environmental and logistical issues, and personal and performance issues (Arnold *et al.*, 2018:204). Unfortunately, the development and implementation of an adequate recovery regime for players remains a challenge (Bezuglov *et al.*, 2021:2). With all the various recovery strategies and modalities developed over the years to enhance sport performance, sleep is regarded as the most important recovery regime for and by athletes (Bezuglov *et al.*, 2021:2; Marshall *et al.*, 2016:61). In this regard, a survey on what recovery modalities a range of endurance athletes prefer, prolonged sleep and napping were rated between 61.4 – 81% among them (Bezuglov *et al.*, 2021:5). To highlight the importance of sleep for optimal sport performance, the innate relationship between acute and chronic sleep loss and various bodily systems are provided in Figure 1 (Balk *et al.*, 2017:4).

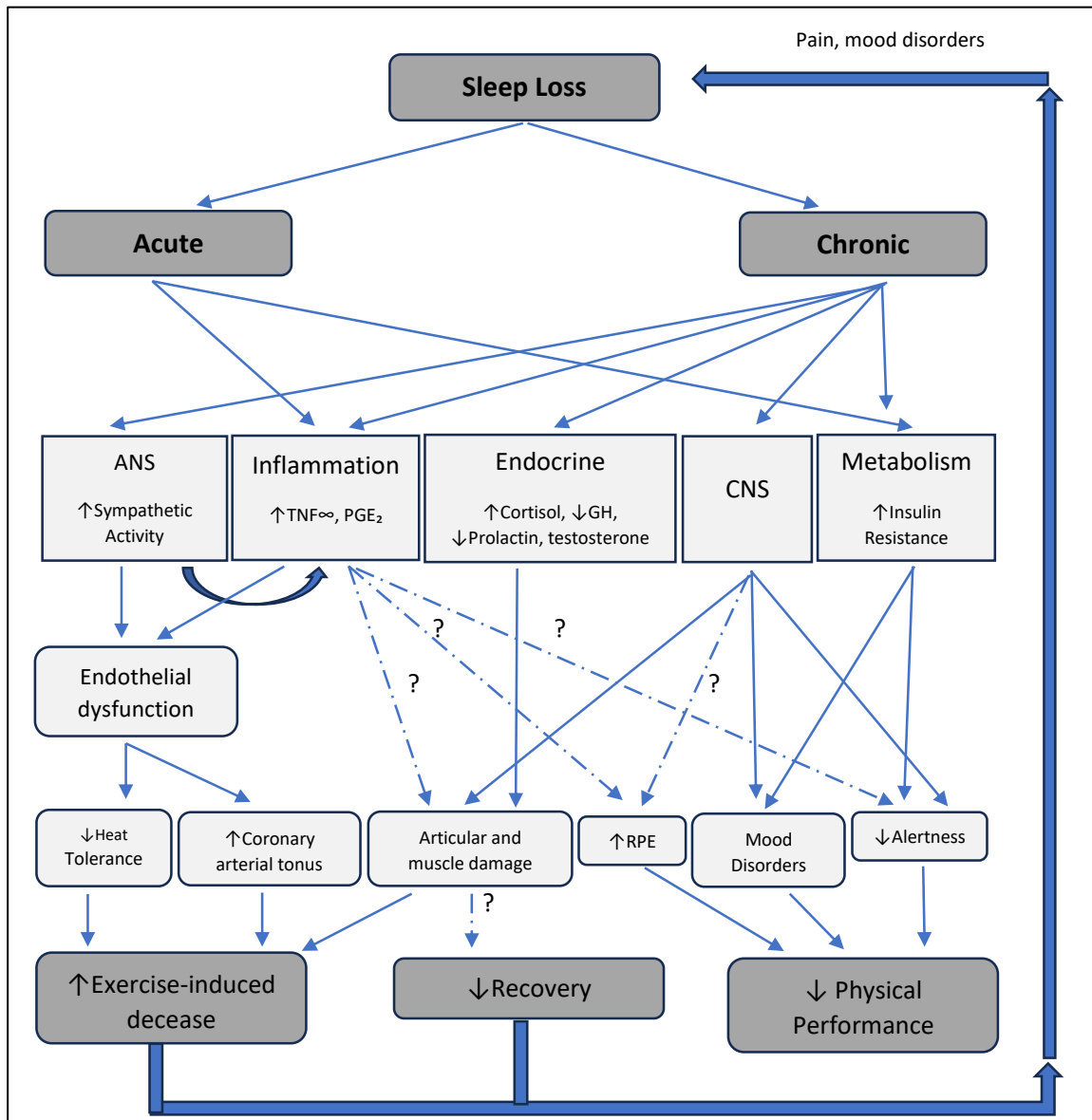


Figure 2.1: Representation of the possible effects of sleep loss/deprivation (acute or chronic) on muscle recovery, exercise-induced diseases, and physical performance.

ANS = autonomic nervous system, THF ∞ = tumour necrosis factor alpha, PGE $_2$ = prostaglandin E $_2$, GH = growth hormone, CNS = central nervous system, RPE = rate of perceived exertion, solid arrows = link, and dashed arrows = probable link, ↑ = increase, ↓ = decrease.

Sleep quality and quantity of athletes could be influenced by *acute* (e.g., bright light, excitement and arousal of the game and the outcome, first night effect of playing away, the use of electronic stimulants, acute napping, caffeine, and alcohol) and/or *chronic* stressors (e.g., napping, early morning sessions, inconsistent match schedules, and individual chronotype) (Nèdèlèc *et al.*, 2015:1389). It is, therefore, important to be cognisant of the different stressors that are likely to affect playing performances and to account for these during tournaments or single matches. Within the literature, information is available on the effect of sleep on performance markers (such

as physical and psychological measures), though a gap exists in the effect of sleep on match performances.

Sleep is considered one of the most effective ways to enhance a player's recovery and thereby ensure optimal performance (Marshall *et al.*, 2016:61). In this regard, it is recommended that the average healthy adult obtain between 7-9 hours of sleep, whilst 9-10 hours are advised for athletes to reach their full potential (Bonnar *et al.*, 2018:684). Unfortunately, in the sporting world, student-athletes are not always ensured a good night's rest, as various factors can lead to sleep deprivation (SD). Social demands, academic performance, financial challenges, and adjusting to life away from home are challenges that students must face. In addition, student-athletes have extra stressors such as spending substantial amount of time on attending practices, training sessions, traveling, team meetings, and participating in various competitions (Lopes Dos Santos *et al.*, 2020:1). More specifically, SD can be defined as "*no sleep or reduction in the usual total sleep time, usually lasting one to two days, with the wake periods extending beyond the typical 16-18 hr*" (Sandoval *et al.*, 2017:906). Sleep deprivation in athletes can be caused by several factors, including exposure to congested schedules, late-night matches, bright lights, caffeine, alcohol consumption, electronic stimulation, and travel fatigue to merely name a few (Fullagar *et al.*, 2015:12). Evaluating the effect of SD on performance, Cullen *et al.* (2019:2729) reported a detrimental effect for aerobic mean power output (-44.2 W) ($p = 93\%$, $d = -0.63$) and counter movement jump height (-6.60 cm) ($p = 94\%$, $d = -0.69$) following a night of total SD compared to normal sleep. In addition, three consecutive nights of sleep restriction (total sleep time: 4.0 ± 0.2 h) compared to normal sleep duration (total sleep time: 7.4 ± 0.5 h) may cause a significant decrease in maximal vertical jump height performance ($p = 0.02$) and slower average response time during a psychomotor vigilance task ($p = 0.04$) from baseline to sleep restriction (Mah *et al.*, 2019:1984). Not only is the vertical jump test used to measure explosive power, but it can also be utilised to measure central nervous system fatigue and readiness to perform (Watkins *et al.*, 2017:3305). A decrease in sleep quality and quantity can lead to an autonomic nervous system imbalance, which could replicate the symptoms that are linked to overtraining syndrome (Fullagar *et al.*, 2015:161). To minimise any detrimental effects on performance, various sleep hygiene protocols (SHP) have been developed to aid in the sleep quality and quantity of athletes – Refer to table 1 (Nèdèlèc *et al.*, 2015:1548). In this regard, time spent in bed (baseline 8:54h vs. post-intervention 9:32h; $p = 0.02$) and total sleep time (baseline 7:13h vs. post-intervention 7:40h; $p < 0.01$) were significantly increased in junior tennis players following a SHP of a single week (Lever *et al.*, 2021:253). The extent to which more acute bouts of SHP are similarly effective across a wide array of physiological and psychological aspects would require further Research.

Furthermore, O'Donnell and Driller (2017:526) noted that the implementation of SHP consisting of five specific requirements over a week period significantly increased (± 17.6 min, $p = 0.008$) the total sleep time. These included avoiding caffeine and other stimulants prior to sleep, maintaining a regular bedtime, ensuring a cool, quiet and dark bedroom, implementing relaxation strategies before bed, and avoiding the use of light-emitting technology devices prior to sleep. Further Research demonstrated how a 2-week SHP resulted in significantly greater sleep duration (+ 1h:39m, $p = 0.002$) compared to the no sleep hygiene protocol following a late-night soccer match (match time: 20:45) (Fullagar *et al.*, 2016:6). Research has indicated how the implementation of an SHP of 5–7-week sleep extension period (subjects extended their nocturnal sleep duration) can significantly improve sprint times relative to baseline measurements ($M_{diff} = -0.70$ sec, $p < 0.001$) (Mah *et al.*, 2011:946) see Table 1. Though these physical characteristics (sprint times, vertical jump height, CMJ, and aerobic mean power output) are deemed vital for performance, limited to no research could be found on the effect of SHP on match performances. In this regard, Research has indicated that sleep extension significantly ($p < 0.05$) improved a basketball player's accuracy and reaction times during a match, while sleep restriction negatively affected time trial performance, sprint times and mean and peak power outputs during a Wingate Test. However, no research could be found on the effect of an SHP on match performances in soccer players and, therefore, presents a gap in the literature worth exploring. For soccer-specific performance indicators (PIs), analysing internal and external match loads (measured through global positioning systems (GPS) and technical actions (measured through video footage to indirectly quantify the physical demands of soccer players) are considered vital to quantify their match performances (Nèdèlèc *et al.*, 2014:1518, Uthoff *et al.*, 2022:93).

Though the main goal is to win during a competitive sports match, the match-outcome is dependent on the performance of the whole team and not a single player per se (Modric *et al.*, 2019:1). In this regard, various *physical-* (i.e., running speeds and direction alterations, sprinting, tackles and jumps among others) and *technical-actions* (i.e., shooting, passing, and dribbling among others) are performed during a match which are all contributing factors for success (Nèdèlèc *et al.*, 2015:1547-1548). The technical actions are also known as PIs, which can be defined as “*the selection and combination of variables that define some aspect of performance*” (Harrop & Nevill, 2014:907; Russel *et al.*, 2013:2869). Research on PIs in soccer specifically has shown that losing teams tend to make significantly more passes (365.5, $p < 0.001$) compared to when they drew (242) and won (272), while teams that won (78%; $p = 0.006$) and lost (79%; $p = 0.001$) had significantly higher percentages of successful passes compared to teams that drew, thereby highlighting that pass quality is more important than pass quantity (Harrop & Nevill, 2017:911). Regarding the match loads, Modric *et al.* (2019:8) reported how top-level European players cover, on average, a total distance of 10.7 km per game and players from the Croatian

Soccer League cover an average distance of 10.3 km per game, with between 6.4-10% of the total distance in the high-intensity zones. These different total distance and distance in high intensity zone gives us an indication that different leagues will have different demands on the players. During the matches of the 2018 FIFA World Cup, the Confederation of African Football (CAF) (10.2 km) teams covered substantially less distance than the Union of European Football Association (UEFA) (10.7 km) (Tou *et al.*, 2019:3). Although these values are significantly less (9.37 km) when examining collegiate level soccer players (Curtis *et al.*, 2018:2907). Unfortunately, in South Africa, no information is available on national, international, and collegiate male players match demands or PIs, making this an area of concern?

Considering the above-mentioned findings and shortcomings, the objectives of the literature review are (i) to describe the importance of recovery, and especially sleep, for optimal sports performance and (ii) to describe the importance of match demands and PIs for success in team sports (iii) to investigate the effects of sleep (deprivation and hygiene protocols) on match performances of team athletes. Only English literature from (2011-2023) that included a study method and detailed description are included. For the investigation on sleep, team athletes over a range of sports codes will be included due to limited research available on soccer (association football). Concerning the aspects vital for success during a match, special reference will be made to soccer athletes as this was the population further studied. Younger population (<18y) players were tested in the past, but only studies which made use of adult populations (>18y) as test subjects were included. Computer searches were performed using Google Scholar, Web of Science, ScienceDirect, PubMed and the North-West University library. More specifically, keywords used during the searches included “sleep deprivation”, “sleep hygiene strategies”, “recovery”, “match demands”, “soccer”, and “performance”.

Firstly, the study will investigate the importance of sleep and the physiology thereof, followed by the influence on sports performance and secondly, the study will discuss sleep and its influence on internal and external match demands. Lastly, the study will investigate PIs and sleep influence thereon. In the subsequent section, a brief overview of the different stages of sleep, sleep intervention methods, and the effect of sleep on performance will be discussed, followed by the systems used for match analysis (i.e. match demands and PIs) with their respective metrics.

2. SLEEP

Sufficient and high-quality sleep is essential for various factors contributing to sports performance, such as enhancing mental and physical recovery from intense training blocks, preventing lapses

of concentration and in-game fatigue, and minimising the risk of injury (Kirschen *et al.*, 2018:1). To achieve optimal sports performance, it is important for efficient energy transfer and integration of the neuro-musculoskeletal system, which relies on the recovery process following sustained and demanding physical exertion. Moreover, sleep plays a pivotal role in the recovery of the neuro-musculoskeletal system and the restoration of energy stores that are important for athletic performance in the future (Chandrasekaran *et al.*, 2020:5). During a competitive season, athletes should attempt to incorporate the ideal balance between matches, stress induced by training, work, competitions, and recovery to ensure optimal physical and mental preparation (Fullagar *et al.*, 2016:1). However, during their congested schedules, such balance is more difficult to obtain due to daily and academic stress, late night kick-off, travelling through different time zones or long inland travels, playing in multiple competitions and tournaments. Ironically, these latter aspects increase the need for athletes to follow more ideal recovery protocols to decrease post-match fatigue, reduce the risk of injuries, and regain their performance levels (Howle *et al.*, 2019:75; Nèdèlèc *et al.*, 2015:1548). Fullagar *et al.* (2015:12) reported how disruptive sleep may ultimately lead to reduced sleep duration that can affect core temperature, emotional regulation, and levels of melatonin secretion, which can all result in delayed sleep onset. For this reason, the measurement of sleep, of which there are several direct and indirect methods, is an important component of sleep research. Sleep quality and quantity can be measured in various ways. Questionnaires like the Pittsburgh Sleep Quality Index (PSQI) and a sleep diary can be used to measure subjective sleep quality (Turczyn *et al.*, 2021:9). While objective sleep can be measured thoroughly with actigraphy (Turner *et al.*, 2023:156).

2.1 Stages of Sleep

For adequate physiological- (inflammation and metabolism) and psychological-recovery (memory, motivation, and learning ability), 7-9 hours of sleep are suggested to assist in mental and physical performance (Marshall & Turner, 2016:61). The neurotransmitter serotonin, which is secreted almost exclusively by neurons in the midline of the brainstem, excites the pineal gland to produce melatonin, which is stimulated by the absence of light to thereby promoting the initiation of sleep at night (Marshall & Turner, 2016:61).

A typical night's sleep is composed of 90-minute cycles that are divided into periods of rapid-eye-movement sleep (REM), also known as slow-wave sleep (and associated with dreams), and non-REM (NREM), which is further divided into four stages (see Figure 2) (Fullagar *et al.*, 2015:162). With regards to the first NREM sub-stage, which lasts between 10 seconds and 10 minutes, the individual is still consciously aware of their surroundings, and there is a high potential for waking.

The second sub-stage, which lasts between 10-20 minutes, is the beginning of actual sleep, which is then followed by stages 3 and 4, known as the deep stages of sleep and together, these two stages last between 30-40 minutes (Marshall & Turner, 2016:61-62). After stage 4 (deep sleep), the process re-enters the REM stage (West, 2018:3).

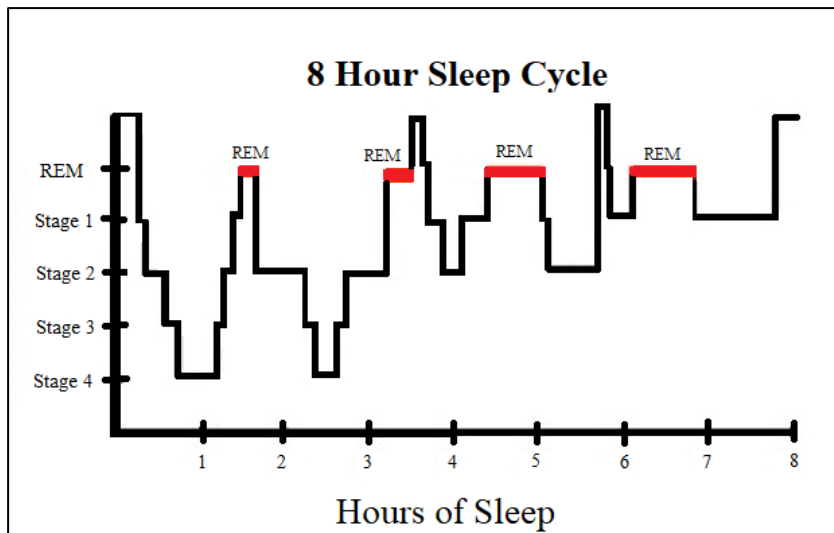


Figure 2.2: Schematic representation of the different stages of sleep during an 8-hour sleep cycle (adapted from Sharma *et al.*, 2021:7).

During the deep sleep stage, recovery is amplified by the release of growth hormones, cerebral blood flow is at its lowest and muscle relaxation is complete, allowing optimal tissue growth and repair (Nèdèlèc *et al.*, 2015:1388; West, 2018:3). For elite athletes, it is important to establish the duration of their normal sleep quality and quantity to help them fully recuperate physiologically and psychologically (Robey *et al.*, 2014:410). In this regard, polysomnography (PSG) and questionnaires are traditional procedures to identify sleep disorders, though PSG is impractical (trained physicians are needed to wire electrodes on players' bodies, players need to sleep in laboratories, etc.) and expensive (Sharma *et al.*, 2021:1). Subjective questionnaires are predominantly used within the sporting population as athletes can continue with their normal routines. Elite soccer players need to increase the duration of the different sleep stages to ensure low metabolic activity and for the endocrine system to increase the secretion of growth hormones to allow physiological restoration (Nèdèlèc *et al.*, 2015:1548). Sleep loss reduces the overnight improvement in motor learning as the number of specific sleep stages and motor task learning seem to correlate with each other (Fullagar *et al.*, 2015:164). Neurobehavioral functions continuously decrease with sleep restriction in a dose-response way, with athletes reporting an increased personal perception of sleepiness (Turczyn *et al.*, 2022:10).

Unfortunately, sleep deprivation is a major concern for sports performance as it influences the quality and quantity of sleep obtained (Pallesen *et al.*, 2017:813). Sleep restriction (SR) takes place when athletes wake up earlier or fall asleep later than their normal sleep pattern, while sleep deprivation (SD) is when athletes do not sleep for long periods and experience extreme cases of sleep loss (i.e., whole nights) (Fullagar *et al.*, 2015:165). There are different conditions and situations (light, match-induced arousal, napping, inconsistency in schedules, travel fatigue, inter-player variability in sleep preferences, and caffeine or alcohol consumption) that can interfere with and affect the players' sleep (Nèdèlèc *et al.*, 2015:1387). More reasons for poor sleep quality in athletes include jet lag, noise, hotel beds, anxiety before competing and performing, stress, television interviews, unusual competition times, and doping tests (Arazi *et al.*, 2019:93). Pallesen *et al.* (2017:822) found that during an SD condition (no sleep the night prior to testing), athletes performed significantly ($p < 0.05$) worse in the continuous kicking test compared to their rested condition. This has led researchers to investigate ways to minimise the negative effects of either SR or SD, collectively termed sleep hygiene recommendations. These sleep intervention strategies are, therefore, implemented to improve players' sleep quality and quantity with the aim of ultimately enhancing their performance (Nèdèlèc *et al.*, 2015:1556).

2.2 Sleep intervention methods

To minimise any external factors affecting sleep, various sleep hygiene interventions have been developed to aid in the sleep obtained (Bonnar *et al.*, 2018:684). Napping and sleep extension strategies help athletes to increase the amount of sleep that they can obtain, which can have a positive effect on their athletic performance (Bonnar *et al.*, 2018:684; Pallesen *et al.*, 2017:825). According to West (2018:3), an increase in sleep quality and duration might result in a higher success rate in competition and training as various psychological and physiological pathways are affected by optimal sleep. Within an array of research studies, the most common sleep hygiene strategies involve creating a cool ($19 \pm 2^{\circ}\text{C}$) and low-light (8 ± 5 lux) environment at 21:00 pm and limiting excessive light and electronic stimulants (e.g., computers, mobile phones, and television). Additional factors include not going to bed when you are not sleepy, keeping to a regular bedtime and waking routine, executing rituals to aid relaxation and preparing for bed, avoiding high-intensity exercise right before bed, having a shower before going to bed, removing the bedroom clock, avoiding alcohol and caffeine prior to sleep, consuming a light, high-glycaemic index meal with a few proteins (Nèdèlèc *et al.*, 2015:1555; Vitale *et al.*, 2019:17; Vitale *et al.*, 2019:2714).

2.2.1 Sleep duration

Sleeping less than 6 hours the night before an injury was associated with ($p = 0.028$) fatigue-related injuries in soccer, football, basketball, and running among youth athletes (Nèdèlèc *et al.*, 2015:1396). For athletes to reach their full potential, 9-10 hours of sleep is suggested, whilst healthy adults only need 7-9 hours of sleep (Bonnar *et al.*, 2018:684).

2.2.2 Bedtime routine

Any efforts to alter the players routine, whether by engaging in physical activities or by using medication will be futile and can lead to incomplete recovery (Rankov., 2020:874). Players should perform their own rituals, such as making lists for the next day, reflecting on what happened during the day, taking a warm bath or shower, oral hygiene, reading, and preparing their clothes for the next day (Rankov., 2020:878).

2.2.3 Exposure to bright light

When the light fades, our brain recognises it as night, and all nocturnal functions are triggered, including the secretion of melatonin, our sleep hormone, while exposure to light stops the secretion of melatonin (Rankov., 2020:878). Elite soccer players experience exposure to stadium lights during games and post-game, which can potentially influence their sleep patterns; this has a stimulating effect on melatonin level and exhibit an inverse correlation with alertness (Nèdèlèc *et al.*, 2015:1391). Sleep can be disrupted by external noise, and the phases of light sleep are the most sensitive to noise. Therefore, athletes who travel should use earplugs when travelling to external noise in different environments (Rankov., 2020:880).

2.2.4 Temperature

Sleep can be impacted by the alteration of core body temperature by interfering with the thermophysiological sequence that initiates the sleep process (Nèdèlèc *et al.*, 2015:1391). A room temperature of 18-21°C is considered for optimal sleep (Rankov., 2020:880).

2.2.5 Food and drink

A high-glycaemic index carbohydrate and protein meal should be consumed by the player within the hour following the match to optimise muscle-damage repair and replenish substrate stores (Nèdèlèc *et al.*, 2013:9). Caffeine is a psychoactive substance used by athletes, and studies showed that consuming 400mg of caffeine up to 6 hours prior to bedtime can result in sleep disturbances (Nèdèlèc *et al.*, 2015:1392). After training and competition, players are prone to

consuming alcohol, which leads to socialising and may lead to sleep loss (Nèdèlèc *et al.*, 2015:1392). Alcohol can derange the sleep phases, and the quality of our sleep decreases after two nights of alcohol intake in a row (Rankov., 202:882).

2.3 Effect of sleep on performance

The sleep quality and quantity of high-performance athletes can be negatively affected, with many of the athletes reporting sleep disturbances that will affect athletic performance outcomes negatively (Turczyn *et al.*, 2022:10). The effectiveness of sleep and its regulation rely on the integration and control of the sleep process by the pituitary-hypothalamic-limbic system, though SD can impact this system, thereby influencing the endocrine, cardiovascular, and neuromotor performance (Chandrasekaran *et al.*, 2020:5).

Table 2.1 exhibits a summary of the relevant studies that have investigated the effects of sleep on sports performance, followed by a short summary thereof.

Table 2.1: Studies examining the effects of sleep on sports performance.

Authors, date, and article title	Subject (Number, age, sport, and country)	Intervention	Results
Azari <i>et al.</i> (2019) Effect of Overnight Sleep Deprivation on Appetite and Physical Performance in Elite Female Soccer Players.	12 Elite female soccer players (28.5 ± 3.45 years) Iran	Subjects were evaluated after normal sleeping conditions and after a sleep-deprived night (whole night) to evaluate physical performance and appetite.	Reaction time significantly ($p \leq 0.05$) increased after sleep deprivation, and anaerobic (peak power, minimum power, and fatigue index) significantly ($p \leq 0.05$) decreased after sleep deprivation.
Boukhris <i>et al.</i> (2020) A 90 min Daytime Nap Opportunity Is Better Than 40 min for Cognitive and Physical Performance.	14 Amateur Male football, rugby, and handball players. (20.3 ± 3.0 years) Tunisia	A 40 and 90-minute nap from 14:00 to 14:40 and 15:30, respectively, to determine the effect of different nap opportunities and no nap on physical performance and attention.	Nap improved six 30-s maximal shuttle run higher distances and total distance. A significantly higher distance was achieved after the 40-minute nap ($p \leq 0.0005$) and 90-minute nap ($p \leq 0.0005$) compared to no nap. For total distance, the 90-minute nap was significantly ($p \leq 0.04$) higher than the 40-minute nap.

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Caia <i>et al.</i> (2018) The influence of sleep hygiene education on sleep in professional rugby league athletes.	24 professional rugby league players. (25 ± 3.3) Australia	Male	2 Weeks of baseline measuring of sleep. 12 Athletes had two 30-minute sleep hygiene education seminars for successive weeks, while the other 12 athletes had no education.	Sleep hygiene intervention resulted in more time in bed (ES = 0.53 ± 0.49), earlier bedtime (ES = 0.53 ± 0.48), and an increase in sleep duration (ES = 0.47 ± 0.44).
Cullen <i>et al.</i> (2019) The effects of a single night complete and partial sleep deprivation on physical and cognitive performance: A Bayesian analysis.	10 Male athletes (27 ± 6 years) United Kingdom	Male athletes	7 Days between three randomised experimental trials. Partial sleep (4-hour sleep opportunity), complete sleep deprivation, and normal sleeping conditions were used.	Aerobic mean power output (W) (-44.2, 99%CI) and countermovement jump (cm) (-6.60, 100%CI) decreased significantly compared to normal sleep.
Fowler <i>et al.</i> (2015) Effects of sleep hygiene and artificial bright light interventions on recovery from simulated international air travel.	13 Physical active males (24.3 ± 4.7) Australia	Physical active males	24 Hours of international travel were simulated in the INT and CON conditions.	Sleep duration decreased significantly (p < 0.01) for both trials during travel, while total sleep duration during and after travel was almost significant (p = 0.06) in INT (17.0 h) compared to CON (15.7).

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<p>Fowler <i>et al.</i> (2021) Sleep Hygiene and Light Exposure Can Improve Performance Following Long-Haul Air Travel.</p>	<p>20 trained athletes. (21.9 ± 3.6) Qatar</p>	<p>Physically male</p>	<p>A baseline test was performed on four consecutive days prior to travel. Athletes were divided into an intervention (INT) and a control (CON) group. The INT group followed a sleep hygiene intervention, while the CON group followed their normal sleeping behaviour.</p>	<p>There was a very likely improvement in countermovement jump peak power (ES 1.10, ± 0.55) and likely improvements in 5m (0.54, ± 0.67) and 20m (0.74, ± 0.71) sprint times when comparing the INT and CON groups across the four days post-travel.</p>
<p>Fox <i>et al.</i> (2021). The Association Between Sleep and In-Game Performance in Basketball Players.</p>	<p>7 professional Basketball Players. (24 ± 4 years) Australia</p>	<p>Semi-Male</p>	<p>Sleep was monitored for periods of up to 14 days for the entire in-season phase.</p>	<p>Sleep efficiency the night before the game improved blocks during competition, and free-throw accuracy, assists, rebounds, and steals were positively correlated with subjective sleep quality.</p>
<p>Jarraya <i>et al.</i> (2012) The effect of partial sleep deprivation on the reaction time and attentional capacities of the handball goalkeeper.</p>	<p>12 volunteer goalkeepers in handball (18.5 ± 1.7 years)</p>	<p>Healthy male</p>	<p>Effect of sleep deprivation of sleep between 22:00 to 03:00 and 03:00 to 07:00 compared to normal sleep on goalkeepers' reaction time.</p>	<p>Reaction time significantly increased from normal sleep to SDE ($p < 0.001$) and SDB ($p < 0.001$)</p>

Tunisia

<p>Lever <i>et al.</i> (2021) A Combined Sleep Hygiene and Mindfulness Intervention to Improve Sleep and Well-Being During High-Performance Youth Tennis Tournament</p>	<p>17 junior players (female n = 7, and male n = 10) (15.4 ± 1.1 years) Australia</p>	<p>High-level tennis controlled (unassisted and normative sleep behaviour), and intervention (sleep education workshop) conditions were used. Prior to sleep intervention, a sleep education workshop was held. 1 Week of sleep intervention was used to determine the effect of SHP on tennis performance.</p>	<p>Baseline (home environment), Total time in bed (p < 0.02) and total sleep time (p < 0.01) significantly increased in a 1-week SHP.</p>
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<p>Mah <i>et al.</i> (2011) The Effects of Sleep Extension on the Athletic Performance of Collegiate Basketball Players.</p>	<p>800 Collegiate Athletic Association (NCAA) students from different sporting environments. United States</p>	<p>National Athletic students from different sporting environments. United States</p> <p>2-4 Weeks baseline period of normal sleep. 5-7 Weeks of extended sleep, with a minimum of 10 hours bedtime</p>	<p>Shooting accuracy and reaction time significantly improved ($p < 0.001$ and $p < 0.05$), respectively, and sprint times decreased significantly ($p < 0.001$) after the sleep extension period.</p>
<p>Nobari <i>et al.</i> (2022) In-Season Quantification and Relationship of External and Internal Intensity, Sleep Quality, and Psychological or Physical Stressors of Semi-Professional Soccer Players.</p>	<p>18 Male Semi-Professional Soccer Players (29 ± 4.1 years) Iran First League</p>	<p>20 In-Season consecutive weeks, 47 training sessions and 20 matches.</p>	<p>Negative relationship between average TD and delayed onset muscle soreness and sleep and average high speed running distance.</p>
<p>O'Donnell and Driller (2017) Sleep-hygiene Education Improves Sleep Indices in Elite Female Athletes.</p>	<p>26 Female and international Netball Athletes (26 ± 6)</p>	<p>1 Week of sleep baseline monitoring (PRE) followed by a sleep education session and a further week of sleep monitoring (POST).</p>	<p>Total sleep time ($p = 0.01$) and wake variance ($p = 0.03$) significantly improved from PRE to POST.</p>

New Zealand

Pallesen *et al.* (2017) The Effects of Sleep Deprivation on Soccer Skills.

19 Male Junior Soccer Players
(16.5 ± 1.3 years)

Players were assigned to follow specific sleep conditions, either complete sleep-deprived night or normal sleep conditions. Continuous kicking test performance decreased with sleep deprivation.

Norway

Soccer skills (juggling, dribbling, ball control, continuous kicking, 20 and 40m sprint test, and 30 m sprint with change of direction) tests were conducted to determine the effect of sleep on soccer skills.

No significant difference in juggling, dribbling, ball control, and sprinting 20/40m after sleep deprivation.

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<p>Roberts <i>et al.</i> (2019) Effects of total sleep deprivation on endurance performance and heart rate indices used for monitoring athlete readiness</p>	<p>13 Male Cyclists (33 ± 6 years) Australia</p>	<p>A randomised counterbalanced crossover study that used two conditions, SD and NS. Each condition was followed for six consecutive days. To determine the effect of SD on cycling performances.</p>	<p>SD impaired prolonged self-paced endurance performance by 10%.</p>
<p>Roberts <i>et al.</i> (2019) Extended Sleep Maintains Endurance Performance Better than Normal or Restricted Sleep.</p>	<p>9 Male Cyclists (30 ± 6 years) Australia</p>	<p>+30% of the habitual time in bed.</p>	<p>Sleep extension significantly ($p < 0.01$) improved 60 min time-trial performances in cyclists.</p>
<p>Saadat <i>et al.</i> (2015) The effects of sleep deprivation on Profile of Mood States and cognitive tasks.</p>	<p>26 Pediatric anaesthesiologists (32 – 56 years) USA</p>	<p>Profile of Mood States (POMS) and Visual analogue score (VAS) was measured after regular non-call day and on the post-call day (3 pm-7 am)</p>	<p>Total Mood Disturbances, sleepiness, feeling jittery, anger, tension, confusion, and fatigue were significantly affected ($p < 0.05$).</p>

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Schwartz and Simon Jr (2015) Sleep extension improves serving accuracy: A study with college varsity tennis players.	7 Female and 5 Male College tennis players. (22.2 ± 2 years) USA	>9 hours of sleep per night for one week.	Sleep extension improved tennis serve accuracy.
Swinbourne <i>et al.</i> (2018) The Effects of Sleep Extension on Sleep Performance, Immunity and Physical Stress in Rugby Players.	25 Highly trained rugby union players (25 ± 2.7 years) Auckland University, New Zealand.	Participants completed an initial three-week high-intensity training block, and then a two-week maintenance block followed. A second block of three weeks of high-intensity training was performed with a sleep extension intervention.	Athletes' total sleep time and quality improved with beneficial changes in reaction time compared to the control period.
Teece <i>et al.</i> (2021) Sleep and Performance during a pre-season in Elite Rugby Union Athletes.	29 Professional Rugby Union Athletes (23 ± 3 years) New Zealand	High Sleep Group (> seven h 30 min) vs Low Sleep Group (< 7 h 30 min)	Significant (p = 0.02) improvement in aerobic capacity for High Sleep Group No differences in speed and strength measures (p ≥ 0.05) between the groups.

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<p>Vitale <i>et al.</i> (2019) Acute sleep hygiene strategy improves objective sleep latency following a soccer-specific session: A randomised controlled trial.</p>	<p>32 professional male soccer players (≥ 18 years) Italy</p>	<p>Non- Two groups: n = 12 in the control group (CG) and n = 17 in the experimental group (EG). The control group maintained normal sleep during the study, while the experimental group followed acute sleep hygiene strategies. Sleep was measured two nights before (PRE) and two nights after (POST1 and POST2) late-night small-sided games.</p>	<p>Subjective sleep quality was better in EG than in CG POST1 (P = 0.016), with significant improvements over PRE-values (p = 0.004).</p>
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SD= Sleep Deprivation; NS = Normal Sleep; SDE = Sleep Deprivation End; SDB = Sleep Deprivation Beginning; SHP = Sleep Hygiene Protocol; TD = Total Distance; INT = Intervention; CON = Control

From the above results, a study examining moderately trained cyclists reported how sleep deprivation led to a 10% weaker performance for a prolonged (60-minute) self-paced endurance test (Roberts *et al.*, 2019:2695). After executing sleep extension (± 92 min extra sleep per night) for three consecutive nights, their 60-minute time-trial performances improved by ± 2 minutes, whereas a sleep reduction (± 123 min less per night) for two consecutive nights slowed their time-trial performances by ± 1.5 minutes (Roberts *et al.*, 2019:2520). Though not significant, this can potentially make the difference between a winning or losing outcome. Significantly greater ($p = 0.02$) aerobic improvements were observed during a Bronco test for a high sleep (> 7 h 30 min) group compared to the low sleep (< 7 h 30 min) group, with a 3.9s difference in time between the two groups (Teece *et al.*, 2021:6).

Comparing the effect of no-nap compared to 40- and 90-minute nap periods (after lunch from 2 pm – 3h30pm) on six 30-s maximal shuttle sprints, Boukhris *et al.* (2020:6) reported additional 10-meter distances covered during each repetition ($p < 0.0005$) after the 40-minute nap, and 13-meter additional distance ($p < 0.0005$) after the 90-minute nap compared to no-napping. Furthermore, they found that the total distance (distance covered during all six 30-s shuttles) was 55 meters greater ($p < 0.0005$) after the 40-minute nap and 89 meters more ($p < 0.0005$) after the 90-minute nap compared to no napping (Boukhris *et al.*, 2020:6). These findings imply that players and coaches can plan nap opportunities before late night/afternoon matches and training sessions to thereby improve performances.

Schwartz and Simon (2015:543) measured the relative number of accurate tennis serves after sleep deprivation (35.7%) and sleep extension week (41.8%), reporting a significant improvement ($p < 0.05$) following the one week of sleep extension. In addition, Mah *et al.* (2011:946) found that basketball players' shooting accuracy (successful field goals out of 15) (10.2 vs 11.6; $p < 0.001$), sprinting (16.2 sec vs. 15.5 sec; $p < 0.001$) and reaction time (310.84ms vs. 274.51ms, $p < 0.04$) improved significantly from baseline to end of sleep extension following a 5–7-week period of extended sleep. While Fox *et al.* (2021:335) found that sleep quality on the night preceding the competition had a positive effect on various PIs in semi-professional male basketball players, they also reported that blocks made during the competition were positively correlated with sleep efficiency on the night prior to competition and that free-throw accuracy assists, rebounds, and steals were positively correlated with higher subjective sleep quality. However, no significant associations were found between performance and sleep duration. Azari *et al.* (2019:95) also noted how a single night of total SD can significantly decrease reaction time (5.94 sec vs. 5.33 sec; $p \leq 0.05$) compared to normal sleep. Jarraya *et al.* (2013:506) found that the reaction time of handball goalkeepers significantly increased from reference night ($398.28 \pm 4.91 \text{ ms}^{-1}$, $p < 0.001$) to partial SD at the beginning ($560.87 \pm 7.33 \text{ ms}^{-1}$) (slept from 03:00 to 07:00h) and to SD at the

end (593.00 ± 8.27) (slept from 22:00 to 03:00h, $p < 0.001$). At the same time, Swinbourne *et al.* (2018:6) found that the mean reaction time of rugby players improved ($228.8 \pm 24.5 \text{ ms}^{-1}$ to $220.0 \pm 18.4 \text{ ms}^{-1}$) following sleep extension during a three-week rugby pre-season block. Based on these findings, key performance metrics such as accuracy, reaction time, and sprinting performances can improve because of sleep extension.

Regarding subjective measures, mood and daytime sleepiness scores of the aforementioned basketball players improved significantly ($p < 0.001$) as measured by the Epworth Sleepiness Scale (ESS) (Mah *et al.*, 2011:946). Following an SD night, total mood disturbances, sleepiness, feeling jittery, anger, tension, confusion, and fatigue were significantly affected ($p < 0.05$) for paediatric workers compared to day shift (Saadat *et al.*, 2015:66). Furthermore, SD can hamper the replenishment of muscle glycogen stores after exercise, weaken the energy supply for repairing myofibrillar micro-damage and subsequent contractile utilisation (Kirschen *et al.*, 2018:2).

In conclusion, six studies analysed the effect of SD on sports performance, three studies analysed the effect of sleep extension on performance, and one study analysed the effect of different nap opportunities on performance. Research on SD showed slower reaction times and decreased anaerobic power, aerobic mean power, CMJ height, kicking test, and self-paced endurance tests, while mood, tension, and anger are also affected. Only a few studies investigated the effect of sleep deprivation on soccer skills, and for this reason, Pallesen *et al.* (2017) were included in this chapter even if the subjects were younger than 18 years. Nobari *et al.* (2022:12) found that there was a large negative relationship between sleep and average high-speed running distance in semi-professional soccer players in the early-, mid-, and end-season. When sleep is extended, shooting accuracy improves, reaction time decreases, sprint times improve, as well as a tennis serve accuracy and 60-minute time trail performance. Max shuttle run distances improved after the player napped during the day. A sleep education workshop led to higher total time in bed and total sleep time. Various aspects can have an influence on the quality and duration of sleep that can affect the internal and external responses during matches (Nèdèlèc *et al.*, 2015:1387).

3. MATCH-SPECIFIC PERFORMANCE MEASURES

With soccer being one of the most investigated sports in the world and scientific analysis growing consistently, coaches and authors try to identify a winning profile for individuals and teams (Filetti *et al.*, 2017:602). Filetti *et al.* (2017) investigated the effect of technical-tactical (technical efficiency index; TEI) and physical (physical efficiency index; PEI) on the outcome of soccer matches. Significant ($p < 0.0001$) correlations were found between TEI and PEI, while PEI

showed a lower likelihood of winning than TEI factors (Filetti *et al.*, 2017:602). However, no studies could be found on the effect of sleep on the match-specific performance measures.

3.1 Global Positioning System (GPS)

During a competitive match, athletes are required to perform repetitive high-intensity, linear and non-linear efforts, combined with recovery periods of different lengths (Gomez-Piqueras *et al.*, 2019:3). To monitor such activities in real-time the use of global positioning systems (GPS) has become more common around the world to generate physical loading profiles (i.e. distance and speed variables) of athletes both during training and official matches (Ehrmann *et al.*, 2016:360; Nunez *et al.*, 2019:75). Depending on the system being operated, over 30 orbiting satellites are used for satellite-based navigation, the GPS devices use unique signals that are transmitted through the orbiting satellites to find the location of the athlete (Hennessy & Jeffreys, 2018:83). For the most part, GPS devices are used to monitor external demands (e.g., distance and velocity) whilst simultaneously capturing heart rate (HR) data as a proxy for internal demands (Theodoropoulos *et al.*, 2020:2). The use of such technologies can also be utilised to discover a more optimal balance between recovery and training stress to decrease the risk of injury and to achieve optimum performance (Ehrmann *et al.*, 2016:360). Match demands like total distance (TD) covered, distances covered at different intensities, number and intensity of decelerations and accelerations, distances covered at different speeds, and body impacts are the most measured metrics within the sporting fraternity (Castillo *et al.*, 2020:196).

Internal exercise intensity for matches is quantified by continuous monitoring of HR for each game, whereby the HR is measured with HR belts fitted to the player's chest (Torreno *et al.*, 2016:941). Based on Research incorporating these technologies, it has been well established that professional male soccer players can cover distances of 9-14 km per match, varying between low, medium, and high intensities (Gomez-Piqueras *et al.*, 2019:3). Backline U20 international rugby players cover a total distance of 6.23 km per match while the forwards can cover 5.37 km per match (Ball *et al.*, 2020:377). Male elite-level hockey players cover on average (5420 ± 1518m) per game, while the strikers (120 ± 20 m/min) and midfielders (116 ± 15 m/min) achieved higher intensities than defenders (105 ± 13 m/min) (Lombard *et al.*, 2021:985). It is important to note that substantial intra-match variability is present across most of these parameters as performances are dependent on the level of play, number of matches (i.e. eight home and ten away matches as in the cited study), recovery, home and away fixtures, quality of opposition (Teixeira *et al.*, 2021:1). Within the research literature that focuses on and match performances, the most established parameters are total distance covered, distance covered at different

intensities, number of accelerations and decelerations, distance covered at different speeds, and impacts on the body (Castillo *et al.*, 2020:196) and should, therefore, be tracked across multiple occasions. Furthermore, given that male soccer players will be examined further in the study (refer to chapters 3 and 4), a greater emphasis will be placed on their specific match demands.

3.1.1 Movement classification system for GPS – special reference to soccer

Match analyses are common on elite level during sporting activities by examining *external* (e.g. movement analysis) and *internal* (e.g. heart rate) demands (Theodoropoulos *et al.*, 2020:2). The following parameters were used by Borghi *et al.* (2020:228) to measure U19 male soccer player load: very high-speed running distance (VHSRD, total distance >19.8 km.hr⁻¹), total sprints over 25 km.hr⁻¹ (S > 25 km.hr⁻¹), total distance (TD), number of Power Plays (PP; > 20 W.kg⁻¹), and the total number of accelerations above three m/s² (Acc > 3 m/s²). In the study by Modric *et al.* (2019:4), they used the following variables to measure the distance in the five-speed zones: walking (< 7.1 km.hr⁻¹), jogging (7.2-14.3 km.hr⁻¹), running (14.4-19.7 km.hr⁻¹), high speed running (19.8-25.1 km.hr⁻¹), and maximal sprinting (> 25.2 km.hr⁻¹). While high-intensity accelerations were (> 3m/s²) and high-intensity decelerations (< 3 m/s²).

Varley *et al.* (2012:123) categorised both constant velocity and acceleration as 1-3, 3-5, and 5-8 m/s² and deceleration to start off at 5-8 m/s². Barron *et al.* (2014:737) used the Sprint software default settings of the Catapult GPS system to measure deceleration (zone 1:-20 to -5.0 m/s²; zone 2: -5.0 to -4.0 m/s²; zone 3:-4.0 to -2.0 m/s²; zone 4: -2.0 to 0.0 m/s²) and acceleration (zone 5: 0.0 to 2.0 m/s²; zone 6: 2.0 to 4.0 m/s²; zone 7: 4.0 to 5.0 m/s²; zone 8: 5.0 to 20.0 m/s²). To measure external player load in professional soccer players, Torreno *et al.* (2016:941) used the following classifications: >13 km.hr⁻¹ for distances covered at moderate speed and >18 km.hr⁻¹ for distances covered at high speed. Wehbe *et al.* (2014:836) used the following measures for movement analyses: standing (0 to ≤ 0.6 km.hr⁻¹), walking (> 0.6 to ≤ 7.1 km.hr⁻¹), jogging (>7.1 to ≤ 14.3 km.hr⁻¹), running (> 14.3 to ≤ 19.7 km.hr⁻¹), high-speed running (>19.7 to ≤ 25.1 km.hr⁻¹) and sprinting (> 25.1 km.hr⁻¹). They also described high-speed running and sprinting as high-intensity running (HIR) (>14.3 km.hr⁻¹) and high-speed running and sprinting as very high-intensity running (VHIR). In contrast Pons *et al.* (2019:4) used the following variables to describe movement walking (0-6 km.hr⁻¹), jogging (6-12 km.hr⁻¹), running (12-18 km.hr⁻¹), intense running (18-21 km.hr⁻¹), sprinting at low intensity (21-24 km.hr⁻¹), and sprinting at high intensity (> 24 km.hr⁻¹). These different variables will provide insight into the external training and match load with the aim of preventing overtraining and injury risk, as well as aiding in recovery (Ehrmann *et al.*, 2016:361).

By making use of the above-mentioned norms, research has indicated the average match demands in Division 1 men's soccer matches as follows: distance (m) 9367 ± 2149 , average speed (m/min) 92 ± 20 , high-speed running distance ($>14.4 \text{ km}\cdot\text{hr}^{-1}$) 1700 ± 369 , average HR_{max} (%) 78 ± 8 , and high-intensity acceleration ($\geq 4 \text{ m/s}^2$) 121 ± 33 (Curtis *et al.*, 2018:290). Knowing these norms and what effect sleep has on the locomotive metrics can help coaches understand what their players will experience during the games. Combining the internal (HR) and external (GPS) variables can give coaches a clear idea of the exercise and match intensity (Alexandre *et al.*, 2012:2890)

3.1.2 Heart intensity zone

The percent of HR_{max} ($\%\text{HR}_{\text{max}}$) values assigned to the different zones by Kalapotharakos *et al.* (2021:3170) are as follows:

- zone 1 is 50-60% of HR_{max} ,
- zone 2 is 60-70% of HR_{max} ,
- zone 3 is 70-80% of HR_{max} ,
- zone 4 is 80-90% of HR_{max} , and
- zone 5 is 90-100% of HR_{max} .

Research has indicated that the average heart rate of elite-level soccer players during the first half of a game for all playing positions is 87.1% of their HR_{max} , while wide midfielders demonstrated significantly ($p < 0.05$) smaller averages than the other playing positions (Arrones *et al.*, 2014:9). Torreno *et al.* (2016:943) found that the players HR during the match was $86.0\% \pm 4.9\%$ of HR_{max} , while that of wide midfielders was substantially lower during the first half ($83 \pm 8\% \text{HR}_{\text{max}}$) and 2nd half ($81 \pm 6\% \text{HR}_{\text{max}}$) than the other playing positions. Such high HR values give an indication of the cardiovascular stress that is imposed on players during training and matches (Morgans *et al.*, 2014:255).

In Table 2.2, studies making use of GPS systems within the sport of soccer are presented and subsequently discussed.

Table 2.2: Studies examining movement patterns using GPS technology in soccer

Authors, Date, and Article Title	Subject (Number, Age, Sport, and Country)	Intervention	Results
Arrones <i>et al.</i> (2014) Match-play activity profile in professional soccer players during official games and the relationship between external and internal load	30 Elite European soccer players Spain	Investigated internal and external match demands during the clubs' competitive matches. Match analyses were performed 4-15 times on each player. Only data from the first half was used. Relative total distance at different intensities was measures	The average HR of players is 87.1% of HR _{max} . Wide midfielders have significantly ($p < 0.05$) lower average HR during the game than other positions. Wide midfielders significantly ($p < 0.05$) higher distances $> 18 \text{ km}\cdot\text{h}^{-1}$ and $> 21 \text{ km}\cdot\text{h}^{-1}$
Barron <i>et al.</i> (2014) Accelerometer-derived load according to playing position in competitive youth soccer.	38 sub-elite soccer players (17.3 ± 0.9 years) England	Players were classified by their playing position. 8 English College Home games were monitored in the competition phase. To measure acceleration and deceleration activities during both halves	In acceleration zone 7 ($4\text{-}5 \text{ m/s}^2$), WMF covered significantly greater distances than CD ($p \leq 0.05$) and FW ($p \leq 0.05$). Significant ($p = 0.02$) lower distance covered in the seco nd half compared to the first half for zone 3 ($p = 0.00$), zone 4 ($p = 0.02$), zone 5 ($p = 0.00$), and zone 6 ($p = 0.00$).

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<p>Borghgi <i>et al.</i> (2021)</p> <p>Differences in GPS variables according to playing formations and playing positions in U19 male soccer players.</p>	<p>23 professional male soccer players (≥ 17 years and ≤ 19 years)</p> <p>Italian</p>	<p>Total distance covered and very high-speed running distance, as well as the distance covered in acceleration and deceleration zones during the first and second half, was measured.</p> <p>Three playing formations were used.</p> <p>31 Matches were analysed, and 180 individual match sessions were collected</p>	<p>Total distance ($p < 0.0001$) and very high-speed running distance ($p < 0.0076$) significantly decreased from the first to the second half.</p> <p>CM ($p = 0.0005$) and S ($p = 0.0132$) had significant differences in TD from the first to second half.</p>
<p>Curtis <i>et al.</i> (2018) Match Demands of National Collegiate Athletic Association Division I Men's Soccer.</p>	<p>18 Division 1 Soccer players (20 ± 1 year)</p> <p>USA</p>	<p>24 Matches were observed in Division 1 collegiate soccer in 2015 to determine accelerations, decelerations, running movement characteristics by different playing positions, and average HR</p>	<p>The average distance for all the positions (9367m), average m/min (92m/min), average HR (78bpm), and high-intensity acceleration (121).</p>
<p>Dalen <i>et al.</i> (2016)</p> <p>Player Load, Acceleration, and Deceleration During Forty-Five Competitive Matches of Elite Soccer.</p>	<p>310 elite soccer players (25.38 ± 4.37 years)</p> <p>Norway</p>	<p>Data from 45 Domestic home games were collected over three full seasons to analyse the total player load and the number of accelerations and decelerations.</p> <p>Matches were played on grass surfaces.</p>	<p>The average distance covered during the first and second half was 6823m and 6503m, respectively.</p> <p>5% decrease in player load from the first half to the second half.</p>

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			FB (85) and WM (87) had more accelerations than CD (61), CM (74) and attackers (74)
Filetti <i>et al.</i> (2017) A Study of Relationships among Technical, Tactical, Physical Parameters and Final Outcomes in Elite Soccer Matches as Analysed by a Semiautomatic Video Tracking System.	360 Elite soccer players (27.7 ± 6.2) Italy	70 Games of Italian Serie A were analysed	The correlation between the technical efficiency index (TEI) and physical (physical efficiency index (PEI) was significant ($p < 0.001$). TEI showed a higher effect on the probability of winning than PEI factors.
Lombard <i>et al.</i> (2021) Relationship between physiological characteristics and match demands in elite-level male field hockey players.	23 elite-level field hockey players (24 ± 3 years) China	GPS data were analysed for 26 matches to record locomotive activities during the match.	Defenders and midfielders had significantly ($p = 0.0001$) higher total distances compared to strikers. Defenders had significantly ($p \leq 0.0001$) lower high-speed distance running than midfielders and strikers had lower.
Modric <i>et al.</i> (2019) Analysis of the Association between Running	101 professional soccer players	14 Matches were analysed.	Significant differences ($p < 0.05$) were found for all running performances in different playing positions.

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Performance and Game Performance Indicators in Professional Soccer Players.	(23.85 ± 2.88 years) Croatia	The players were monitored by GPS in each match to determine the effect of running performance on the outcome of the game	
Nobari <i>et al.</i> (2021) Comparison of Running Distance Variables and Body Load in Competition Based on Their Results: A Full-Season Study of Professional Soccer Players.	13 professional soccer players (28.6 ± 2.7 years) Iran	Thirty-three matches were analysed. The players were monitored by GPS in each match to compare total distance, average speed, total sprint distance, and maximal speed in different match results and 1 st and seco nd halves.	Average speed was significantly ($p < 0.05$) higher when teams lost compared to when they won or drew the game.
Teixeira <i>et al.</i> (2021) Effects of Match Location, Quality of Opposition and Match Outcomes on Match Running Performance in a Portuguese Professional Football Team.	23 Male Professional Football players (32.02 ± 1.19 years) Portugal	Location, quality of opposition and match outcome on running performance	Running performance is influenced by playing position and match-related contextual factors.

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<p>Torreno <i>et al.</i> (2016) Relationship Between External and Internal Loads of Professional Soccer Players During Full Matches in Official Games Using Global Positioning Systems and Heart-Rate Technology.</p>	<p>26 professional outfield players (27.3 ± 3.4 years) Spain</p>	<p>Internal and external player loads of soccer players were measured with GPS devices. Distance per minute, total distance, distance travelled at high speed, and % of HR max was measured. Match analyses were performed 3-15 times on each player over two seasons (3-15 games), Natural grass fields were used for the study.</p>	<p>Substantial differences between 1st and 2nd were found for meters/min. Playing positions significantly impacted the TD covered per match. The distance travelled above high speed (> 18 km/h) was lower in the 2nd half compared to the first half. Wide midfielders had substantially lower % of HR_{max} values than the other playing positions during the 1st and 2nd halves.</p>
<p>Turczyn <i>et al.</i> (2022) Does Sleep Quality between Back-to-Back Matches Influence Running Performance in Canadian Female University Soccer Players? A GPS-based Time-Series Analysis.</p>	<p>12 Female University Soccer Players (19.4 ± 1.69 years) Canada</p>	<p>Matches analysed with ≤ 24 hours recovery between two matches.</p>	<p>Intensity, total distance, sprint count, sprint distance, and acceleration decreased between game one and game 2.</p>

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<p>Wehbe <i>et al.</i> (2014) Movement Analysis of Australian National League Soccer Players Using Global Positioning System Technology.</p>	<p>19 professional full-time male soccer players (26.0 ± 4.7 years) Australia</p>	<p>GPS tracking devices were used to determine activity profiles for different playing positions (defenders, midfielders and attackers) Eight pre-season games were analysed.</p>	<p>Total distance ($p < 0.001$) and average speed (m/min) ($p < 0.001$) were significantly lower in the 2nd half compared to the 1st half. Midfielders covered ($p \leq 0.05$) higher total distance significantly during the match compared to defenders</p>
<p>Wellman <i>et al.</i> (2015) Quantification of Competitive Game Demands of NCAA Division 1 College Football Players Using Global Positioning Systems.</p>	<p>33 NCAA Division 1 soccer players (20.7 ± 1.0 years) America</p>	<p>GPS data were assessed as movement profile variables during 12 matches of the regular season. The duration of the games was 60 minutes.</p>	<p>The wide receiver's total distance covered during the game was significantly ($p \leq 0.05$) higher than the other playing positions. Wide receivers also had significantly ($p \leq 0.05$) higher sprint efforts and maximal acceleration efforts.</p>

HR = Heart Rate; WMF = Wide Midfielder; CD = Central defender; FW = Forward; CM = Central midfielder; S = Striker; FB = Full Back; WM = Wing Midfielder; GPS = Global positioning system; TD = Total distance; CB = Centre back.

In summary, based on the information presented in Table 2, the least number of matches analysed was eight, while the maximum number of games analysed during a study was 45 games across three different seasons, and the average amount of matches being analysed was 20 matches. Two studies analysed the % of HR_{max} during the games; seven of the studies found that midfielders covered more distance and had acceleration than other playing positions, while four of the studies reported lower distance and intensity in the second half compared to the first half. One of the studies found that the average speed was higher in teams that lost compared to when they won or drew. In the following section, the three main match demands analysed in soccer are further discussed.

3.1.3 GPS metrics

a. Total distance

Match demands based on GPS data can benefit coaches in determining position-specific demands during matches and planning training activities around these demands to reach the same level of physiological and physical demands in training as during the game (Hennessy *et al.*, 2018:88). Different playing positions and formations resulted in different total distance (TD) outcomes. In this regard, a 4 (defender)-4 (midfielder)-2 (attacker) formation covered the highest average TD (10.51 ± 0.88 km, CV = 8.35%), while other playing formations 4-3-3 and 3-5-2 covered slightly different distances respectively (4-3-3: 10.08 ± 1.04 km, CV = 10.33% and 3-5-2: 10.39 ± 1.12 km, CV = 10.80%) (Borghini *et al.*, 2021:234). In addition, the same study found that central midfielders (CM) covered higher TD during the first (5.92 ± 0.36 km) and second half (5.57 ± 0.42 km) than any other position. Regarding the effect thereof on the match outcome, Nobari *et al.* (2021:5) noted significant differences between the winning team's TD (9.36 ± 1.64 km) and the losing team's TD (8.67 ± 2.82 km) (ES = 2.30, 95% CI [1.25, 3.20]). Turczyn *et al.* (2022:13) found that female soccer players running performances significantly ($p = 0.001$) reduced between game 1 (9.58 ± 0.63 km) and game 2 (9.02 ± 0.73 km) with ≤ 24 hours recovery between the games.

b. Acceleration and deceleration

Dalen *et al.* (2016:355) have shown that parameters, such as the number of accelerations, are position specific. For example, the average total number of accelerations for all playing positions achieved during a match equated to 76 ± 22 , whereby wide midfielders (WM) achieved the most accelerations (87 ± 25) and central defenders (CD) the least (61 ± 22).

Regarding decelerations, an average of 54 ± 16 decelerations were achieved during a match, with 28 ± 9 and 27 ± 10 being attained during the first and second halves, respectively (Dalen *et al.*, 2016:355).

c. Intensity

Similar findings are extended to other parameters such as distance per minute (Pons *et al.*, 2019:4). Pons *et al.* (2019:4) found that the average distance per minute per game is 110.1 ± 18.5 m, whereas Wehbe *et al.* (2014:838) found the average speed (distance per minute [m.min⁻¹]) values varied according to position during games: defenders (104.65 ± 737), midfielders (116.09 ± 4.88 m.min⁻¹), and attackers (111.85 ± 13.15 m.min⁻¹). Arrones *et al.* (2014:7) showed that the distance per minute for the first half was (118.9 ± 10.7 m.min⁻¹) and that 32.2% of this distance was spent walking, 38.4% low-speed running, 19.7% medium-speed running, 5.4% high speed running, and 4.2% sprinting. Arrones *et al.* (2014:7) also showed that wide midfielders covered significantly ($p < 0.05$) greater distances > 18 km.h⁻¹ and > 21 km.h⁻¹ than any other playing position. In female soccer players, Turczyn *et al.* (2022:12) found that the distance per minute significantly ($p = 0.04$) decreased between game 1 (113.2 ± 3.3 m.min⁻¹) and game 2 (109.2 ± 4.3 m.min⁻¹) (≤ 24 hours apart).

The research above shows that midfielders tend to (i) cover the highest distance during games, (ii) achieve the highest number of accelerations compared to other playing positions and (iii) that winning teams cover more distance than losing teams. Furthermore, GPS technologies can potentially benefit teams in establishing workloads that players can tolerate and further determine workloads that may assist in reducing injuries as well as assisting in return to play protocol after an injury (Hennessy *et al.*, 2018:89). Another important aspect that can affect the outcome of matches is the PIs of the specific sport (Mitrotasios, 2018:15).

4. PERFORMANCE INDICATORS – WITH A SPECIAL REFERENCE TO SOCCER

PIs are generally defined as “*the selection and combination of variables that define some aspect of performance*” (Harrop & Nevill, 2014:907). Performance analyses in soccer, therefore, provide concise, objective data to players and coaches to maximise team performance (Goes *et al.*, 2021:482), especially in preparation for big tournaments and matches. Insights into technical and tactical requirements of modern-day team/individual sports competitions are provided by PIs, which can also be used to build the best strategy, improve team performance, monitor player load, and enhance tactical decision-making

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(Kubayi & Torioa, 2020:215). Performance profiling can be used by coaches to evaluate the success of a team, elements of a team, or an individual and can also help to build an effective strategy, make rational tactical decisions, and improve team performance (Kubayi & Toriola, 2020:215). Profiling of the ideal performance can help coaches and players predict the future behaviour of teams and increase their chances of success (Harrop & Nevill, 2014:907-908). The variables specific to soccer are classified as total shots, shots on target, shots inside the penalty area, passes, successful passes, passes in the opposition half, fouls received, dribbles, crosses, corners, offsides committed, yellow cards, and red cards among others (Harrop & Nevill, 2014:910). The following table consists of the definitions of PIs during a match.

Table 2.3: Definitions of match-related performance indicators

Performance indicators	Definition	Reference
Total shots	“Shots (attempted) on the opposing goal, including shots that are not “on goal”	Herold <i>et al.</i> (2021:160)
Shots on target	“Shots on goal including goals. Excludes crossbar and goalpost contacts that do not lead to a goal”	Herold <i>et al.</i> (2021:160)
Shots inside the penalty area	“Shots attempted from within the penalty box area”	Herold <i>et al.</i> (2021:160)
Passes	“The sum of all the passes completed”	Herold <i>et al.</i> (2021:160)
Successful passes	All successful passes are added together during the game.	Herold <i>et al.</i> (2021:160)
Passes in the opposition half	Completed passes in the offensive team half.	Herold <i>et al.</i> (2021:160)
Fouls received	The opposing team is penalised by the referee for any infringement.	Liu <i>et al.</i> (2015:1207)

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Dribble	The attacking player in possession of the ball attempts to beat the opponent.	Liu <i>et al.</i> (2015:1207)
Crosses	Constitutes when a pass between the sideline and edge of the goalbox is made and travels into the central area in the penalty box.	Herold <i>et al.</i> (2021:160)
Corners	When the ball passes over the goal line, having last touched a player from the defending team.	Liu <i>et al.</i> (2015:1207)
Offsides	The player being in an offside position result in a free kick for the opposing team.	Liu <i>et al.</i> (2015:1207)
Yellow cards	A player can be shown a yellow card by the referee for handball, time-wasting, persistent infringement, dangerous play, etc.	Liu <i>et al.</i> (2015:1207)
Red cards	When the referee sanctions a player with a straight red card or because of a second yellow card.	Liu <i>et al.</i> (2015:1207)

According to Mitrotasios (2018:15) the following PIs showed significant differences between successful and unsuccessful teams during the UEFA-Euro 2012: total attempts (13.2 vs 12.6; $p \leq 0.03$), attempts on target (7.2 vs. 6.0; $p \leq 0.05$), corners (5.7 vs 5.0; $p \leq 0.02$), offsides (2.3 vs. 1.7; $p \leq 0.02$), fouls committed (13.9 vs. 15.0; $p \leq 0.01$), fouls suffered (13.7 vs. 12.9; $p \leq 0.02$). PIs can be selected by coaches on their coaching philosophy, and not purely based on scientific literature (Herold *et al.*, 2021:158). The extent to which PIs vary as a function of sleep quality has not been previously measured and, therefore, presents a noteworthy gap in the existing literature.

In Table 2.4, studies making use of PIs within the sport of soccer are presented and subsequently discussed.

Table 2.4: Studies examining performance indicators in soccer

Authors, date, and article title	Subject (Number, age, sport, and country)	Intervention	Results p values
Harrop & Nevill (2014) Performance indicators that predict success in an English professional League One soccer team.	English League One soccer players	46 Matches played during the 2012-2013 league season were analysed to determine the difference between offensive and defensive PIs between teams that won, lost, and drew.	Successful passes were significantly lower when teams drew compared to when they won ($p < 0.006$) and lost ($p < 0.001$).
Mitrotasios (2018) Differences in Performance Indicators between successful and unsuccessful Teams in UEFA-EURO 2012.	Players from European Nations that competed in the UEFA-Euro 2012.	16 European nations competed over 31 matches. All the games were analysed to determine if the PIs influenced the outcome of the match.	Total shot attempted ($p \leq 0.03$), total shots attempted on target ($p \leq 0.05$), corners ($p \leq 0.02$), offsides ($p \leq 0.02$), fouls committed ($p \leq 0.01$), and fouls suffered ($p \leq 0.02$) had a significant impact on the outcome of the game.

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Kubayi & Toriola (2014) Match Performance Indicators that Discriminate Between Winning, Drawing and Losing Teams in the 2017 AFCON Soccer Championship.	Professional African soccer players	32 Matches during the 2017 Africa Cup of Nations (AFCON) Soccer Championship to determine the match PIs that differentiate between winning, losing, and drawing.	Winning teams scored significantly ($p < 0.05$) more goals and on average had more total shots, shots on target, fouls, offsides, yellow cards, and red cards.
Yang <i>et al.</i> (2018) Key team physical and technical performance indicators indicative of team quality in the soccer Chinese super league.	Professional players of the Chinese Super League	420 Matches were analysed during the 2014 season to examine the tactical and physical performances that contribute to greater season success.	Teams that were higher ranked had significantly ($p < 0.001$) higher ball possession in opponent's half, and final 1/3 entries ($p < 0.023$). Top ranked teams covered significantly ($p < 0.001$) total distance while sprinting than lower ranked teams.
Zhou <i>et al.</i> (2021) Long-term influence of technical, physical performance indicators and situational variables on match outcome in male professional Chinese soccer.	Professional players of the Chinese Super League	1429 Matches were analysed, between 2012 and 2017 season to determine if the role of PIs varied over the seasons.	Shots on target, possession, total distance in possession of the ball, total distance out of ball possession, quality of opposition, and match location had an influence on the game ($p < 0.05$).

In summary, five studies (n=5) analysed the effect of PIs on the outcome of the game. The least amount of match studies used to analyse was 31, and the maximum amount of match studies used was 1429 between the 2012 and 2017 seasons. Total shots, shots on target, offsides, and fouls were higher in winning teams in two of the studies; one study found that teams that drew had lower successful passes than teams that won or lost.

Harrop and Nevill (2014:911) reported that losing teams made significantly ($p < 0.001$) more passes compared to when teams drew or won games. Kubayi and Toriola (2020:215) found that losing teams had higher total passes (260.30 ± 49.10), accurate passes (69.28 ± 5.74), corners (5.10 ± 2.95), and ball possession (51.20 ± 5.52) on average; these findings could indicate that the losing teams were not creating enough scoring opportunities by advancing forward. Furthermore, the literature revealed that successful passes between teams winning ($p = 0.006$) and losing ($p = 0.001$) were significantly higher compared to teams drawing.

Kubayi and Toriola (2020:217) reported that goals scored (1.80 ± 0.83), total shots (11.05 ± 4.83), shots on target (4.70 ± 2.62), fouls (18.60 ± 5.19), offside (2.35 ± 1.76), yellow cards (1.55 ± 1.10), and red cards (0.05 ± 0.22) were higher (not statistically significant) in winning teams compared to the losing team. Winning teams displayed higher ball possession in the opponent's half, final 1/3 entries, and entries into the penalty area when the style of play focused on ball possession (Yang *et al.*, 2018:163). Yang *et al.* (2018:163) found that better-ranked teams (1-8) also committed more fouls than lower-ranked teams (13-16), indicating that an aggressive style of play may increase the probability of team success.

There was a significant effect ($p \leq 0.05$) on winning the match during the Chinese Soccer Super League (CSL - seasons 2012-2017) for shots on target, total distance in possession with and without the ball, possession, quality of opposition, and match location (Zhou *et al.*, 2021:600).

5. SUMMARY

With the professionalism of the sporting arena increasing annually, researchers are prompted to find new and more novel ways of optimising performance. One of the more promising avenues through which performance can be considerably improved is by decreasing the time needed to recover. Since sleep deprivation is a real-life problem athletes face, various sleep hygiene recommendations have been developed to aid athletes in their sleep regime. Various studies have reported on the detrimental effects of sleep deprivation on sports performance, as well as how a SHP can aid in performance. Unfortunately, the majority of studies only examined the effects thereof on physical and psychological performance measures and not so much for real-

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life competitions. Since notational and match analysis are deemed vital for success, it is imperative for athletes to allow optimal recovery to maximise their match performances. As sleep is regarded as the most important recovery aspect, and no other recovery method could replace sleep, it would be important to prioritise sleep for athletes to recover optimally (Miles *et al.*, 2019:748).

The effect of sleep on isolated performances, such as reaction time, continuous kicking test, CMJ, and sprint times, is mentioned in this chapter. No research could be found on the effect of sleep on match demands and PIs in soccer during a game, which can be attributed to the large amount of data that is needed = to make an accurate conclusion. Given the specific gaps identified, the present study will investigate specific sleep interventions to determine the effect sleep has on match demand and PIs in soccer during a match.

Shortcomings observed during the investigation for the literature review regarding sleep are that most of the studies focused on the effect of sleep on skills in a controlled environment. No studies could be found on the effects of sleep on skills and PIs during a match. Another aspect that can be looked at in sleep hygiene interventions is to individualise the strategy to the player's routine and environment; players following a sleep hygiene intervention can be taken out of their sleeping habits and routine.

The identified finding highlights the importance of sleep for athletes. Sleep plays a significant role in restoring certain performance elements among soccer players. Endurance, sprint, and reaction times improved during sleep hygiene intervention periods. However, more Research should be done on what effect sleep has on match-specific performance measures.

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CHAPTER 3

EFFECTS OF A SLEEP HYGIENE INTERVENTION PERIOD ON THE PHYSICAL PERFORMANCE INDICATORS OF MALE UNIVERSITY- LEVEL SOCCER PLAYERS DURING A TOURNAMENT

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EFFECTS OF A SLEEP HYGIENE INTERVENTION PERIOD ON THE PHYSICAL PERFORMANCE INDICATORS OF MALE UNIVERSITY- LEVEL SOCCER PLAYERS DURING A TOURNAMENT.

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ABSTRACT

Performance indicators (PIs) are commonly used in soccer to provide concise data to players and coaches to maximise performance. Sleep deprivation is a common occurrence in soccer, thereby implicating performance. Therefore, the aim of this study was to determine the effect of a sleep hygiene protocol (SHP) on various soccer match PIs. Sixteen male university-level soccer players from the North-West University took part in the study. Their matches were evaluated in comparison to their respective opponents over a period of 14 matches, consisting of five matches (no-sleep intervention), four matches (sleep intervention) and five matches of no intervention. During the intervention period, they completed at least ten sleep hygiene requirements for a period of four weeks. The results demonstrated a significant positive difference for the number of connections ($p = 0.05$, ES 1.3) and dribbles ($p = 0.01$, ES = 1.8) made, with the number of successful passes and crosses demonstrating a moderate to large effect size (ES > 0.8). Successful passes (24.9%), successful passes in opposition half (10.2%), crosses (28.6%), and shots taken in the penalty area (24.7%) demonstrated a large percentage difference compared to the no-intervention period. The study conclude that an SHP can have a significant effect on certain match PIs as well as a positive effect on PIs that can have an influence on the result of a game.

KEYWORDS: sleep hygiene protocol, performance indicators, soccer, successful, team

1 INTRODUCTION

Sleep is widely regarded as a critical process for physiological and cognitive functioning (7). It is exceptionally important for athletes in terms of optimal decision-making capacity, cognitive recovery, and restoration of the metabolic and neural costs associated with the waking period (19,24). In this regard, seven to nine hours of sleep are recommended by the National Sleep Federation for full restoration, though less than seven hours per night has been reported by athletes (10). Generally, up to 70% of soccer players experience insufficient sleep or sleep deprivation (reduced sleep by 2.5 hours per night or total sleep deprivation over several days) prior to a major competition, largely attributed to anxiety and mood disturbances, late-night matches, congested schedules, light and noise exposure, caffeine, alcohol consumption and travel fatigue to name a few (18,26,29). Sleep deprivation, in turn, can result in heightened levels of perceived exertion and lower cognitive processing that can lead to poor concentration and attention, reduced arousal and motivational levels, and physical performance decrements (16). In this regard, Pallesen and colleagues (20) reported how sleep-deprived athletes (no sleep the night prior to testing) performed significantly ($p < 0.05$) worse in a continuous soccer kicking test compared to their rested condition.

To combat the negative consequences of poor sleep, researchers and scientists have developed various guidelines to aid sleep, which is collectively termed “sleep hygiene” (26). The implementation of a sleep hygiene protocol (SHP) can entail creating a cool ($19 \pm 2^\circ\text{C}$) and dark (60 ± 12 watts) environment, minimising noise and distraction, creating a comfortable place without any electronic devices, appropriate napping (five to 30 minutes), and a 30- to 60-minutes period of quiet, relaxation before bedtime (28). Furthermore, consistent sleep patterns, active daytime behaviours (massages, stretching, electrical stimulation, and active recovery), using red-light treatment and dawn simulation (to slightly increase the illuminance before waking up in the morning) have also been reported to create a SHP environment (18).

Evidence for the efficacy of SHP was shown by Mah and colleagues (15), who reported a significant improvement from baseline for sprinting (16.2 sec vs 15.5 sec; $p < 0.001$), reaction time (310.84 m.s vs 274.51 m.s; $p < 0.04$) and shooting accuracy (successful field goals out of 15: 10.2 vs 11.6; $p < 0.05$) for basketball players. Furthermore, Schwartz and Simon (23) compared the number of accurate tennis served following a sleep-deprived and sleep extension week and reported a significant improvement (35.7 to 41.8% $p < 0.05$) following a single week of sleep extension. In addition, Roberts and colleagues (22) reported a 3% (2 minutes) improvement during a 60-minute cycling time trial performance following a three-night consecutive sleep extension period (average of 92 min extra sleep per night). Moreover, Fox and colleagues (5) not only reported an increase in sleep efficacy following a SHP but also noted a positive correlation

between this sleep efficacy and various PIs in semi-professional male basketball players (such as blocks, free-throw accuracy, assists, rebounds, and steals). PIs are generally defined as “*the selection and combination of variables that define some aspect of performance*”, which is seen as a vital aspect that can affect the outcome of a competition (8). Though ample research is available on the effectiveness of SHP on various physical and psychological parameters – see Bonnar et al. (2) and Vitale et al. (26) for full review – limited research exists on its effects during a genuine tournament setting.

Performance profiling is generally used to evaluate the success of either a team, elements of a team, or an individual by investigating the factors contributing to success to thereby build an effective strategy, make rational tactical decisions, and ultimately, improve team performance (11,20). Within soccer, these variables are divided into three groups: *offence* (total shots, shots on target, shots inside the penalty area, passes, successful passes, passes in the opposition half, fouls received, dribbles, crosses, corners, offsides committed), *defence* (yellow cards, red cards, fouls committed, corners against, and crosses against) and *contextual variables* (match location) (8). According to Kubayi and Toriola (11), losing teams demonstrated higher ball possession (51.20 ± 5.52), total passes (260.30 ± 49.10), accurate passes (69.28 ± 5.74), and corners (5.10 ± 2.95) on average compared to winning teams, while successful passes between teams losing (69.28 ± 5.74) and teams winning (69.10 ± 6.50) were higher compared to teams drawing. However, none of these findings were significant. Regarding the defensive component, Yang and colleagues (29) reported that higher-ranked teams (1-8) also committed more fouls than lower-ranked teams (13-16), concluding that an aggressive style of play can lead to team success. Kubayi and Toriola (11) found higher values in winning teams compared to losing teams regarding total shots (4.73%), shots on target (23.68%), offsides (46.88%), fouls (6.59%), yellow cards (34.78), and red cards (0.05%). Therefore, PIs can be informative for evaluating team success and taking into consideration the effect that specific interventions might have on performance. Whether or not changes in SHP might influence key aspects of performances in soccer is presently unknown, as no research could be found on the effect of sleep on PIs during a soccer game.

Based on the dearth of information on SHP in soccer, the main objective of the study was to determine the effect of SHP on match PIs of university-level male soccer players during a semi-elite tournament consisting of 14 matches.

2 METHODS

2.1 Experimental Approach to the problem

A repeated measure, quantitative intervention research design was conducted over an entire soccer tournament. Data were collected during a semi-elite tournament in the 2022 season, comprising 16 matches completed over 16 weeks (one match per week) excluding semi-finals and finals) while only 14 matches were used in the final analysis. Ethical approval was obtained from the institutional review board (XXX-00299-21-A1-02) prior to data collection.

2.2 Sample

A convenient sample technique was used in the proposed study. Sixteen ($n = 16$) male university-level soccer players from a tertiary institution took part in the study (Average age: 22.2y; Stature: 167.6cm; Mass: 62kg). Their matches were analysed against the respective opponents over a period of 16 matches. All participants provided signed informed consent prior to data collection.

2.3 Procedures

The tournament (ABC Motsepe League) consisted of 16 competitive (home and away) group matches in a regional league, but only 14 matches were used in the final analysis, with teams competing against each other twice over this period in the 2022 season. The primary team that was part of the NWU Tawana team and injury and illness free, as well as their respective opponent's PIs were recorded and analysed following each respective match, though for the purpose of this study, only the team executing the intervention period's results will be discussed. Five matches were set out as baseline matches (no intervention took place), with the following four matches set out as the intervention period, separated by a 1-week wash-out period with the last five matches again set out as baseline measures (25). Therefore, ten matches were used for baseline measures, with four matches set out for SHP.

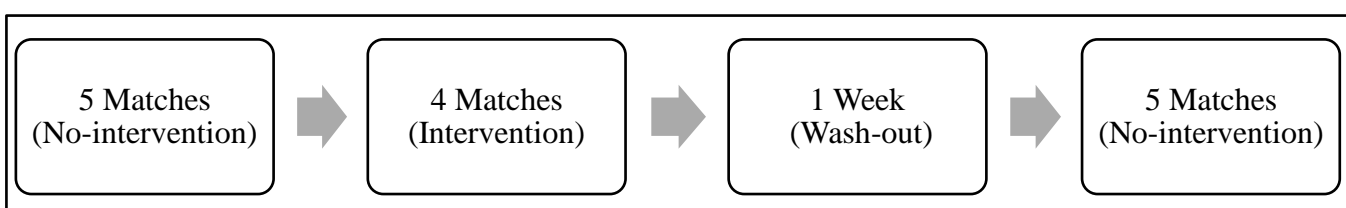


Figure 1: Outline of intervention study over the tournament.

The additional two matches were set out if any errors might occur (cancellation or postponement of matches, poor video capturing, players getting injured, sick, or any reason for them not to complete all the league games) during any of the previous matches.

2.3.1 Match performance indicators

PIs are defined as "the selection and combination of variables that define some aspects of performance and help achieve athletic success" (12). Video analysis was used to determine the following match PIs that is categorised into the following three groups: contextual variable (match location), offensive variables (passes, successful passes (%), passes in the opposite half, total shots, shots on target, shots inside the penalty box, dribbles (attempt to beat an opponent), crosses (made into the penalty box), corners (corners taken by the team after the ball went into touch), offsides committed, and fouls received), and defensive variables (corners against, crosses against, fouls committed, red cards, and yellow cards) (4,8,11). In addition, as requested by the head coach, connections were also recorded (three or more consecutive successful passes). Depending on where the team played, the location was marked as "home" or "away". As with Harrop and Nevill's (8) study, data were collected for the whole 90 minutes (including injury time). The following table consists of the definitions of PIs during a match.

Table 1. Definitions of match-related performance indicators

Performance indicators	Definition	Reference
Total shots	"Shots (attempted) on the opposing goal, including shots that are not "on goal"	Herold <i>et al.</i> (2021:160)
Shots on target	"Shots on goal including goals. Excludes crossbar and goalpost contacts that do not lead to a goal"	Herold <i>et al.</i> (2021:160)
Shots inside the penalty area	"Shots attempted from within the penalty box area"	Herold <i>et al.</i> (2021:160)
Passes	"The sum of all the passes completed"	Herold <i>et al.</i> (2021:160)

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Successful passes	All successful passes are added together during the game.	Herold <i>et al.</i> (2021:160)
Passes in the opposition half	Completed passes in the offensive team half.	Herold <i>et al.</i> (2021:160)
Fouls received	The opposing team is penalised by the referee for any infringement.	Liu <i>et al.</i> (2015:1207)
Dribble	The attacking player in possession of the ball attempts to beat the opponent.	Liu <i>et al.</i> (2015:1207)
Crosses	Constitutes when a pass between the sideline and edge of the goalbox is made and travels into the central area in the penalty box.	Herold <i>et al.</i> (2021:160)
Corners	When the ball passes over the goal line, having last touched a player from the defending team.	Liu <i>et al.</i> (2015:1207)
Offsides	The player being in an offside position result in a free kick for the opposing team.	Liu <i>et al.</i> (2015:1207)
Yellow cards	A player can be shown a yellow card by the referee for handball, time-wasting, persistent infringement, dangerous play, etc.	Liu <i>et al.</i> (2015:1207)
Red cards	When the referee sanctions a player with a straight red card or because of a second yellow card.	Liu <i>et al.</i> (2015:1207)

Sportscodes video analysis software (SportsCode v. 8.9, Sportster, Australia) was used by two analysts to analyse all the recorded games using the tagging function. Percentage errors were used to conduct both intra-observer and inter-observer reliability suggested by Hughes and colleagues (9). The principal analyst (Mr. Reece Hammil) assessed intra-observer reliability by re-analysing three random matches to guarantee a sufficient degree of reliability. A second qualified analyst with the same familiarity and experience with the software re-analysed all the matches to assess inter-observer reliability, with an ICC score of 0.84. The original test (A) was then compared with the retest (B) of inter and intra-analysis to calculate the percentage

differences with the expected limit of agreement being less than 5%, which is in line with previous studies.

2.3.2 Sleep Hygiene intervention Period (SHP)

During the no-intervention period (comprising of five matches before, and five matches after the intervention period), the soccer players followed their own sleep routine to thereby act as their own control group. Within these conditions, players were allowed to self-regulate their exposure to electronic equipment, pre-bed light (60 ± 12 Watts), and sleeping patterns. During the intervention period, all the players completed the SHP over a four-week period (comprising four matches). The sleep intervention period started a week prior to the first intervention match – which is similar to previous research and was completed for a three-week period (3,6) to accurately measure if any changes took place because of an SHP.

A week of no intervention was organised following the intervention period to serve as a wash-out period (25). During the intervention period, participants were asked to adhere to at least 10 of the following sleep hygiene recommendations in their own home setting:

Recommendations included setting a cool temperature and low Watt-light and removing alarms or clock appliances. Each participant received SleepSpec Optical Insert Sleepshades glasses to wear during the night before sleeping to minimise light exposure. They also received an eye mask and earplugs, if they wished, to wear to minimise light and noise. In addition, they were asked to minimise exposure to electronic media by 20:00 in the evening. They were also requested to go to bed at 21:30, following either a hot bath or shower. In addition, they were advised to minimise any bathroom disruptions and obtain at least eight hours of uninterrupted sleep. Furthermore, they had the option to take a short nap early afternoon (before 14:00) and consume either a glass of warm milk or camomile tea prior to bed. They were requested to adhere to at least ten of the 16 listed recommendations and mark daily what recommendations were adhered to. Lastly, the participants were requested to abstain from ingesting any drugs or participating in strenuous physical activity that may influence the physical or physiological responses of the body for at least 48 hours before the scheduled matches.

On match days, the participants were asked to complete an electronic questionnaire (Google form) regarding their previous night's quality and quantity of sleep, namely the sleep and sporting activity questionnaire. No interference took place during any matches as each match was recorded and analysed afterwards.

2.3.3 Statistical Analyses

All analyses were completed using Statistical Package for Social Sciences (SPSS, IBM SPSS 26.0). The Shapiro-Wilk test evaluated the departure from normality ($p < 0.05$) for the PIs and outcomes. Descriptive statistics (averages, standard deviation, minimum, and maximum values) of each variable were drawn and reported as a mean \pm SD. The alpha-value (i.e., type-I error rate) was set at 0.05, with statistical significance accepted at $p \leq 0.05$. Between-group differences in performance were evaluated using Cohen's d as the standardised effect size, which was interpreted as trivial: < 0.2 , small: $0.2 - 0.6$, moderate: $0.6 - 1.2$, large: $1.2 - 2.0$, and very large: >2.0 (1).

3 RESULTS

Concerning the subjectively reported sleeping patterns prior to the intervention, the average bedtime was reported as 01:00, wake time as 07:40, time to fall asleep as approximately 21 minutes, and an average sleep duration of 7 hours. After the intervention, this information changed to an average bedtime of 22:30 ($p < 0.001$) and wakening time of 08:00 in the morning, with the participants reporting an average of 19 ($p = 0.001$) minutes to fall asleep and averaging 8 ($p = 0.002$) hours of sleep per night. Concerning the sleep hygiene principles (SHP), most players implemented the following (from most to least implemented): wearing light-reducing glasses for the entire night until going to bed; wearing a sleep mask to eliminate any light whilst sleeping; sleeping at least 8 hours; avoid napping after 14:00; consuming a glass of camomile tea prior to going to bed; changing their electronic stimulants to a "cool" light setting; avoiding any electronic stimulation 30minutes prior to going to bed; avoid consuming caffeine from 17:00 and lastly, taking a warm bath/shower immediately prior going to sleep.

Regarding the PIs observed during the matches, a summary of the main PIs is provided in Table 1 between the no-intervention and intervention periods, together with the mean and standard deviation values as well as the percentage difference between the two time periods.

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Table 2. Descriptive statistics of PIs between intervention and no-intervention

	SHP = 1 no-SHP = 0	Mean	Percentage difference (%) (SHP vs. No-SHP)
Successful Passes	0	211.7 ± 52.1	24.9%
	1	281.8 ± 91.5	
Successful Passes in opponent half	0	92.5 ± 31.7	10.2%
	1	103.0 ± 39.7	
Unsuccessful Passes	0	73.1 ± 21.0	4.4%
	1	76.5 ± 13.6	
Connections	0	34.6 ± 11.0	38.0%
	1	55.8 ± 25.8	
Total Shots	0	11.9 ± 3.0	8.5%
	1	13.0 ± 4.1	
Shots on Target	0	5.1 ± 1.7	-11.8%
	1	4.5 ± 3.1	
Shots in the Penalty Area	0	5.5 ± 2.9	24.7%
	1	7.3 ± 4.1	
Fouls Committed	0	13.9 ± 4.1	0.7%
	1	13.8 ± 6.6	
Offsides Committed	0	3.2 ± 0.6	37.5%
	1	2.0 ± 1.8	
Yellow Cards	0	1.9 ± 1.4	17.3%
	1	2.3 ± 1.7	
Dribbles	0	4.9 ± 2.3	47.3%
	1	9.3 ± 2.6	
Crosses	0	12.5 ± 5.4	28.6%
	1	17.5 ± 8.5	
Corners	0	4.0 ± 1.5	-5.0%
	1	3.8 ± 3.0	

Note: SHP = Sleep Hygiene intervention Period ; no-SHP = No-Sleep Hygiene intervention Period

The results from the independent t-test are provided in Figure 2. The number of connections ($p = 0.05$, $ES = 1.3$) and dribbles ($p = 0.01$, $ES = 1.8$) completed demonstrated a statistically significant as well as a large effect size compared to the no-intervention period, with the number of successful passes ($p = 0.09$, $ES = 1.1$) only showcasing a large effect size and the crosses a moderate effect ($p = 0.20$, $ES = 0.8$) despite a lack of statistical significance.

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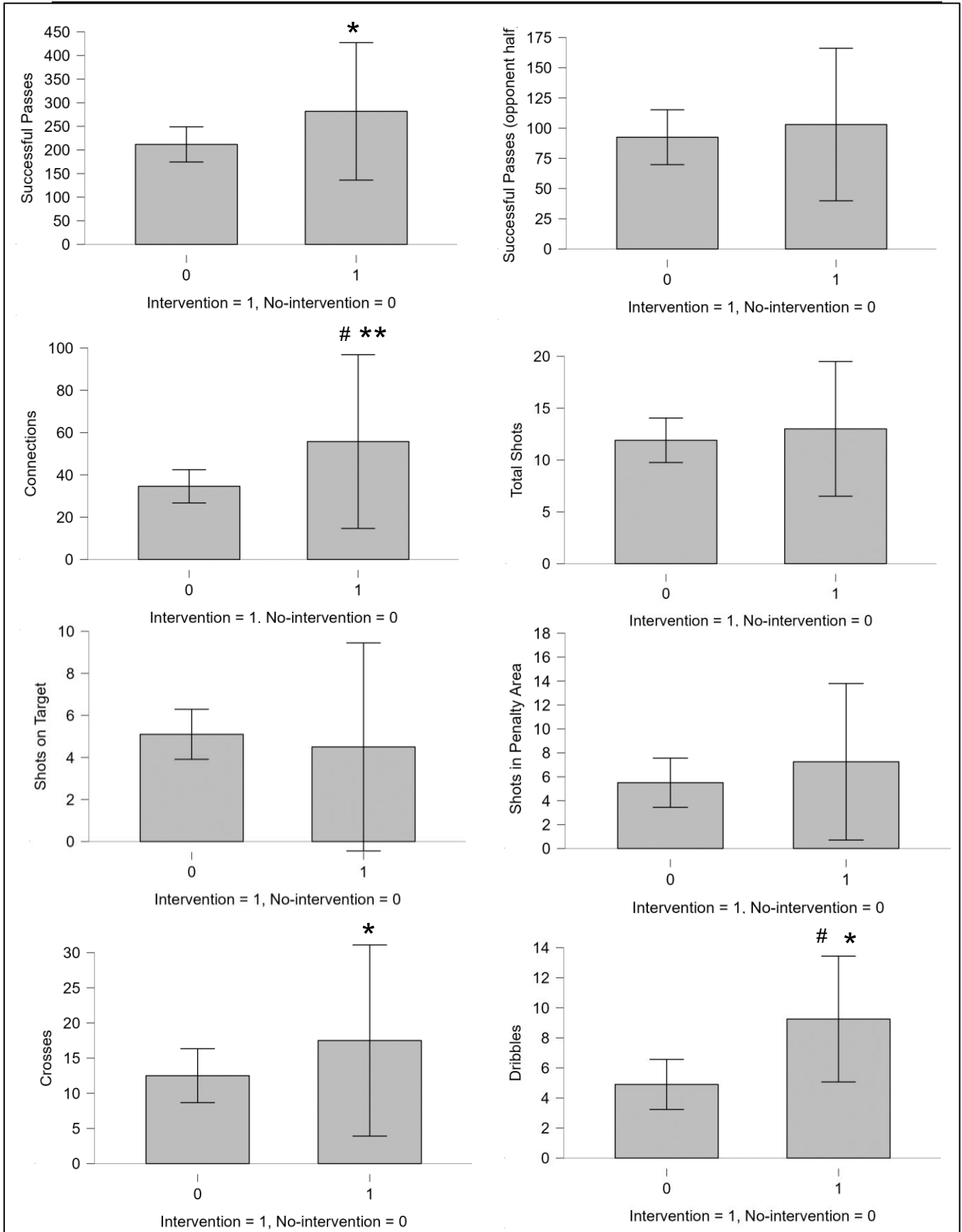


Figure 2. Results for the main PIs between a sleep intervention and no-intervention period.

Note: # = $p < 0.05$; * Moderate effect size (ES = 0.6 – 1.2) ; ** Large effect size (ES = 1.2 – 2)

4 DISCUSSION

The objective of the study was to determine the effect of a SHP on the physical PIs of male university-level soccer players during a tournament consisting of 14 matches. To our knowledge, this is the first study to investigate the association between sleep and PIs for soccer matches over a tournament period, which would enhance the ecological validity of the findings. The novel findings of the present study highlight that an acute SHP can have meaningful implications in terms of the number of connections and dribbles completed during matches despite drastic differences in the level of play and match outcomes.

For this study, a total of 14 matches were analysed based on various PIs as reported in the literature. Ten of these matches were set out as no-intervention matches to serve as a baseline measure for the team, whilst four matches were analysed where the entire squad completed the sleep hygiene intervention period.

The results of our study demonstrated a large, statistically significant ($p \leq 0.05$, $ES \geq 1.3$) differences in the number of dribbles and connections made between the no-SHP and SHP conditions. While statistical significance is of value for researchers, the smallest performance change can be the difference between a winning and losing outcome (31). Therefore, the authors also calculated the percentage change between the two periods. In this regard, crosses (28.6%), dribbles (47.3%), connections (38%), successful passes (24.9%), successful passes in opposition half (10.2%) and shots taken in the penalty area (24.7%) demonstrated large improvements from no-intervention until completion of the sleep intervention period. Unsuccessful passes (4.9%) and fouls committed (1.4%) had the smallest positive change from baseline to intervention.

Previous research from Fox and colleagues (5) found that sleep quality on the night preceding the competition had a positive effect on PIs such as blocks in semi-professional male basketball players. While free-throw accuracy assists, rebounds, and steals were positively correlated with subjective sleep quality. However, no significant associations were found between performance and sleep duration (5). To our knowledge, most research has investigated the effect of sleep on PIs in controlled environments but not during tournaments. One of these studies found that collegiate basketball players' reaction time, mood, sprint times, and free-throw accuracy improved after a sleep extension period compromising of 10-hour time in bed over 5-7 weeks (27). These findings were supported by Reyner and colleagues (21), who showed that serving accuracy in tennis decreased by up to 53% when sleep was reduced to five hours compared to a normal night's sleep. Regarding the above-mentioned studies, only one investigated the effect of sleep on PIs during a game, making it difficult to compare our results to studies conducted in a controlled environment. Our results demonstrated an improvement in successful passes and successful

passes in the opposition half, which is similar to the improved assists reported by Fox and colleagues (5) during a basketball match. This can be due to enhanced sleep quality influencing reaction time, daytime alertness, vigour, and mood whilst also decreasing fatigue (26). These improvements that stem from an enhancement in sleep quality can explain the increased number of successful passes and connections during our investigation, as players must react to a defender trying to intercept the passes and attacking players calling for the ball from different positions. It is widely known that sleep deprivation impacts athletes' subjective well-being, such as fatigue, mood, and cognitive clarity (28). In this regard, Pallesen and colleagues (20) noted how performance diminished during a continuous kicking test in a controlled environment following sleep deprivation compared to the rested condition.

Upon further analysis by doing a Spearman's rank correlation between variables during the SHP, several strong relationships were observed, firstly, between successful passes and 1.) successful passes in the opposition half ($r = 0.97$, $p = 0.02$), 2.) more connections ($r = 0.99$, $p = 0.004$), and 3.) shots on target ($r = 0.99$, $p = 0.006$). Furthermore, a strong relationship was observed between successful passes in the opposition half and 1.) more connections ($r = 0.99$, $p = 0.01$), and 2.) shots on target ($r = 0.99$, $p = 0.005$). In addition, the number of connections made also demonstrated a strong relationship with the number of shots on target ($r = 0.99$ and $p = 0.001$). During the no-SHP the only correlation seen was between successful passes and successful passes in opposition half ($r = 0.6$, $p = 0.05$) and connections ($r = 0.9$, $p = 0.001$). Therefore, strengthening the assumption that by merely increasing the sleep obtained, a series of events can occur that might ultimately change the outcome of a match. In this regard, the current results demonstrated how successful passes improved by 24.9% from the baseline to intervention, which led to more successful passes in the opposition half (10.2%), allowing the team to have more attacking opportunities for crosses (28.6%) and shots taken in the penalty area (24.7%).

An inadequate amount of sleep can impact visual-spatial intelligence (VSI) and visual perception, as studies done on functional imaging demonstrated how sleep deprivation can result in a change within specific brain regions (frontal and parietal cortices experience significant effects) (17). A '*connection*' refers to three consecutive passes made by the attacking team, with an increase of 38% noted following the sleep hygiene intervention. Therefore, cognitive tasks (looking where the pass comes from and knowing where to pass the ball) that involve the frontal-parietal network, such as VSI (to scan for information in the context of a soccer match), can be influenced by sleep or a lack thereof (17). Connections allow teams to keep possession of the ball for longer during the game and build pressure on the opposition team. Additionally, by increasing the number of connections, a team is likely to make more successful passes and increase the proportion of ball possession in the opponent's half, which, according to Yang and colleagues (30), is key for success. Additionally, Liu and colleagues (14) found that ball possession and average pass streak

(consecutive passes attempted in a series of passes) had a positive effect on a winning outcome. It is important to note that although an acute SHP did not appear to influence the match outcomes, the SHP did influence key factors that may increase the *probability* of a favourable outcome. Whether longer-term implementations of an SHP can continue to influence performance or at least prevent performance decrements during more dense playing schedules would require further research.

The current results demonstrated an increase of 47.3% for dribbles made following the SHP. A dribble in soccer can be described as an attacking player in possession of the ball attempting to beat the opponent by moving past the defender (14). A decrease in sleep duration has a negative influence on decision-making in athletes, as well as certain aspects of cognitive functioning that can result in reduced levels of attention, vigilance, and reaction time (13). The above-mentioned influences of sleep can alter the players' ability to perform a successful dribble and to make a quick decision based on the defending team position to either pass or dribble past the defender (16). Therefore, the player must be vigilant and pay attention to their surroundings.

5 PRACTICAL APPLICATIONS

Though the sleep intervention did not have an influence over the match outcomes, certain key PIs did show improvements compared to no intervention. Coaches and technical analysts can investigate the possibility of adding connections to PIs; the number of passes that determine a successful connection may differ between coaches depending on the game model they follow. PIs can be influenced by several factors the match location (home and away), the quality of the opposition and the weather on the day. For a more in-depth analysis of the effects of sleep on PIs, future studies should focus on individual sleep hygiene strategies, as individuals do not react alike during sleep interventions.

6 ACKNOWLEDGEMENTS

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CHAPTER 4

EFFECTS OF A SLEEP HYGIENE INTERVENTION PERIOD ON THE INTERNAL AND EXTERNAL, INTER- AND INTRA-MATCH DEMANDS OF MALE UNIVERSITY-LEVEL SOCCER PLAYERS DURING A TOURNAMENT

(To be submitted to: **International Journal of Performance Analysis in Sport**)

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EFFECTS OF A SLEEP HYGIENE PERIOD ON THE INTERNAL AND EXTERNAL, INTER- AND INTRA-MATCH DEMANDS OF MALE UNIVERSITY-LEVEL SOCCER PLAYERS DURING A TOURNAMENT.

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ABSTRACT

Soccer is a physiologically and psychologically demanding sport, requiring players to optimise their sleep to effectively enhance their recovery and ensure optimal performance during a match. Therefore, the aim of this study was to determine the effect of a sleep hygiene protocol (SHP) on the internal and external match demands during an 8-match tournament (ABC Motsepe League). Sixteen male (average age: 22.2y; stature: 167.7cm; mass: 62kg) university-level soccer players from the North-West University took part in the study. Outputs by all the players for each match and match half were analysed, consisting of two matches (no-sleep hygiene protocol – No SHP), four matches (sleep-hygiene protocol – SHP, adhering to ten SHP principles) and again two matches of no SHP. Comparing the match halves of the No-SHP and SHP, significant differences were found for total distance ($p < 0.001$), distances completed whilst jogging ($p < 0.001$), running ($p < 0.001$) and sprinting ($p = 0.03$), as well as distances covered in the medium ($p = 0.05$) and high-velocity ($p < 0.001$) zones, and low ($p < 0.001$) and medium ($p < 0.001$) decelerative zones and for all accelerative zones ($p < 0.001$). Therefore, it is recommended players and coaching staff implement sleep hygiene guidelines more regularly, as it may result in noteworthy performance improvements.

Keywords: distance, GPS (global positioning system), HR (heart rate), performance, soccer.

1. INTRODUCTION

Athletes require adequate sleep to optimise their decision-making abilities, support cognitive recovery, and restore the metabolic and neural costs depleted during training and competitions (Nèdèlèc *et al.*, 2013; Silva *et al.*, 2021). According to research, athletes should aim to obtain at least eight hours of sleep per night to improve their mood, alertness, and cognitive performance and decrease daytime sleepiness (Clemente *et al.*, 2021). With soccer being the most popular sport in the world, athletes are exposed to different internal and external stressors such as travel fatigue, sleep loss, social and economic pressures, and academic demands – which all affect their sleep quality and quantity (Benjamin *et al.*, 2020; Borghi *et al.*, 2020).

Soccer is a physically demanding team sport characterised by intermittent, spontaneous movements that heavily tax the aerobic, anaerobic, and neuromuscular systems (Swallow *et al.*, 2020). To effectively evaluate these physical requirements during training and matches, various factors should be analysed, such as internal and external demands in relation to the technical and tactical components (Ispyrlidis *et al.*, 2020). Player's movement patterns (external loads) can be monitored with global positioning systems (GPS) technology, and the internal load by using perceptual (e.g., rate of perceived exertion [RPE]) and/or physiological (e.g., heart rate [HR]) measures (Torreno *et al.*, 2016).

GPS technology quantifies various physical performance parameters in sports, such as total distance covered, distances covered at varying intensities, accelerations and decelerations, distances covered at different speeds, and impacts on the body, to just name a few (Castillo *et al.*, 2020). When investigating the demands placed on soccer players, they are required to execute both linear and non-linear movements at high intensities, interspersed with varying recovery durations (Gomez-Piqueras *et al.*, 2019). In a study by Borghi *et al.* (2020), the average distance covered during a match by U/19 players was 10.51km, although this varied according to playing position. Modric *et al.* (2019) stated that central midfielders CM covered the highest total distance TD (11.16km) and longest distance while running (1.67km) or jogging (4.6km), whereas wide midfielders (WM) covered the maximum distance (640m) in the high-speed running zone. Regarding the accelerations and decelerations, Dalen *et al.* (2016) conveyed that players accelerated on average $76 (\pm 22)$ times whilst decelerating approximately 54 ± 16 times during a match, proportioned almost equally during the first (28 ± 9) and second (27 ± 10) halves respectively.

A study analysing the matches played during the 2014/2015 Bundesliga season testified how the WM and forwards from the winning teams covered a significantly ($p \leq 0.05$) higher total distance at high intensities (21-24 and >24 km/h) compared to the drawing and losing teams (Chmura *et al.*, 2018). Whilst these demands are vital for performance, the players' internal ability to tolerate these demands is critical. As a linear relationship exists between heart rate, intensity,

and fatigue, it is important for players to be able to tolerate these intensities. Therefore, monitoring a player's internal physiological load *via* heart rate (HR) and perceptual loads *via* rate of perceived exertion (RPE) in conjunction with external load monitoring is of utmost importance (Torreno *et al.*, 2016). According to research, the intensity during a soccer match can rise to 70-80% of a player's maximum oxygen consumption ($VO_{2\max}$) and 80-90% of the maximal heart rate (HR_{\max}) (Alexandre *et al.*, 2012). Torrent *et al.* (2016) reported a mean HR_{\max} of $86.0\% \pm 4.9\%$ during matches, with substantial differences between the first- ($87\% \pm 5.2\%$) and the second half ($85.0\% \pm 4.6\% HR_{\max}$). While research indicates that a soccer player spends at least 65% of the duration of the match at intensities of 70-90% HR_{\max} , they rarely go below 65% HR_{\max} (Alexandre *et al.*, 2012). Given these intense physical and physiological demands, recovery strategies in soccer teams are vital as they compete in congested schedules with limited recovery time between matches (Field *et al.*, 2021).

Though ample recovery strategies exist, sleep as a recovery tool is the most preferred choice by a wide range of athletes (Bezuglov *et al.*, 2021). Unfortunately, various acute stressors (e.g., bright light, excitement and arousal of the game and the outcome, first night effect of playing away, the use of electronic stimulants, acute napping, caffeine, and alcohol) and chronic stressors (e.g., napping, early morning sessions, inconsistent match schedules, and individual chronotype) can influence a players' quality and quantity of sleep (Nèdèlèc *et al.*, 2015). Nobari *et al.* (2022) reported a large negative relationship between sleep and average high-speed running distance in semi-professional soccer players in the early-, mid-, and end-season. Azari *et al.* (2019) also noted how a single night of total SD can significantly decrease reaction time (5.94 sec vs. 5.33 sec; $p \leq 0.05$) compared to normal sleep. To minimise any effects on performance, athletes are advised to follow various sleep hygiene principles (SHP) daily to aid in their sleep quality and quantity (Nèdèlèc *et al.*, 2015). Significantly greater ($p = 0.02$) aerobic improvements were observed during a Bronco test for a high sleep (> seven h 30 min) group compared to the low sleep (<7 h 30 min) group, with a 3.9s difference in time between the two groups (Teece *et al.*, 2021). Though ample research is available on the effectiveness of SHP on various physical and psychological parameters (Bonnar *et al.* 2018; Vitale *et al.* 2019), no research exists on its effects during a genuine competition setting within soccer.

The findings highlight the physically demanding nature of soccer, especially during a competitive season (Modric *et al.*, 2019), thereby increasing the need for optimal recovery. However, no research could be found on the effect of sleep as a recovery tool on the internal and external match demands placed on players across a competitive tournament period. Therefore, the objectives of the present study are to evaluate the effects of a sleep hygiene intervention period (SHP) on the internal (e.g., HR) and external (e.g., GPS) match demands of male university-level soccer players across multiple matches and match halves during a soccer tournament.

2. METHODS

2.1 Sample

Convenience sampling was used in the study to evaluate the full soccer squad ($n = 16$) of the tertiary institution. The sample size is in line with previous research done on sleep hygiene in soccer teams (Nèdèlèc, 2015), examining the entire team (10 – 20 players). To achieve adequate statistical power, an *a priori* sample size of 16 participants was used. The players (average age: 22.2y; stature: 167.6cm; mass: 62kg) represented their institution at a major competitive league over the 2022 season, whereby eight matches were analysed. Ethical approval was obtained (XXX-00299-21-A1-02) prior to the start of data collection, and all players provided informed consent to participate in accordance with the Declaration of Helsinki.

2.2 Methodology

Internal- and external match demands (RPE, GPS, and HR) were analysed during eight competitive matches, where four served as baseline measures, and four implemented the sleep-intervention protocol.

2.2.1 GPS derived variables

The GPS units provided data regarding the repeated efforts, distance, accelerations, decelerations, velocity, and heart rate (H10 chest strap, Polar, Kempele, Finland). Following each match, the GPS unit and heart rate recordings were downloaded and analysed on a laptop with appropriate software that allows the researcher to program the start and end time of each match (Logan Plus V4.7.1, Catapult Sports, Victoria, Australia).

For analyses of the movement patterns, the movement categories for male soccer players from Dwyer and Gabbett's (2012) study were used: stand (0.0 - 0.1 m/s), walk (0.2 - 2 m/s), jog (2.1 - 3.7 m/s), run (3.8 - 6.0 m/s), and sprint (> 6.1 m/s). For the movement to be recorded as an effort, the players had to maintain the velocity for at least one second. For the recording of accelerations and decelerations, an effort had to be maintained for at least 0.5 seconds. In this regard, the following values were recorded: high deceleration (< -4.0 m/s²), medium deceleration (-2.0 to - 4.0 m/s²), low decelerations (-2.0 and 0 m/s²), high accelerations (> 4.0 m/s²), medium acceleration (2.0 to 4.0 m/s²) and low accelerations (0 to 2.0 m/s²) (Nobari *et al.*, 2021:1).

2.2.2 Heart rate monitoring

The Polar Heart Rate monitor measured the heart rate at 1Hz. The HR values were set at $<75\% HR_{max}$, $76-84\% HR_{max}$, and $85\% > HR_{max}$ as calculated from their HR_{max} measured during a previous Yo-Yo IR-1 test (Casamichana & Castellano, 2010). The HR zones were added manually to catapult and then calculated specifically to each player. The data was then displayed on a PDF together with all the external match demands.

2.2.3 Sleep Hygiene intervention Period (SHP)

The players followed their own sleep routine during the No-SHP comprising of two periods of two weeks each (completing one match weekly). Within these conditions, players were allowed to self-regulate their exposure to electronic equipment, pre-bed light (60 ± 12 Watts), and sleeping patterns. The SHP was also completed over a four-week period (also completing four matches). The specific timeline was as follows: no intervention for two weeks (No-SHP), followed by a sleep-hygiene period (SHP) for four weeks, and again two weeks of no intervention (see Figure 1).

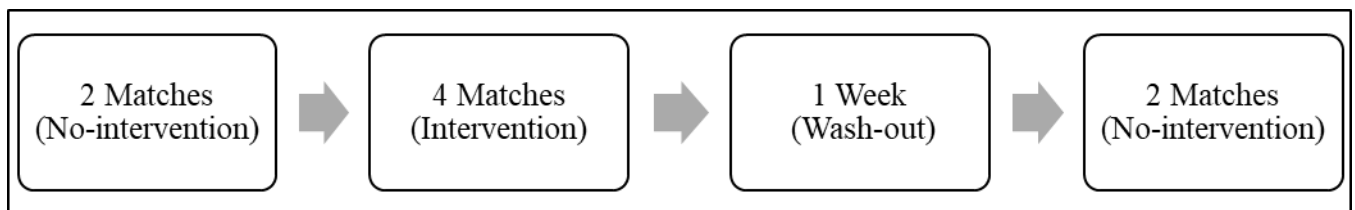


Figure 1: Outline of intervention study over the tournament.

For the SHP, participants started the sleep regime immediately following the last match of the initial no-intervention, thereby ensuring that the intervention took place for an entire week before the match, which is similar to that implemented in previous research (Duffield *et al.*, 2014; Fullagar *et al.*, 2016:a; Lever *et al.*, 2020; O'Donnell & Driller, 2017). During the intervention period, participants were required to adhere to the following recommendations: setting a cool temperature and low Light and removing alarms or clock appliances from the room. Each participant received sleepspect glasses to wear upon finishing their late afternoon training until going to bed to increase melatonin secretion. Furthermore, they could wear an eye mask and earplugs to minimise light and noise. In addition, they were requested to minimise exposure to electronic media by 20:00 in the evening and to set any electronic stimulants to the "night-mode" function from 19:00. They were also requested to go to bed at 21:30 following a hot bath or shower and consuming a glass of hot milk or chamomile tea. They were requested to adhere to at least ten of the 16 listed recommendations and mark what was adhered to daily.

During both periods, players slept in their own home setting. The participants were further requested to abstain from ingesting any drugs or participating in strenuous physical activity that

may influence the physical or physiological responses of the body for at least 48 hours before the scheduled matches. A week of no intervention was organised following the intervention period to serve as a wash-out period.

2.3 Data collection procedure

Upon waking, the participants completed an electronic questionnaire regarding their previous night's quality and quantity of sleep on the sleep and sporting activity questionnaire (Fullagar *et al.*, 2016). Ten minutes prior to the start of the match, a Catapult GPS (MinimaxX V4.0, Catapult Innovations, Victoria, Australia) unit was fitted to the upper back using a harness supplied by the manufacturer. The 10Hz GPS unit is regarded to be valid and reliable for velocity ($r = 0.96$; $r = 0.97$), acceleration ($r = 0.98$), deceleration ($r = 0.98$, $r = 0.99$), and total distance covered (TEM = 1.3%) (Johnston *et al.*, 2014). In addition, a fixed Polar HR (Polar Electro, Kempele, Finland, model H10) monitor and belt were fitted to measure HR intervals. This was used to evaluate their internal and external match loads (HR, accelerations, decelerations, time spent in various intensity zones, etc.). Then, 15 minutes after the match the same fieldworker asked the players to rate their perceived effort (RPE) on a 6-20 Likert scale. This score was then noted on a printout Likert scale data sheet.

The collected data during the no-intervention period and data found in the literature (normative) were used as baseline data to compare to the SHP data and to infer whether the SHP had a significant impact on the internal and external match demands of players. By gathering data over the eight matches against various opponents, changes and relationships between the different matches and match demands were examined.

2.4 Statistical Analysis

SPSS software (version 27, IBM) and R (R Core Team, 2023) were used to perform the statistical analyses. The Shapiro-Wilk test was used to evaluate the departure from normality ($p < 0.05$) for all variables. Descriptive statistics (averages, standard deviation, minimum, and maximum values) were calculated for each variable and reported as mean \pm SD unless otherwise stated.

Thereafter, a linear mixed effects model was used to evaluate mean differences in the dependent variable as a function of the intervention (2 levels: SHP, no SHP) and playing half (2 levels: first half, second half) while using match number as a random effect. The alpha-value (i.e., type-I error rate) was set at 0.05, with statistical significance accepted at $p \leq 0.05$. Within-group differences in performances were evaluated using Cohen's d as a standardised effect size, which

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was interpreted as trivial: < 0.2, small: 0.2 - 0.6, moderate: 0.6 - 1.2, large: 1.2 - 2.0, and very large: > 2.0 (Batterham & Hopkins, 2006). SPSS software (version 27, IBM) and R (R Core Team, 2023) were used to perform the statistical analyses.

3 RESULTS

As reported by the players, before the intervention period their average bedtime was reported as 01:00, wake time as 07:40, taking the participants approximately 21 minutes to fall asleep with an average amount of sleep of 7 hours reported. After the intervention, this information changed to an average bedtime of 22:30 ($p < 0.001$) waking time of 08:00 in the morning, with the participants reporting an average of 19 ($p = 0.001$) minutes to fall asleep and averaging 8 ($p = 0.002$) hours of sleep per night. Concerning the sleep hygiene principles, most players implemented the following (from most to least implemented): wearing light-reducing glasses for the entire night until going to bed; wearing a sleep mask to eliminate any light whilst sleeping; sleeping at least 8 hours; avoiding napping after 14:00; consuming a glass of camomile tea prior to going to bed; changing their electronic stimulants to a “cool” light setting; avoiding any electronic stimulation 30minutes prior to going to bed; avoid consuming caffeine from 17:00 and lastly, taking a warm bath/shower immediately prior going to sleep.

Table 1 shows the descriptive statistics pertaining to the internal match demands measured during the different experimental conditions (i.e. No-SHP and SHP) for the first and second halves.

Table 1. Descriptive and inferential statistics (M ± SD) of Internal Match Demands between SHP and No-SHP.

Variables	No-SHP		SHP	
	First Half	Second Half	First Half	Second Half
Player Load	511.47 ± 21.58	464.44 ± 21.58	554.84 ± 20.69*	463.70 ± 20.69
HR Minimum (bpm)	97.38 ± 3.25	97.03 ± 3.3	93.38 ± 3.12	106.58 ± 3.16**#
HR Average (bpm)	155.41 ± 3.18	153.18 ± 3.23	161.05 ± 3.05*	154.86 ± 3.09

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HR Maximum (bpm)	187.82 ± 3.29	185.03 ± 3.34	189.81 ± 3.16*	185.03 ± 3.2
Low HR zone (%)	14.25 ± 4.59	19.81 ± 6.08	10.68 ± 3.34	15.51 ± 5.09
Moderate HR zone (%)	30.97 ± 3.09	29.26 ± 2.93	29.28 ± 2.51	38.83 ± 3.25 [#]
High HR zone (%)	54.16 ± 4.69	50 ± 4.96	59.95 ± 3.56**	46.65 ± 3.96

*Significant ($p < 0.05$) difference within groups between halves; ** significant ($p < 0.001$) difference within groups between halves; # significant ($p < 0.05$) difference between groups (No-SHP vs SHP) for respective halves; ## significant ($p < 0.001$) difference between groups (No-SHP vs SHP) for respective halves: % = percentage; bpm = beats per minute; RPE = Rate of Perceived Exertion; SHP = Sleep Hygiene Intervention Period; No-SHP = No-Sleep Hygiene Intervention Period

No statistically significant differences could be found between the two halves during the no-intervention period. During the SHI period, the first half was characterised by significantly higher player loads ($p < 0.001$, ES = 0.80), lower HR_{min} ($p < 0.001$, ES = 0.44), and higher HR_{max} ($p = 0.039$, ES = 0.36). Time spent in respective HR zones indicated a shift in zones, with more time spent in the medium HR zone ($p = 0.001$, ES = 0.14) and less in the high HR zone ($p < 0.001$, ES = 0.71) during the second half. Comparing the different halves between the no-intervention and post-intervention conditions, the HR_{min} ($p = 0.006$) and time spent in the medium HR zone ($p = 0.040$) were significantly higher during the SHP compared to the second half. Table 2 shows the descriptive and inferential statistics of the external match demands measured during the No-SHP and SHP conditions for the first and second halves.

Table 2. Descriptive and inferential statistics (M ± SD) of external match demands between SHP and No-SHP.

Variable	No-SHP		SHP	
	First Half	Second Half	First Half	Second Half
Total distance (m)	3751.24 ± 137.91	3478.12 ± 163.52	4532.97 ± 135.93 ^{***#}	3696.46 ± 179.57
Intensity (m/min)	81.09 ± 2.97	80.08 ± 2.97	96.31 ± 2.85 [#]	86.65 ± 2.85
Stand (m)	11.59 ± 1.87 [#]	9.71 ± 1.87 [#]	7.62 ± 1.79	6.95 ± 1.79
Walk (m)	1881.47 ± 67.85*	1594.41 ± 67.85	1961.05 ± 65.04*	1691.11 ± 65.04

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Jog (m)	1086.71 ± 72.65	1008.97 ± 72.95	1505.87 ± 69.64 ^{###}	1195.65 ± 69.64
Run (m)	487.65 ± 49.96	506.35 ± 49.96	774.57 ± 47.89 ^{###}	590.49 ± 47.89
Sprint (m)	55.92 ± 10.79	66.35 ± 10.79	92.19 ± 10.34 [#]	62.76 ± 10.34
Velocity zone - low (m)	117.44 ± 5.03	108.56 ± 6.31	125.89 ± 3.07 [*]	114.16 ± 5.10
Velocity zone - moderate (m)	55.47 ± 5.04	49.28 ± 4.77	65.97 ± 3.44 [#]	64.41 ± 4.72 [#]
Velocity zone - high (m)	23.41 ± 2.53	20.84 ± 2.25	36.78 ± 2.38 ^{###}	27.43 ± 2.23
Deceleration zone - high (m)	2.71 ± 0.59	2 ± 0.57	3.78 ± 0.58 [*]	2.59 ± 0.41
Deceleration zone - moderate (m)	40.55 ± 4.92	38.42 ± 4.45	67.78 ± 4.94 ^{###}	48.81 ± 4.08
Deceleration zone - low (m)	949.06 ± 68.93	933.03 ± 63.48	1312.84 ± 55.61 ^{###}	1083.65 ± 66.15
Acceleration zone - low (m)	1515.71 ± 95.65	1477.94 ± 87.71	2033.11 ± 75.99 ^{###}	1661.41 ± 92.94
Acceleration zone - moderate (m)	58.68 ± 6.61	54.84 ± 5.94	89.19 ± 5.44 ^{###}	69.76 ± 5.08
Acceleration zone - high (m)	11.19 ± 1.42	11.13 ± 1.46	19.27 ± 1.41 ^{###}	14.92 ± 1.33

*significant (p < 0.05) difference within groups between halves; ** significant (p < 0.001) difference within groups between halves; # significant (p < 0.05) difference between groups (No-SHP vs SHP) for respective halves; ## significant (p < 0.001) difference between groups No-SHP vs. SHP) for respective halves; m = meter; m/min = meter covered per minute; SHP = Sleep Hygiene Intervention Period; No-SHP = No-Sleep Hygiene Intervention Period

The only significant difference reported during the no-intervention period between halves was for walking (0.2-2m/s) (p = 0.02, ES = 0.49). Numerous significant differences were observed between halves during the intervention period. In this regard, total distance (p < 0.001, ES = 0.82), walk (0.2-2 m/s) (p = 0.003, ES = 0.52), jog (2.1-3.7 m/s) (p < 0.001, ES = 0.84), run (3.8 – 6 m/s) (p < 0.001, ES = 0.84), sprint (>6m/s) (p = 0.01, ES = 0.43) was less during the second half. Regarding running velocities, the low- (p = 0.03, ES = 0.38) and high zones (p < 0.001, ES = 0.82) demonstrated significant decrements following the second half. All deceleration intensities

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were lower in the second half (high: $p = 0.027$, $ES = 0.38$, medium: $p < 0.001$, $ES = 0.79$, low $p < 0.001$, $ES = 0.72$). Similar results were seen for accelerations: low: $p < 0.001$, $ES = 0.76$), medium: $p < 0.001$, $ES = 0.63$, and high: $p < 0.001$, $ES = 0.62$.

Regarding the differences between the no- vs post-intervention conditions between specific halves, again, numerous significant differences were observed. In this regard, following the intervention period, higher total distances ($p < 0.001$, $ES = 0.97$), and distances in movement zones jogging ($p < 0.001$, $ES = 0.97$), running ($p < 0.001$, $ES = 0.95$) and sprinting ($p = 0.03$, $ES = 0.52$) were observed comparing the first halves. In addition, distances covered in the moderate ($p = 0.05$, $ES = 0.48$) and high ($p < 0.001$, $ES = 0.97$) zones, as well as distances covered in the medium ($p < 0.001$, $ES = 0.98$) and low ($p < 0.001$, $ES = 1.01$) decelerative zones, and for all accelerative zones ($p < 0.001$, $ES > 0.9$) were higher during the SHP. The only significant difference seen for the second half between No-SHP and SHP was for distance covered in the medium velocity zone ($p = 0.05$, $ES = 0.48$).

Individual data points and between-group differences for key internal and external match demands are shown in Figure 4.2. The SHP had a significant ($p < 0.05$, $ES > 0.6$) impact on various external loads over the complete duration of the match compared to the no-SHP. However, no statistically significant difference was found for RPE scores after completing the matches (SHP: 12.53 ± 0.6 ; no-SHP: 12.75 ± 0.63).

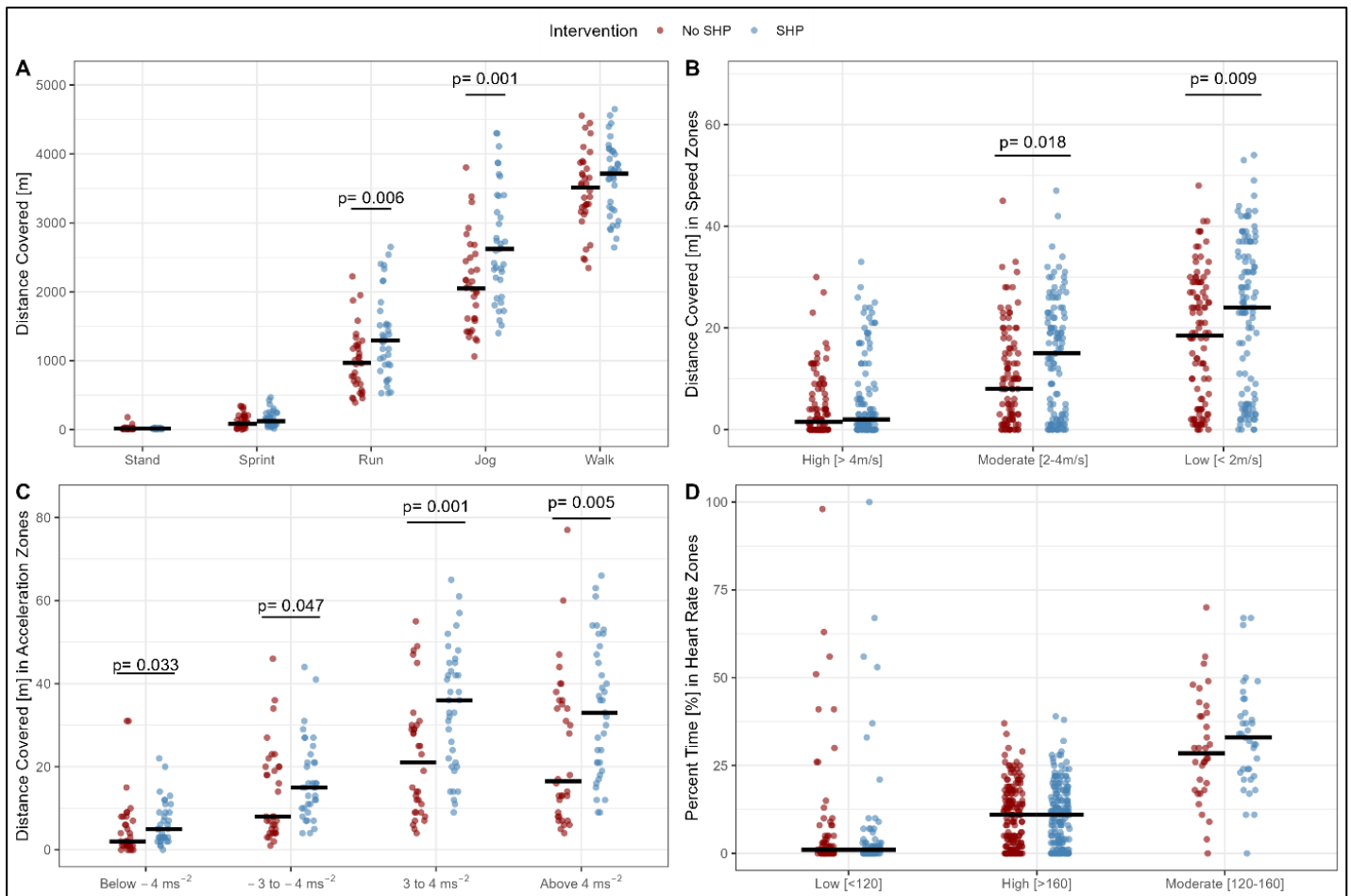


Figure 2. Internal and External match demands across all matches between a sleep intervention and no-intervention period.

4 DISCUSSION

The aim of this study was to determine the effect of a SHP on the internal and external match demands of male university-level soccer players across various matches as well as between halves during a tournament. Within the soccer coaching establishment, it is widely acknowledged that players will experience an increased strain following a match, and factors that prolong or result in inadequate post-match recovery can potentially induce greater symptoms of fatigue and reduced performance (Nédélec *et al.*, 2013). Statistically significant ($p \leq 0.05$) differences were noted for several internal match demands following a sleep intervention period comprising of four weeks. While total distances covered, distance covered while running, jogging, and sprinting, moderate and high-velocity zones, as well as accelerations and decelerations, demonstrated greater values compared to the no-intervention period ($p < 0.05$). Despite the widely held assumption that sleep aids the recovery process and subsequently has positive performance changes, to date limited evidence exists supporting this notion, let alone focusing

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on soccer players and real-life competitions. Moreover, the majority of previous studies examined the effect of sleep during controlled environments on metrics such as sprint time, running tests (aerobic and anaerobic), and reaction tests. To our knowledge, this is the first study to investigate the association between sleep and internal and external soccer match demands over a tournament period.

Our results showed that the minimum HR was higher, and the average and maximum HR values were lower during the SHP for the second half, though more time was spent in the moderate HR zone and less in the high zone in the second half ($p < 0.05$). Time spent in the moderate Zone was also significantly more compared to the No-SHP period during the second half ($p < 0.05$). This is in line with (Torreno *et al.*, 2016) reporting substantial differences for % of HR_{max} during the first ($87.0\% \pm 5.2\%$) and second ($85.0\% \pm 4.6\%$) halves. Comparing the halves between the No-SHP and SHP, where players spend more time in the moderate HR zone can be due to the players pacing themselves due to fatigue setting in and thereby shifting the time spent in the high HR zone to the moderate HR zone. This finding is in line with previous research that found a decrease in the time spent within the 85-90% HR zone and an increase in time spent in the lower 75-80% HR zone during the second half (Alexandre *et al.*, 2012). Reasons that can explain these findings is that HR values during a soccer match rarely reach values below 65% of HR_{max} ; therefore, with the consistent fluctuations in intensity during the game, it seems as though the maximal oxygen consumption is restricted by local factors such as the active muscles oxidative capacity (Alexandre *et al.*, 2012). This, in turn, can influence the external match demands during a game, as seen with less distance covered and less time spent in high-intensity zones.

Regarding the external match demands, during the No-SHP condition, only walking (0.2-2m/s) ($p = 0.02$) was significantly higher during the first half. Following the intervention period, numerous performance decrements were seen in the second half, ranging from the total distances covered to various velocity zones and accelerations and decelerations ($p < 0.05$). These values are similar to previous research where Silva *et al.* (2021) stated that the distance covered during the second half was lower compared to the first half in 3 consecutive matches a week. However, no significant difference could be found for high-speed running or maximum speed obtained. Dalen *et al.* (2016) reported a similar number of accelerations during the first- (38 ± 12) and second half (37 ± 12) and deceleration values between the first (28 ± 9) and second half (27 ± 10). Rampinini *et al.* (2011) found that the mean TD (-10.3% , $p < 0.001$) and high-intensity running (HIR) were significantly lower during the second half compared to the first half. This can be attributed to the players experiencing fatigue during the second part of the match and particularly at the end of a match; though neuromuscular mechanisms can impair performance, it differs according to the exercise intensity, contraction mode, and duration (Rampinini *et al.*, 2011). According to Mah *et al.* (2011), they conveyed a sleep extension period can lower fatigue and

improve vigour scores as measured from a Profile of Mood States questionnaire, which can partially explain our results; the players felt rejuvenated and motivated to go hard at the beginning of the match and then fatigued during the second half as expressed. Mah *et al.* (2011) further discovered significant improvements in rendering sprinting (16.2 sec vs 15.5 sec; $p < 0.001$) and reaction times (310.84ms vs 274.51ms, $p < 0.04$) in basketball players' performance after a 5-7-week period of sleep extension.

Comparing the two intervention periods following the SHP, numerous positive differences were observed. Though no studies could be found on the effect of sleep on the different internal and external match demands, the results can be partially explained through the motor performance characteristics vital for soccer performance,

Teece *et al.* (2021) reported significantly greater ($p = 0.02$) aerobic improvements during a Bronco test for a high sleep (> seven h 30 min) group compared to the low sleep (<7 h 30 min) group, with a 3.9s difference in time between the two groups. Energy conservation and nervous system recuperation can be disrupted by sleep when non-rapid eye movement (NREM) is reduced (Fullagar *et al.*, 2016). Furthermore, reductions in rapid eye movement (REM) sleep can affect emotional regulation, localised recuperative processes, and periodic brain activation (Fullagar *et al.*, 2016). For soccer players to be effective they must not only be able to sprint fast during linear movements but be able to accelerate and decelerate rapidly while changing direction.

Soccer is characterised as a multidirectional team sport, with players frequently accelerating in different directions, decelerating, re-accelerating, and executing successive directional changes. To reach higher speeds in short periods of time, athletes must effectively accelerate over very short distances (e.g., 5 m). Therefore, players with higher maximum acceleration rates will be more likely to achieve superior performances in linear sprints up to 20 m. The acceleration and deceleration values were higher during the SHP period. Therefore, higher acceleration during a game will allow players to achieve higher velocities faster during linear sprints while more quality decelerations will allow players to be able to accelerate again.

Though no significant differences were observed in the rating of perceived exertion (RPE) for players between the No-SHP and SHP periods, this can still be interpreted as novel. Players rated their respective exertion similarly across the two periods, though outperforming the external match demands following the sleep extension period. Therefore, this indicates that although players “worked harder” based on the physiological data, they did not experience this increased load. As noted, earlier sleep can be seen as a recovery method, and as the current study implemented a sleep extension period over a 4-week period, a rollover effect might have taken place between training and matches, therefore having a positive outcome collectively.

In conclusion, extending the duration of sleep has been effective, as seen with numerous positive changes when comparing the players' baseline sleep quality (thereby, their usual sleep)

to a sleep extension period. The most significant observation of this study was the effect sleep has on different movement patterns. As a relationship exists between the quality and duration of sleep and its impact on performance and the risk of injuries, it is vital that athletes focus on this aspect. Training and competition schedules should be considered when improving strategies for sleep quality and quantity, as late-night training, competition time, and travel schedules may affect players sleeping patterns. Future studies should focus on individualizing sleep hygiene strategies and focus on a more in-depth analysis of external factors such as match location (home and away), weather on the day, and quality of opposition. In addition, the coaching staff should take into consideration the school and assessment schedules of collegiate or younger athletes, as the teaching load can be an extra stressor on the players, subsequently affecting their sleep. Sleep hygiene strategies should be contextualised within a comprehensive selection of strategies instead of relying on individual data.

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6 DECLARATION OF INTEREST

The authors hereby declare that the disclosed information is true and correct and that no other situation of real, potential or apparent conflict of interest is known to the authors.

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CHAPTER 5

SUMMARY,

CONCLUSION,

LIMITATIONS AND

RECOMMENDATIONS

SUMMARY, CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

1 SUMMARY

The purpose of this study was twofold. Firstly, to determine the effects of a sleep hygiene intervention period (SHP) on the physical performance indicators of male university-level soccer players during a soccer tournament. Secondly, to determine the effect of an SHP on the internal (heart rate and rate of perceived exertion) and external (movement patterns *via*. global positioning systems) match demands across multiple matches and match halves of male university-level soccer players during a soccer tournament. The data, results, and insights derived from this study will provide players and the coaching staff with the necessary information on the extent to which an acute intervention focused on sleep, sleep deprivation and sleep extension can affect performance and how to implement interventions or preventive measures to enhance performance.

The following research question was posed: what are the effects of an SHP on the internal- and external match demands and match performance indicators of university-level male soccer players? Chapter 1 provided an overview of the problem that underlies the research question, the objectives and hypotheses of the study, as well as the structure of the dissertation. A repeated measure, quantitative intervention research design, was used to test the set-out hypothesis. A large gap in the research was found during the completion of Chapter 1. In this regard, it was identified that further research is warranted examining the effects of a sleep hygiene intervention period on various performance indicators (PIs) and internal and external match loads during a competition period. This leads the researcher to conduct a thorough literature review regarding the effects of sleep on sports performance.

The title of Chapter 2, "*Literature Overview: The importance of sleep on match performances in team sport athletes*", was comprised. Various sleep hygiene strategies and their effect on sports performance were discussed, and therefore, the effect of acute and chronic sleep loss was visually presented to show how sleep affects the human body in the short and long term. This led to the main aim of this chapter, to give an overview to the reader of the research available regarding the different sleep hygiene strategies and their effect on different sporting codes. It was followed up with the different sleep stages, match-specific performance measures for soccer players, and PIs during a soccer match. This led to the first main purpose of the chapter, namely, to provide the reader with an overview of the available literature regarding the effects of sleep on sports performance. The available literature from the past 12 years (2011-2023) with regard to the different sporting codes, subjects, and the effect of sleep on sports performance was provided.

Six studies analysed the effect of sleep deprivation on sports performance, three studies analysed the effect of sleep extension on performance, and one study analysed the effect of nap opportunities on performance. Fourteen studies were used to show the internal and external match demands during a soccer match. Regarding PIs during soccer matches, five studies examined the different PIs analysed in soccer. This was exemplified by a written summary of the available literature.

Literature suggests that athletes should aim to obtain 9-10 hours of sleep to enter the deep sleep stage for longer periods of time. During this period, known as the non-REM sleep phase, growth hormones are released, cerebral blood flow is at its lowest, and muscle relaxation is complete, all allowing for optimal recovery through tissue growth and repair. It was noted that athletes following sleep hygiene principles spent longer time in bed, went to bed earlier, and their sleep duration increased, thereby enhancing their overall well-being and performance.

Overall, the literature supports the implementation of a sleep extension or period (SHP) for improving various physical performance measures such as sprint times, peak power output, and aerobic and anaerobic performance. Additionally, improving sleep quality and duration also enhanced skills such as basketball free-throw accuracy and tennis serve accuracy. One widely used sleep hygiene principle identified was taking brief naps throughout the course of the day. Taking naps during the day increased the total distance during six 30-s maximal shuttle runs, while longer naps of 90 minutes showed better results compared to 40-minute naps. On the contrary, sleep deprivation impaired self-paced endurance performance and a continuous kicking test among others. Unfortunately, no research could be found examining the effects on real-life sports competition performance measures. Within team sports, various match analysis measures are available, with the analyses of movement patterns (by using global positioning systems), physiological measures (such as heart rate and perceived exertion) and video analysis of PIs widely used.

The use of global positioning system (GPS) devices – also known as external match demands – allow researchers and coaches to create game specific demands such as distance covered during the match, number of accelerations and decelerations, as well as the amount of running distance at specific velocities. By supplementing this with heart rate monitoring, valuable information regarding the internal match demands and the different stages of the game can be drawn, allowing athletes to prepare and recover optimally which will subsequently improve their match performances.

In addition to examining the movement patterns, certain PIs can also be analysed which can ultimately impact the outcome of the game. Total attempts, corners, offsides, and fouls suffered

had a positive impact on the game. Literature displayed that higher-ranked teams had more ball possession, possession in the opponent's half, and final 1/3 entries.

For athletes to optimise the recovery that takes place during the sleep stages, sleep duration and the quality thereof should improve. Various sleep hygiene principles are recommended for athletes to implement daily to extend the sleep obtained. These recommendations consist of but are not limited to, avoiding caffeine and other stimulants prior to sleep, maintaining a regular bedtime, ensuring a cool, quiet, and dark bedroom, implementing relaxation strategies before bed, and avoiding the use of light-emitting technology devices prior to sleep. By following these recommendations, it was widely demonstrated in the literature how athletes' sleep quality and quantity improved, ultimately enhancing their performance.

Shortcomings observed during the literature review of the effect of sleep on different performance measures were the following: Studies rendering the effect of sleep on performance measures completed the test in a controlled environment (i.e. testing measures), while only one study examined a real-life basketball game. Participants forming part of a sleep hygiene intervention group were taken away from their normal sleeping routine. Therefore, future research should aim to improve sleep quality and quantity in the athlete's preferred environment. Several studies have been conducted to investigate the effects of sleep on physical and psychological parameters, however, irrespective of the valuable contributions made to date, the underlying effects thereof on a real-life sport competition remained inconclusive.

Therefore, the following research questions were posed: "What are the effects of an SHP on match PIs of university-level male soccer players during a semi-elite tournament?" Secondly, "What are the effects of an SHP on the internal (e.g., heart rate and perceived exertion) and external (e.g., movement patterns) match demands across multiple matches and match halves of male university-level soccer players during a soccer tournament?". In this regard, Chapters 3 and 4 were used to discuss the listed research questions in an article format.

The first article was compiled in accordance with the guidelines of the Journal of Strength and Conditioning Research and titled "*Effects of a Sleep Hygiene Intervention Period on the Physical Performance Indicators of Male University-level Soccer Players during a Tournament*" and presented in Chapter 3. The purpose of this article was to determine the association between an SHP and the various PIs as analysed during a soccer match. During the SHP, athletes reported an average of eight hours of sleep per night and preferred wearing light-reducing glasses for the entire night until going to bed whilst taking a hot shower or bath, the least implemented recommendation among the players. The most significant ($p < 0.05$) findings were that connections and dribbles improved significantly from baseline to intervention, and successful passes ($ES = 1.1$) showed a large effect size. Percentagewise, dribbles (47.3%), connections

(38%), successful passes (24.9%), successful passes in opposition half (10.2%), and shots taken in the penalty area (24.7%) improved during the SHP. Unsuccessful passes (4.9%) and fouls committed had the smallest change when comparing baseline to intervention. Relationships were also found between some of the PIs, concluding that successful passes ultimately led to more connections, shots on target, and connections. The results of this study indicate how the implementation of a SHP can have an influence over various PIs during a game, which can ultimately influence the outcome of the game.

Chapter 4 posed the second research question. The second article, titled "*Effects of a Sleep Hygiene Intervention Period on the Internal and External, Inter- and Intra-Match Demands of Male University-level Soccer Players During a Tournament*" was compiled in accordance with the guidelines of The International Journal of Performance Analysis in Sport. The main aim of this article was to determine the effect of an SHP on internal and external match demands during a soccer tournament. Regarding the internal match demands, player load, HR_{min}, and HR_{max} differed significantly ($p < 0.05$) during the SHP compared to the No-SHP condition. During the second half, significantly ($p < 0.05$) more time was spent in the medium HR zone and less time in the high HR zone when compared to the first half. Higher values were found during the SHP for the HR_{min} and time spent in the medium HR zone during the second half. The intervention period showed numerous significant ($p < 0.05$) differences between the halves, namely total distance, walk (0.2-2 m/s), jog (2.1-3.7 m/s), run (3.8 – 6 m/s), sprint (>6m/s) was worse the second half. Decrements were also noted for the low-, and high-intensity zones for running velocities ($p < 0.05$) during the second half. All the deceleration intensities were significantly ($p < 0.05$) lower in the second half, while accelerations showed similar results with high, medium, and low intensities. The differences between the No-SHP and SHP showed that a SHP had a significant ($p < 0.05$) effect on running, jogging, and distance in moderate (2-4 m/s), and low (<2 m/s) speed zones, as well as all the acceleration zones throughout the match. However, the HR zones showed no significant differences between the SHP and No-SHP throughout the match. In conclusion by improving sleep, PI during a game can be significantly improved, which ultimately can have an influence on the outcome of the match. Furthermore, numerous positive changes were reported for internal and external match demand when the duration of sleep was extended.

2 CONCLUSION

Findings derived from the research are presented in accordance with the established hypotheses outlined in Chapter 1:

Hypothesis 1: *Due to a lack of scientific literature on the effects of an SHP on performance indicators, no set hypothesis could be established for the first aim of the study.*

The results found in the study are completely novel to the literature. Significant differences were found during the SHP for PIs during the matches. Dribbles ($p = 0.05$) and connections ($p = 0.01$) improved significantly from baseline to the intervention period, while successful passes showed a large effect size ($ES = 1.1$). While correlations were found between successful passes and successful passes in the opposition half, more connections and shots on target. Furthermore, successful passes in the opposition half led to more connections and shots on target. While connections lead to more shots on target.

Hypothesis 2: *A SHP will lead to significantly ($p < 0.05$) higher sprint velocities, time spent in high-intensity zones, player loads and lower HR_{max} values in male university-level soccer players compared to baseline values.*

Hypothesis 2 is partially accepted based on the results from the effect of an SHP on the internal and external match demands. During the SHP, time spent in respective HR zones indicated a shift ($p < 0.05$) in zones, with more time spent in the medium HR zone and less in the high HR zone during the second half of the SHP. Player load was significantly higher in the first half during the SHP. The sprint velocity and running distances in the high zone decreased ($p < 0.05$) during the second half of the intervention period. However, no significant differences could be found between the No-SHP and SHP throughout the match for distance covered in high-speed zones and sprinting.

3 LIMITATIONS AND RECOMMENDATIONS

The study showed the effect of a SHP on athletes participating in different matches during a university-level soccer tournament. However, sleep did not have the same effect on all PIs and match specific demands. This finding indicates that specific limitations should be considered when interpreting the results of the study.

- During the intervention more matches could have been used to analyse the effect of the SHP on match performances due to the quality of opposition, match location (home and away), and weather also influencing PIs and match demands.
- Different recovery strategies, such as cold-water immersion, contrast water therapy, and massages, should be combined to improve the athlete's ability to recover for the next training session or match.
- Mood states could have been investigated following SHP and before games to examine fatigue levels.

- Subjective measures were used to measure sleep quality and quantity; using objective sleep measures such as actigraphy to measure sleep can give more accurate values of sleep quality and quantity.
- Sample size: might be another concern, as only one soccer team were used during the investigation.

Despite the limitations listed above, the present study provides a basis for further research centred around sleep as recovery. To the knowledge of the authors, no previous research could be found on the effect of sleep on athlete's performances during a soccer tournament. According to the author's knowledge, this is the first study to report on the effects of improving sleep quality and quantity on PIs and match specific demands. Based on the results, it is clear that sleep is a valuable recovery technique shown to have beneficial effects on athletes during a soccer tournament.

Recommendations for future research should include note the following:

- Investigate both the match demands and PIs simultaneously and draw conclusions and correlations from the findings.
- Investigating individualized sleep hygiene strategies that suit the players' schedules and preferences. For a more in-depth analysis future studies should consider investigating the combination of sleep hygiene strategies and external factors such as match location (home and away), weather on the day, and quality of the opponents.
- Individual sleep routines should be considered when implementing a SHP, the SHP should be more individualised to the specific player's environment and routine.
- School and assessment schedules of university athletes should be considered, as the teaching load can be an extra stressor on the players.
- Competition formats and playing formations implemented by the coaching staff should be noted – i.e. 4-4-3 or 5-4-3-2 formats, and also the duration played by each position to draw comparisons.
- Include a larger sample size (i.e. measure two teams playing against each other).

ANNEXURES

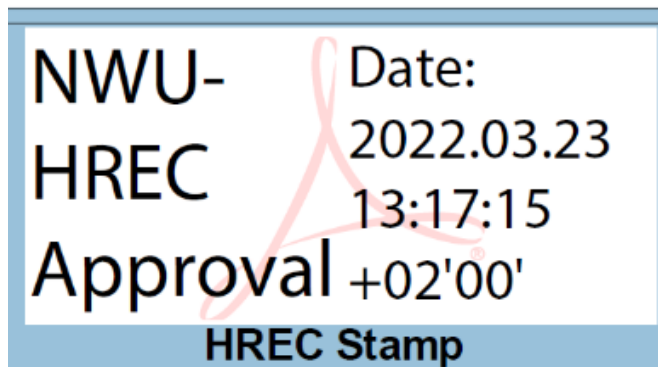
- A. INFORMED CONSENT DOCUMENTATION
- B. DATA COLLECTION SHEETS
- C. QUESTIONNAIRE PERTAINING THEIR GENERAL INFORMATION, DEMOGRAPHY, AND SLEEP HABITS
- D. QUESTIONNAIRE PERTAINING THEIR ACUTE RECOVERY STATES AND SLEEP AND SPORTING ACTIVITY
- E. PSYCHOLOGICAL QUESTIONNAIRES: RATING OF PERCIEVED EXERTION
- F. LANGUARE EDITING LETTER
- G. INFORMATION FOR AUTHORS
- H. METHOD

ANNEXURES

Annexure A: Informed consent documentation



*Physical Activity,
Sport & Recreation*



**INFORMED CONSENT DOCUMENTATION FOR A RESEARCH PROJECT FOR UNIVERSITY-
LEVEL SOCCER PLAYERS**

**TITLE OF THE RESEARCH STUDY: EFFECTS OF A SLEEP HYGIENE PROTOCOL ON THE
MATCH-LOADS AND PERFORMANCE INDICATORS OF MALE UNIVERSITY-LEVEL
SOCCER PLAYERS DURING A TOURNAMENT.**

ETHICS REFERENCE NUMBERS:

PRINCIPAL INVESTIGATOR: DR. ADELE BROODRYK (SPORT SCIENCE)

POST GRADUATE STUDENT: MS. LR. DIAB / MR. MG. PREVOO

**ADDRESS: BUILDING K21, OFFICE 219, CNR OF THABO MBEKI & MEYER STR,
POTCHEFSTROOM**

CONTACT NUMBER: 018029901804

You are being invited to take part in a **research study** that forms part of our research project. Please take some time to read the information presented here, which will explain the details of this study. Please ask the researcher or person explaining the research to you any questions about any part of this study that you do not fully understand. It is very important that you are fully satisfied that you clearly understand what this research is about and how you might be involved. Also, your participation is **entirely voluntary** and you are free to say no to participate. If you say no, this will not affect you negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you do agree to take part now.

This study has been approved by the **Health Research Ethics Committee of the Faculty of Health Sciences of the North-West University (NWU.....)** and will be conducted according to the ethical guidelines and principles of Ethics in Health Research: Principles, Processes and Structures (DoH, 2015) and other international ethical guidelines applicable to this study. It might be necessary for the research ethics committee members or other relevant people to inspect the research records.

What is this research study all about?

- *The overall objective of this study is to determine the effectiveness of a sleep hygiene period (SHP) on various physical, physiological, psychological and match performances in soccer players.*
- *This study will be conducted over an annual competition period during a major competition league (such as the ABC Motsepe League) during the season of 2022. All physical testing data collection will take place at the NWU Tawana Soccer fields, with all the match performance indicators recorded at the competition arena. This study involves the measurement of body stature and mass, physiological measures (cortisol, and heart rate – HR), psychological measures (anxiety, recovery, sleep), match demands (GPS data and match performance indicators) and physical measures (using various physical performance tests) by experienced health researchers trained in Sports Science.*
- *You will complete two testing sessions; the first testing period will commence prior to the start of the league. During this period you will complete various physical performance tests and psychological questionnaires over a two-week period (one week of no sleep intervention, and one week implementing the sleep hygiene recommendations – SHP). The second testing period will encompass the whole league, where you will complete 10 matches (5 weeks) of no sleep intervention (completing your normal, personalised routines), and two weeks whilst incorporating the sleep recommendations in your home setting. No physical testing will take place during this period, you will only complete psychological questionnaires with your match performances analysed.*

- *Throughout the testing periods, you will complete various sleep, recovery, and anxiety questionnaires.*
- *Fifty (n = 50; 25 male and 25 female) participants are anticipated to partake in this study.*

The objectives of this study are:

- *To determine the baseline sleep behaviours, HRV, anxiety and cortisol states prior to the physical performance tests and matches of university-level soccer players.*
- *To determine the relationships between baseline HRV, anxiety, cortisol, and sleep hygiene behaviours prior to, and between the physical performance tests and matches of university-level soccer players.*
- *To determine the effects of an SHP on the subjective measures of sleep and recovery during competition and various physical performance tests of university-level soccer players.*
- *To determine the effects of a SHP on HR, HRV and sleep phases (measured by a nomadic device) of university-level soccer players while sleeping.*
- *To determine the relationship between HR, HRV, sleep phases (measured by a nomadic device) and subjective measures of sleep quality and quantity of university-level soccer players.*
- *To determine the effects of an SHP on the anxiety states of university-level soccer players during competition and various physical performance tests.*
- *To determine the effects of an SHP on the hormonal concentrations of university-level soccer players during competition and various physical performance tests.*
- *To determine the effects of an SHP on the physical performance indicators of university-level soccer players during various physical performance tests.*
- *To determine the effects of an SHP on the match performance indicators of university-level soccer players during a competition.*
- *To determine the effects of an SHP on the internal and external match demands of university-level soccer players during a competition.*

Why have you been invited to participate?

- *You have been invited to be part of this research because you are representing your university at a major tournament (i.e., ABC Motsepe League) during the 2022 season.*

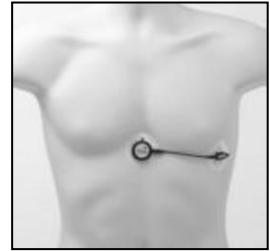
- *You also comply with the following inclusion criteria: you are currently injury and illness-free and part of the NWU Tawana soccer team.*
- *You will not be able to take part in this research if you become injured or ill during the tournament and are not able to complete at least 75% of the matches. In such instances you will be granted a second opportunity to complete the study if you wish.*

What will be expected of you?

- *You will be expected to:*
 - *Complete the informed consent form as received during the information session prior to the start of testing. Informed consent will be obtained by an independent person not directly involved in the study and will take approximately 30 minutes to complete.*
 - *Attend a familiarization and detailed information session during which all the procedures and equipment will be made available, this will approximately take an hour to complete. The protocol will be explained to you thoroughly during the information session.*
 - *Complete a questionnaire that pertains your demographic information, playing and injury history, and information on your recovery states and sleeping habits on the first day of testing. This will take approximately 30 minutes to complete.*
 - *Complete various questionnaires regarding your sleep quality and quantity during the sequence of the testing period. Together with this, your ongoing recovery and anxiety state prior to, and during the testing periods will be examined by making use of questionnaires. All these questionnaires will take you an hour, however not all the questionnaires will be completed daily.*
 - *Complete an online questionnaire pertaining to your sleep and recovery states over the past 24 hours – this will be done during the testing period, every morning upon waking. This is a short questionnaire and will take approximately five minutes to complete. Upon arrival at the sports field prior to the matches, you will complete an anxiety questionnaire on paper also demanding five minutes for completion. Five minutes prior to the start of the match, you will be asked to verbally rate how prepared you are feeling. After each training session and match, you will be asked to rate your perceived effort on a 6-20 Likert scale.*
 - *Start implementing a sleep hygiene protocol – SHP a week prior to data collection for both testing periods for the duration of the intervention period in your own home*

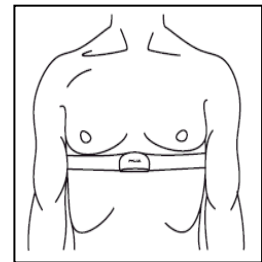
setting. You will receive various tools to assist you with the various recommendations (i.e., eye masks, light-reducing glasses, ear plugs, low-wattage light globes).

- Be fitted with an Actiheart (a small heart rate monitor applied to your left chest area) for 48-hour period over the course of the testing periods to wear during the night and testing sessions. This will be removed after 48 hours upon fitting. Therefore, over a week period it will be fitted and removed twice for exportation and recharge purposes.



- Be screened by the NWU gate officers by displaying your green token for successful completion of the NWU COVID-19 monkey survey and body temperature taken upon arrival at the sports grounds. You will be requested to display your green token to the research team prior to the start of testing.
- Have your body mass and stature collected every Tuesday upon arrival at the sport. This will require you to wear minimal clothing. These measurements will be taken in a private, enclosed location and will take more or less 2 minutes to complete.

- Wear an H10 heart rate monitor and belt during the same periods as the Actiheart (at night and during the physical tests and matches) and lie down for 2 minutes whilst your recovery states are measured every morning upon waking or arriving at the sport grounds. This monitor and belt should be kept on for the duration of the testing session/match.



- Provide saliva samples by making use of the passive drool method into a vial. This equipment will be stored in a sealed plastic bag 48 hours prior to collection taking place. Depending on your salivary flow, the collection can vary between one and five minutes.
- Complete various physical tests (explosive power, 40m sprint, repeated sprint test, reactive agility test, hand-eye coordination test, and Yo-Yo IR1 test) twice within a two-week period (which will be separated by a washout period of a week). Each day's respective tests will take you an hour. This will form part of the specific training session allocated by your coach for the day.
- Wear a GPS sampling unit and HR monitor and belt within a vest specifically designed match analyses. This is a vest that is worn underneath the playing shirt, it is lightweight and will not obstruct your play in any way. Before commencement of the tournament, you will be allowed to wear the GPS harness with



the unit and HR belt during a practice session to familiarize yourself with the equipment, to ensure that you feel do not feel uncomfortable on the first day of the tournament. You will also get the opportunity to complete the warm-up periods with the equipment to familiarize yourself and make the necessary adjustments.

Will you gain anything from taking part in this research?

- *The direct benefits for you as a participant will be that you will have access to your results by means of a personal report provided within two weeks after each testing period. The data gathered could enable you as a player and your coach to compile specific and effective conditioning programs that will prepare you for the demands of competitions and training, consequently resulting in an improvement of performance. You could also benefit in terms of your own health by using results provided to you to improve your physical condition. In the case of any immediate or unanticipated incidental findings occurring during the time of testing, you will be informed telephonically.*
- *The indirect benefit will be a broadening of sport-specific knowledge in the field of sports science, biokinetics, and coaching science and can additionally be transferred into the larger community. This includes knowledge in the field of physical, physiological, and psychological states and match demands together with the implementation of a sleep hygiene period during various physical tests and matches. Workshops will be held after the completion of the project to empower not only university-level coaches but also developing coaches to construct effective training programs for their athletes.*
- *A sport scientist forming part of the research team will travel with your team during the various matches to assist with strapping and massaging before and after matches.*

Are there risks involved in you taking part in this research and what will be done to prevent them?

- *The risks to you in this study are:*
 - *Physical discomfort: No severe physical stress beyond the risks encountered in normal life and everyday training are anticipated. All the tests are movements that you regularly do in your training program. You will be prepared and familiarised with the physical and mental demands of the maximal test during the familiarisation session. Each test will also be preceded by a proper, standardised warm-up. Should you experience pain or injury at any point, the testing will be stopped for further examination by a medical representative/practitioner (team physiotherapist or doctor). In severe injury cases, you will be transported to a medical facility located close to the testing facility, though no*

injuries are anticipated as the warm-up and physical tests are executed on a regular basis.

- *Social stress: No negative influence due to the presence of other players and the coaching staff are anticipated, due to you being accustomed to participating in a group and in front of the coaching staff and spectators.*
- *Saliva sample: No physical risks are anticipated as this will only require you to provide saliva by drooling through a plastic tube into a vial. You will then be requested to place the sample in a bag for further analysis. If at any point you struggle to produce saliva, a piece of parafilm can be chewed to stimulate salivary flow. All the necessary equipment will be placed in a sealed plastic bag 48 hours prior to data collection.*
- *Psychological stress: You might feel uncomfortable during the anthropometric measurements where body mass and stature will be measured as you will be required to wear minimal clothing. You will be measured alone in a private designated and enclosed area and will be allowed to strip down to as much clothing as is comfortable for you. Testing will be done taking your privacy into consideration.*
- *Honesty: It is important for you to provide honest and accurate feedback concerning training, recovery, hydration status, sleep quality, and quantity, as well as muscle soreness. Researchers will ensure that you understand the importance of honest, accurate, and detailed feedback so that the analyses of your physiological responses to different tests and the training period are accurate.*
- *Injury at the competitions: You will not be exposed to additional risk due to the research conducted, in addition to that related to playing the game. Trained paramedics arranged by the tournament directors will be present at the tournament in case of any injuries.*
- *Researchers will take all the necessary steps to ensure that you are treated respectfully during the study and you will not be forced into anything that you are not completely comfortable with.*
- *Furthermore, permission will be obtained from the NWU Data Gatekeeper Committee to ensure that the researchers adhere to the purposes of the research.*
- *Considering the current pandemic, the following safety precautions will be taken to protect all parties involved in the research process:*
 - *Data collection for this study will only commence if the lockdown alert level guidelines for Covid-19 allow for these research activities to take place. Researchers will also stop data collection-related activities in the event of a change in lockdown alert levels.*

Therefore, researchers will at all times adhere to the restrictions on social interactions and travel when it is in place. However, even after the upliftment of the last-mentioned restrictions, the prediction is that the Covid-19 pandemic will still have an impact on the way that research activities are managed as there is a risk of possible infection by all people that are involved in the study. Therefore, the following precautionary measures will be implemented after the upliftment of social interaction and travel restrictions:

- *All researchers and participants that will be involved in the study will receive training during the information sessions on how to apply the health guidelines during the conduct of the research. Training will also include information on the procedures and steps that must be applied in cases of symptoms of possible infection and infection itself and how support will be provided to those who become infected. Training will also cover all*

information that is related to the procedures that must be fulfilled when researchers and participants return home after testing is completed.

- *Researchers will also place posters on the wall of the testing venue to accentuate all the guidelines that researchers and participants must adhere to before, during, and after testing.*
- *Each morning before testing commences researchers and participants will have to fill in an online Covid-19 screening test via SurveyMonkey, which is a free online survey website. The following question will form part of the survey:*
 - *Do you have any of the following symptoms?*
 - *Do you have a cough?*
 - *Do you have a sore throat?*
 - *Do you have shortness of breath or any breathing problems?*
 - *Do you have difficulties with smelling or tasting?*
 - *In the past 14 days before these symptoms:*
 - *Where you in close contact with someone who is COVID-19 positive?*
 - *Have you travelled to or from another province?*
 - *Have you travelled from another country?*
- *Researchers or participants that react positively to any of the above-mentioned survey questions will not be allowed in the testing venue until they have been tested and medically cleared of being infected with the virus or any other illness and associated symptoms.*
- *Researchers and participants will be requested to make use of private transport to travel to and from the testing venue.*
- *The body temperature of all researchers will be measured and monitored at regular intervals (every 2 hours) using an accurate thermometer during testing days. Researchers*

will only be allowed to continue with data collection if their body temperatures are between 36°C and 37.5°C.

- *The body temperature of all participants will be measured using an accurate thermometer when they report to the testing venue. Participants will only be allowed to continue with testing if their body temperatures are between 36°C and 37.5°C.*
- *Researchers will always wear masks and powder-free, sterile surgical gloves that will be replaced after each participant was tested.*
- *As far as possible researchers will avoid direct or close contact with each other and the participants.*
- *Face masks will be thoroughly sterilised after completion of each test by making use of an approved sterilising agent.*
- *Researchers and participants will have to regularly wash their hands by using an approved hand-sanitiser.*
- *All surfaces and equipment in the testing area will be sanitised before and after each participant has been tested.*
- *Researchers and participants will be requested to bring their refreshments via their own containers and/or water bottles to the venue for use and to ensure that all containers were sanitised before the testing venue was entered.*
- *Only one participant at a time will be allowed in the testing room, and no other persons except the researchers that are involved in data collection will be allowed to enter the room.*
- *Interested individuals will each receive a hard copy of the informed consent form that they will be able to complete at home. The forms will be sealed for three days in a plastic bag after printouts were made, to decrease the risk of Covid-19 infections. The researcher will make use of an independent research assistant to hand out the documents. The assistant will always wear sterile surgical gloves while handing out the informant consent forms. Each researcher will work on a specific electronic device right through the testing period*

and researchers will not be allowed to use an electronic device that was not allocated to him/her.

- *Researchers will ensure that the testing venue is at all times well ventilated by natural air.*
- *During the whole study period, one researcher will stay in regular contact with all participants via WhatsApp for continuous monitoring and feedback concerning the Covid-19 pandemic and the procedures that need to be followed.*
- *Researchers and participants will sign indemnity forms that indemnify the university from any accountability in cases where researchers or participants may become infected with Covid-19 during or just after the testing period.*

All researchers and participants that do not adhere to and fulfil the above-mentioned guidelines will not be allowed to further participate during the data collection period.

Based on the feedback that you will receive from the study outcomes, there are more gains for you in joining this study than there are risks.

How will we protect your confidentiality and who will see your findings?

- *If you provide consent to your data being available for research purposes, confidentiality will be ensured by assigning a code to you only known by the researchers. In the final dataset, it will not be possible to identify you.*
- *Reporting of findings will be anonymous and confidential by not using any individual identifiers in any publications resulting from this study.*
- *Only the researchers involved in this study will have access to the data obtained. Before any data is used for research the principal investigator will first obtain ethical approval from the Health Research Ethics committee at the North-West University. Thereafter data will be made available for analysis.*
- *This service delivery project will be an ongoing project during the duration of a major League. If you consent to your data being available for research purposes, you can expect testing to be conducted at each training session and all matches. However, the project leader will obtain new consent at the beginning of each season. You are still free to withdraw from the project at any time.*
- *As this is a service delivery project, data will be made available to the head coach and relevant sports scientists. You will also have access to only your own data.*

What will happen with the findings or samples?

-
- *This is a once-off collection that will only take place during 2022 and the data will be fully analysed here in South Africa by the Statistical Consultation Services of the NWU. Findings may be submitted to international journals for possible publication and master dissertations will be compiled by making use of this data.*
 - *The hard copies of the data recorded will be stored for a minimum of 7 years in the principal investigator's office, accessible only by the primary researchers, after which it will be destroyed by means of a paper shredder. The electronic data recorded by the GPS units, heart rate monitors, and online questionnaire completed, will be downloaded to a password-protected personal laptop immediately after each match and a backup stored via Google Drive for a minimum of 7 years in the project leader's office, accessible only by the primary researchers, after which it will be erased.*
 - *There is a possibility that the results of this study may be used for further research on performance monitoring of soccer players. However, any further studies utilising your results will require approval by the NWU-Health Research Ethics Committee that will stand in on your behalf.*

How will you know about the results of this research?

- The findings of the research will be shared with you within two weeks after the initial testing period. We will be sharing the findings and recommendations regarding the physical tests and matches with you in a personal report. These reports will be emailed to you individually and will enable you to evaluate the efficacy of your current training program, performance indicators, and effect of a sleep hygiene protocol. You are welcome to contact us regarding the findings of the research. Findings regarding the game analyses and playing position profiles will be shared with the coaching staff, as a group and individual player report.
- After completion of the study, you will also be afforded the opportunity to talk to the researchers about your results. This can be done via electronic platforms that are available (i.e., Zoom, Microsoft Teams, WhatsApp video call, etc.) to communicate with you.
- You will also be informed of any article that may be published as a result of this study.

Will you be paid to take part in this study and are there any costs for you?

No, you will not be paid to take part in the study as this forms part of a service delivery project. You will not have additional travel expenses as all tests will be conducted during training and matches before and during ABC Motsepe League tournaments. Therefore, participation will not incur any additional financial strain on you as the player.

Is there anything else that you should know or do?

- You can contact **Dr. Adele Broodryk** at **018 299 1804** if you have any further questions or have any problems.
- You can also contact the Health Research Ethics Committee via Mrs Carolien van Zyl at 018 299 1206 or carolien.vanzyl@nwu.ac.za if you have any concerns that were not answered about the research or if you have complaints about the research.
- You will receive a copy of this information and consent form for your own purposes.

Declaration by participant

By signing below, I agree to take part in the research study titled: **The effect of a sleep hygiene period on match performance, physical, physiological and psychological states of university-level soccer players (Sleep-study)**

I declare that (please tick the box):

- I have read this information/it was explained to me by a trusted person in a language with which I am fluent and comfortable.
- The research was clearly explained to me.
- I have had a chance to ask questions to both the person getting the consent from me, as well as the researcher and all my questions have been answered.
- I understand that taking part in this study is voluntary and I have not been pressurised to take part.
- I may choose to withdraw from the study at any time without any consequences.
- I may be asked to withdraw from participation at any time if the researcher is of the opinion that it is for my own best interest, or if I do not follow the procedures, as agreed upon.

Signed at (*place*) on (*date*) 20....

.....
Signature of participant

.....
Signature of witness

Declaration by person obtaining consent

I (*name*) declare that (please tick box):

- I clearly and in detail explained the information in this document to.....
- I did/did not use an interpreter.
- I encouraged him/her to ask questions and took adequate time to answer them.
- I am satisfied that he/she adequately understands all aspects of the research, as discussed above
- I gave him/her time to discuss it with others if he/she wished to do so.

Signed at (*place*) on (*date*) 20....

.....
Signature of person obtaining consent

.....
Signature of witness

Declaration by researcher

I (*name*) declare that (please tick box):

- I explained the information in this document to or I had it explained by _____ who I trained for this purpose.

- I did/did not use an interpreter

- I encouraged him/her to ask questions and took adequate time to answer them or I was available should he/she want to ask any further questions.

- The informed consent was obtained by an independent person.

- I am satisfied that he/she adequately understands all aspects of the research, as described above.

- I am satisfied that he/she had time to discuss it with others if he/she wished to do so.

Signed at (*place*) on (*date*) 20....

.....
Signature of researcher

.....
Signature of witness



*Physical Activity,
Sport & Recreation*

Match: _____

Participant number					
Weather forecast (Temperature, wind, humidity)					
Time of testing					
Stature (cm)					
Weight (kg)					
H10 Monitor number					
GPS Number					
Urine colour indication	1	2	3	4	5
Body temperature					
Cortisol measurement	Yes		No		
HRV measurement					
CSAI questionnaire	Yes		No		
MRF (1-10 Likert scale)	Thoughts (1-10)	Body (1-10)		Feeling (1-10)	
Maximal Heart rate (bpm)					

RPE SCALE (1-20 scale)	(1-10)	
HRV rec READING		
SALIVARY CORTISOL	YES	NO
TIME: START OF MATCH (H:MIN)		
BREAK (H:MIN)		
TIME: END OF MATCH (H:MIN)		
STRATEGIC MEETINGS (H:MIN)		
SIGNIFICANT MATCH CHANGES		



Physical Activity, Sport & Recreation

GENERAL INFORMATION

Please write clearly!

GENERAL INFORMATION			
Name & Surname			
Date of Birth	Year	Month	Day
Age: (Years & Months)	Years		Months
Residential address:			
Phone number:			
Email address:			
If female: Date of last menarche:			
Contraceptive usage:			
If yes, please indicate what and duration of usage:			
INFORMATION REGARDING TRAINING HABITS			

Questionnaire pertaining their general information, demographic, and sleep habits

Years you have been playing soccer	1-2y	3-4y	5-6y	7-8y	9-10y	10+ y	
Frequency of training - how many <u>days per week</u> do you normally train?	1	2	3	4	5	6	7
Frequency of training - how many <u>days per week</u> do you normally do weight training?	1	2	3	4	5	6	7
Frequency of training - how many <u>days per week</u> do you normally have field sessions?	1	2	3	4	5	6	7
How many <u>hours per day</u> do you normally train?	1	2	3	4	5	6	7
How many <u>hours per day</u> do you normally spend on weight training?	1	2	3	4	5	6	7
How many <u>hours per day</u> do you normally spend on training on the field?	1	2	3	4	5	6	7
Do you spend any time on psychological preparation for competitions?	Never		Sometimes		Often		Always

COMPETITION DATA

Questionnaire pertaining their general information, demographic, and sleep habits

At what level are you competing this year?			
What is the highest level competed at last year?	Club:	Provincial:	National:
How many matches have you played?	Club:	Provincial:	National:
What were the highest achievements you attained during the last two years? (2019 / 2020)?	Achievement:	Competition:	Date:
INJURIES OVER THE PAST TWO YEARS			
Injured area	Severity	Doctor that made the prognosis	
Head:			
Neck:			
Chest or back:			
Arms:			

Annexure C:
Questionnaire pertaining their general information, demographic, and sleep habits

Trunk:		
Legs:		
Ankles:		

Annexure D: Questionnaire pertaining their acute recovery states and sleep and sporting activity

TO BE COMPLETED IN THEIR OWN TIME OR ON THEIR SMARTPHONES.



Morning Questionnaire

1. Good morning. What time are you completing this questionnaire? Please enter the time (24 hr hour format e.g., 07:00).

--

2. How restful was your sleep? Please tick.

Very	Pretty	Average	Hardly	Not at all
1	2	3	4	5

3. If your sleep was not restful, what was the reason? Please tick the reasons (x). Multiple answers are possible. If your reason is not available, please state.

Unfamiliar sleep environments		Pain	
Urination		Fatigue due to travel	
Nervousness		Hotel bed	
Hunger / Thirst		Strenuous game	
Other:			

4. How long did it take for you to fall asleep after you turned off the lights and went to bed?

Questionnaire pertaining their acute recovery states and sleep and sporting activity

Although this is difficult to estimate, please try your best. Please indicate your approximate estimate of the duration in minutes (e.g., 15):

5a. Did you wake up at all during the night? This includes any interruptions to your sleep. Please tick:

Yes		No	
-----	--	----	--

If players answer YES, they move onto 5b.

5b. How many times did you wake up and what was the total duration?

a. Please specify the frequency and approximate duration:

b. How often were you awake at night?

c. How long in total (time in minutes e.g., 25)?

6. When did you finally wake up? Please enter the time (24 hr hour format e.g., 07:00):

7. When did you get out of bed? Please enter the time (24 hr hour format e.g., 07:10):

8. Please indicate your urine colour for your first urination this morning:

Transparent	Shade of yellow	Light yellow	Dark yellow	Very dark yellow
-------------	-----------------	--------------	-------------	------------------

Questionnaire pertaining their acute recovery states and sleep and sporting activity

1	2	3	4	5
---	---	---	---	---

9. Please indicate what SLEEP HYGIENE PRINCIPLES you incorporated last night:

Went to sleep at 21:30 or earlier		Took a warm bath / shower immediately before going to bed	
Created a cool lighting at 20:00 (only bed lamp on)		Avoided electronic stimulants If yes, state time and devices: _____ _____	
Avoided getting up during the night (i.e., bathroom visits)		Consumed a Luke-warm glass of milk prior to going to bed	
Changed the bed lamp to the 4-Watt globe		Manipulated room temperature (19-20°C)	
Wore sleepspect glasses during the evening		Wore eye mask while sleeping	
Wore ear plugs while sleeping		Took last meal 2-3 hours before sleep	
Removed electronic clocks from room		Obtained at least 8-hours sleep	
Avoided caffeine or any stimulants from 17:00 onwards		Avoided napping after 14:00	
Other:			



*Physical Activity,
Sport & Recreation*

RATING OF PERCEIVED EXERTION

ONLY TO BE ASKED FIFTEEN MINUTES AFTER FINISHING THE TESTS AND MATCH – PLAYERS WILL BE ASKED TO INDICATE VERBALLY HOW THEY FEEL.

SCORE	LEVEL OF EXERTION
6	No exertion at all
7	
7.5	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	(Very hard)
18	
19	Extremely hard
20	Maximal exertion

Annexure F: Language editing letter

Karli Dürr | KD Language Services karli@kdlanguageservices.co.za

I, the undersigned, hereby confirm that I have proofread and edited the Master's thesis entitled:

**EFFECTS OF A SLEEP HYGIENE PERIOD ON THE MATCH-LOADS AND
PERFORMANCE INDICATORS OF MALE UNIVERSITY-LEVEL SOCCER
PLAYERS DURING A TOURNAMENT**

M Prevoo

Please do not hesitate to contact me should you have any questions.

Sincerely,

KDürr

Karli Dürr

26/11/2023

Date

Annexure G: Information for authors

The Journal of Strength and Conditioning Research

The Journal of Strength and Conditioning Research (JSCR) is the official research journal of the National Strength and Conditioning Association (NSCA). The JSCR is published monthly. Membership in the NSCA is not a requirement for publication in the journal. JSCR publishes original investigations, systematic, and narrative reviews and meta-analyses, symposia, research notes, and technical and methodological reports contributing to the knowledge about strength and conditioning in sport and exercise. All manuscripts must be original works and present practical applications to the strength and conditioning professional or provide the basis for further applied research in the area. Manuscripts are subjected to a "double blind" peer review by at least two reviewers selected by Senior Associate Editors who are experts in the field. In some cases a "single blind" peer review may occur if a Senior Associate Editor is forced to serve as a reviewer. All editorial decisions are final and will be based on the quality, clarity, style, rank, and importance of the submission relative to the goals and objectives of the NSCA and the journal. Manuscripts can be rejected on impact alone as it relates to how the findings impact evidence based practice for strength and conditioning professionals, end users, and clinicians. Thus, it is important authors realize this when submitting manuscripts to the journal.

JSCR Senior Associate Editors will administratively REJECT a paper before review if it is deemed to have very low impact on practice, out of scope of the journal, poor experimental design, improperly formatted, and/or poorly written. Additionally, upon any revision the manuscript can be REJECTED if experimental issues and impact are not adequately addressed to reviewers, Senior Associate Editor, or Editor-in-Chief's satisfaction. The formatting of the manuscript is of great importance and manuscripts will be rejected if NOT PROPERLY formatted.

EDITORIAL**MISSION****STATEMENT**

The editorial mission of the JSCR, formerly the Journal of Applied Sport Science Research (JASSR), is to advance the knowledge about strength and conditioning through research. Since 1978 the NSCA has attempted to "bridge the gap" from the scientific laboratory to the field practitioner. A unique aspect of this journal is the inclusion of recommendations for the practical use of research findings. While the journal name identifies strength and conditioning as separate entities, strength is considered a part of conditioning. This journal wishes to promote the publication of peer-reviewed manuscripts that add to our understanding of strength training and conditioning for fitness and sport through applied exercise and sport science. The conditioning process and proper exercise prescription impact a wide range of populations from children to older adults, from youth sport to professional athletes. Understanding the conditioning process and how other practices such as such as nutrition, technology, exercise techniques, and biomechanics support it is important for the practitioner to know.

Original**Research**

JSCR publishes research on the effects of training programs on physical performance and function to the underlying biological basis for exercise performance as well as research from a number of disciplines attempting to gain insights about sport, sport demands, sport profiles, conditioning, and exercise such as biomechanics, exercise physiology, motor learning, nutrition, and psychology. A primary goal of JSCR is to provide an improved scientific basis for conditioning practices. JSCR will ONLY CONSIDER original manuscripts not currently under consideration from other journals. JSCR will NOT CONSIDER any manuscripts previously published on preprint servers or resubmitted manuscripts previously rejected by JSCR.

Article**Types**

JSCR publishes original investigations, symposia, brief systematic, and narrative reviews and

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meta-analyses, technical reports and research notes that are related to the journal's mission. A symposium is a group of articles by different authors that address an issue from various perspectives. The reviews and meta-analyses should provide a critical examination of the literature and integrate the results of previous research in an attempt to educate the reader as to the basic and applied aspects of the topic. Given the large number of meta-analyses submitted, the JSCR will be pre-screening each meta-analysis for correct statistical application and appropriate study inclusion, and will give preference to meta-analyses covering topics where few to no meta-analyses currently exist in the literature. Narrative reviews and meta-narrative reviews are encouraged. There is no word limit to the reviews. However, appropriate length will be determined by Senior Associate Editors and reviewers during the review process. We are especially interested in applied aspects of the reviewed literature. In addition, the author(s) should have experience and research background in the topic area they are writing about in order to claim expertise in this area of study and give credibility to their recommendations. A research note is a brief research study (~1500-2000 words) that typically consists of a simple research design and only few dependent variables. It is formatted identical to an original study with the same features, i.e. Abstract, Introduction, Methods, Results, Discussion, Practical Applications, and References, but with limited tables, figures, and reference numbers.

The JSCR strongly encourages the submission of manuscripts detailing methodologies that help to advance the study and improve the practice of strength and conditioning.

Manuscript**Clarifications**

Manuscript Clarifications will be considered and will only be published online if accepted. Not all requests for manuscript clarifications will be published due to costs or content importance. Each will be reviewed by a specific sub-committee of Associate Editors to determine if it merits publication. A written review with needed revisions will be provided if it merits consideration. Manuscript Clarifications are limited to 400 words and should only pose professional questions to the authors and not editorial comments. If accepted, a copy will be sent to the author of the original article with an invitation to submit answers to the questions in the same manner again with a 400 word limit. It will be reviewed by the sub-committee and revisions requested if needed before it is published. Only one round of correspondence between the research group initiating the Manuscript Clarification and the authors of the investigation in question will be permitted.

Submissions should be sent to the JSCR Editor-In-Chief via email: ratames@tcnj.edu

MANUSCRIPT**SUBMISSION****GUIDELINES**

All manuscripts must be submitted online at <http://www.editorialmanager.com/JSCR> following the instructions below. Manuscripts submitted via e-mail WILL NOT be considered for publication.

1. A cover letter must accompany the manuscript and state the following: "This manuscript is original and not previously published in any form including on preprint servers, nor is it being considered elsewhere until a decision is made as to its acceptability by the JSCR Editorial Review Board." Please include the corresponding author's full contact information, including address, email, and phone number. The corresponding author assumes full ownership for all communication related to the manuscript with the journal office.

2. All authors MUST respond to the automated e-mail and complete the copyright transfer form (eCTA) during the submission process. Manuscript acceptability will not be determined until all eCTAs have been completed. Corresponding authors are strongly encouraged to supervise the completion of eCTAs from all co-authors.

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3. All authors should be actively involved in the publication, be able to defend the paper and its findings, take full responsibility for all of its content, and should have signed off on the final version that is submitted. For additional details related to authorship, see "Uniform Requirements for Manuscripts Submitted to Biomedical Journals" at <http://www.icmje.org/>. All authors must have made significant contributions to manuscript to justify authorship and individual author contributions may be disclosed in the Acknowledgments section. The order of authorship must be agreed upon by all authors prior to initial submission to JSCR.

The development of Artificial Intelligence (AI) authoring tools (e.g., ChatGPT) presents the scientific community with unique challenges. In concordance with the recommendations of other publishers, it is our position that an AI authoring tool does not meet the standards required for authorship as defined by the ICMJE, and authors may not include an AI tool as a co-author of a paper. Thus, it is the position of the JSCR that *authors who use AI tools in the writing of a manuscript, production of images or graphical elements of the paper, or in the collection and analysis of data, must be transparent in disclosing in the Methods section of the paper how the AI tool was used, and which tool was used. Authors are fully responsible for the content of their manuscript; even those parts produced by an AI tool, and are thus liable for any breach of publication ethics.*

4. The NSCA and the Editorial Board of the JSCR have endorsed the American College of Sports Medicine's policies with regards to animal and human experimentation. Their guidelines can be found online at <http://www.editorialmanager.com/msse/>. Please read these policies carefully. Each manuscript must show that they have had Institutional Board approval for their research and appropriate consent has been obtained pursuant to law. All manuscripts must have this clearly stated in the methods section of the paper or the manuscript will not be considered for publication. Exempt studies involving human subjects (i.e. retrospective data analysis, analysis of publically available data, educational research, analysis of surveys and interviews) must include a statement of Institutional Review Board approval per journal policy.

5. All manuscripts must be double-spaced with an additional space between paragraphs. The paper should include a minimum of 1-inch margins and page numbers in the upper right corner next to the running head. Authors must use terminology based upon the International System of Units (SI). A full list of SI units can be accessed online at <http://physics.nist.gov/>.

6. The JSCR endorses the same policies as the American College of Sports Medicine in that the language is English for the publication. "Authors who speak English as a second language are encouraged to seek the assistance of a colleague experienced in writing for English language journals. Authors are encouraged to use nonsexist language as defined in the American Psychologist 30:682- 684, 1975, and to be sensitive to the semantic description of persons with chronic diseases and disabilities, as outlined in an editorial in *Medicine & Science in Sports & Exercise*, 23(11), 1991. As a general rule, only standardized abbreviations and symbols should be used. If unfamiliar abbreviations are employed, they should be defined when they first appear in the text. Authors should follow Webster's Tenth Collegiate Dictionary for spelling, compounding, and division of words. Trademark names should be capitalized and the spelling verified. Chemical or generic names should precede the trade name or abbreviation of a drug the first time it is used in the text."

7. There are no word limitations to original studies and reviews but authors are instructed to be concise and accurate in their presentation and length will be evaluated by the Editor and reviewers for appropriateness.

8. Scientific misconduct (i.e. data fabrication, falsification, deceptive image manipulation, plagiarism, ethics violations, undisclosed conflicts of interest, duplicate publication, and

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human/animal research violations) will not be tolerated. Concerns of alleged scientific misconduct should be brought to the attention of the Editor-in-Chief for review using procedures established by the Committee on Publication Ethics (COPE) (publicationethics.org/resources/flowcharts). Pending review of the claims, consequential actions may include rejection of the submitted manuscript of interest, informing the authors' institution of the alleged misconduct, retraction of a previously-published paper, and potential debarment of the author(s) from future JSCR publication. Additional scientific misconduct details may be found at <http://www.icmje.org/>. Acknowledgment of honest error, omission, or differences in data interpretation that do not alter the findings of a paper may occur via the Manuscript Clarification process or publication of an Erratum.

Please Note

- Please make sure it is noted under the "Subjects" section in the METHODS that the study was approved by an Institutional Review Board (IRB) or Ethics Board and that the subjects were informed of the benefits and risks of the investigation prior to signing an institutionally approved informed consent document to participate in the study. Additionally, if anyone who is under the age of 18 years of age is included, it should also be noted that parental or guardian signed consent was obtained. Please give the age range if the mean and SD suggest the subjects may have been under the age of 18 years. Authors are encouraged to include the IRB protocol or approval number.
- Please make SURE you have all your tables and figures attached and noted in the text of paper as well as below a paragraph of where it should be placed.
- Very IMPORTANT---Table files must be MADE in Word NOT copied into Word.

MANUSCRIPT PREPARATION**1. Title Page**

The title page should include the manuscript title, brief running head, laboratory(s) where the research was conducted, authors' full name(s) spelled out with middle initials, department(s), institution(s), full mailing address of corresponding author including telephone and fax numbers, and email address, and disclosure of funding received for this work from any of the following organizations: National Institutes of Health (NIH); Wellcome Trust; Howard Hughes Medical Institute (HHMI); and other(s). Regarding authorship, each contributor should have played a role in at least two of the following areas: research concept and study design, literature review, data collection, data analysis and interpretation, statistical analyses, writing of the manuscript, or reviewing/editing a draft of the manuscript.

2. Blind Title Page

A second title page should be included that contains only the manuscript title. This will be used to send to the reviewers in our double blind process of review. Do not place identifying information in the Acknowledgment portion of the paper or anywhere else in the manuscript.

3. Abstract and Key Words

On a separate page, the manuscript must have an abstract with a limit of 250 words followed by 3 - 6 key words not used in the title. The abstract should have sentences (no headings) related to the purpose of the study, brief methods, results, conclusions and practical applications, and should include a statement denoting the level of significance set for the study (i.e. $p \leq 0.05$).

4. Text

The text must contain the following sections with titles in ALL CAPS (i.e. INTRODUCTION,

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METHODS, RESULTS, DISCUSSION, PRACTICAL APPLICATIONS, ACKNOWLEDGMENTS, and REFERENCES) in this exact order:

A. Introduction. This section is a careful development of the hypotheses of the study leading to the clear purpose of the investigation. It should include the practical question that forms the basis of the study and how it may influence strength and conditioning practices. In most cases use no subheadings in this section and try to limit it to 4 - 6 concisely written paragraphs. The subject matter does not have to be exhaustively reviewed in this section.

B. Methods. Within the METHODS section, the following subheadings are required in the following order: "Experimental Approach to the Problem," where the author(s) show how their study design will be able to test the hypotheses developed in the introduction and give some basic rationales for the choices made for the independent and dependent variables used in the study; "Subjects," where the authors include the Institutional Review Board or Ethics Committee approval of their project and appropriate informed consent has been gained. Eligibility criteria for subject selection should be included in the manuscript. Authors should include relative descriptive information such as age, height, body mass, and when appropriate the training status and training history of the subjects, e.g. years of training or sport experience. When appropriate, dietary controls and supervision should be described. All subject characteristics that are not dependent variables of the study should be included in this section and not in the RESULTS; "Procedures," in this section the methods used are presented with the concept of "replication of the study" kept in mind. Authors should describe the research design used in the study. Training programs and testing methods used should be described in detail. Authors are strongly encouraged to include a Control group/condition when appropriate. If a Control group/condition is not used, authors MUST provide test-retest reliability coefficients of the measures used during protocols involving multiple testing periods. Test-retest reliability data should be generated from the authors' laboratory and not merely cited from literature obtained in other laboratories. Additionally, reviewers will look for experimental control for time of day, hydration, sleep and nutritional status. "Statistical Analyses," here is where you clearly state your statistical approach to the analysis of the data set(s). It is important that you include your alpha level for significance (e.g., $p \leq 0.05$). Please place your statistical power in the manuscript for the n size used and reliability of the dependent measures with intra-class correlations (ICC Rs). Additional subheadings can be used but should be limited. Authors should report effect sizes and confidence intervals when appropriate. Traditional statistical procedures must be used. The magnitude-based inference (MBI) approach may be used BUT ONLY IN CONJUNCTION with traditional methods.

C. Results. Present the results of your study in this section. Put the most important findings in Figure or Table format and less important findings in the text. Do not include data that is not part of the experimental design or that has been published before. Authors should not replicate data present in the text in tables or figures.

D. Discussion. Discuss the meaning of the results of your study in this section. Relate them to the literature that currently exists and make sure you bring the paper to completion with each of your hypotheses. Authors should emphasize the new and unique findings of the study. Conclusions should be supported by the data presented. Limit obvious statements like, "more research is needed." No subtitles should be included in the Discussion section.

E. Practical Applications. In this section, tell the "coach" or practitioner how your data can be applied and used. It should reflect the answer to the question posed in the Introduction. It is the distinctive characteristic of the JSCR and supports the mission of "Bridging the Gap" for the NSCA between the laboratory and the field practitioner. This section should be limited to 350 words or less.

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5.

References

All references must be alphabetized by surname of first author and numbered. References are cited in the text by numbers [e.g., (4,9)]. All references listed must be cited in the manuscript and referred to by number therein. For original investigations, please limit the number of references to fewer than 60 or explain why more are necessary. The Editorial Office reserves the right to ask authors to reduce the number of references in the manuscript. It is acceptable to cite a published Research Abstract ONLY if it is a sole source of information in that specific scientific area. JSCR forbids the citation of manuscripts published on preprint servers. For journal entries with 6 or more co-authors, please list the first 3 names followed by "et al." When citing chapters within an edited textbook, authors MUST specifically cite the chapter author names (not the editors). Authors must also include the chapter name and page range for all book references. Please check references carefully for accuracy. Changes to references at the proof stage, especially changes affecting the numerical order in which they appear, will result in author revision fees. For End Note Users, the software has been updated to accommodate JSCR's new style of reference formatting. It is recommended that authors update the final reference list by manually checking each reference to ensure proper formatting and accurate information is listed. Questions regarding End Note use or software editing are directed to Clarivate support at 1-800-336-4474. If using End Note please double-check citations and make sure journal article titles do not have all words capitalized and journal titles are abbreviated properly and italicized.

Below are several examples of references:

Journal

Article

Hartung GH, Blancq RJ, Lally DA, Krock LP. Estimation of aerobic capacity from submaximal cycle ergometry in women. *Med Sci Sports Exerc* 27: 452–457, 1995.

Kraemer WJ, Hatfield DL, Comstock BA, et al. Influence of HMB supplementation and resistance training on cytokines responses to resistance exercise. *J Am Coll Nutr* 33: 247-255, 2014.

Book

Lohman TG. *Advances in Body Composition Assessment*. Champaign, IL: Human Kinetics, 1992.

Chapter

in

an

edited

book

Yahara ML. The shoulder. In: *Clinical Orthopedic Physical Therapy*. J.K. Richardson and Z.A. Iglarsh, eds. Philadelphia: Saunders, 1994. pp. 159–199.

Software

Howard A. Moments $\frac{1}{2}$ software_. University of Queensland, 1992.

Proceedings

Viru A, Viru M, Harris R, Oopik V, Nurmekivi A, Medijainen L, Timpmann S. Performance capacity in middle-distance runners after enrichment of diet by creatine and creatine action on protein synthesis rate. In: *Proceedings of the 2nd Maccabiah-Wingate International Congress of Sport and Coaching Sciences*. G. Tenenbaum and T. Raz-Liebermann, eds. Netanya, Israel, Wingate Institute, 1993. pp. 22–30.

Dissertation/Thesis

Bartholmew SA. Plyometric and vertical jump training. Master's thesis, University of North Carolina, Chapel Hill, 1985.

6.

Acknowledgments

In this section you can place the information related to identification of funding sources; current contact information of corresponding author; and gratitude to other people involved with the

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conduct of the experiment. In this part of the paper the conflict of interest information must be included. In particular, authors should: 1) Disclose professional relationships with companies or manufacturers who will benefit from the results of the present study, 2) Cite the specific grant support for the study and 3) State that the results of the present study do not constitute endorsement of the product by the authors or the NSCA. Failure to disclose such information could result in the rejection of the submitted manuscript. In addition, individual author contributions to the manuscript may be listed here.

7.**Figures**

Figure legends should appear on a separate page, with each figure appearing on its own separate page. One set of figures should accompany each manuscript. Use only clearly delineated symbols and bars. Please do not mask the facial features of subjects in figures. Permission of the subject to use his/her likeness in the Journal should be included in each submission. Photo release forms may be downloaded from the Information for Authors page at <https://journals.lww.com/nsca-iscr/pages/informationforauthors.aspx>.

Electronic photographs copied and pasted into Word and PowerPoint will not be accepted. Images should be scanned at a minimum of 300 pixels per inch (ppi). Line art should be scanned at 1200 ppi. Please indicate the file format of the graphics. We accept TIFF or EPS format for both Macintosh and PC platforms. We also accept image files in the following Native Application File

File	Adobe	Photoshop	Formats:
–			(.psd)
–		Illustrator	(.ai)
–		PowerPoint	(.ppt)
– QuarkXPress (.qxd)			

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1. METHOD

1.1 Empirical investigation

1.1.1 Study design

Repeated measure, quantitative, intervention research design will be conducted over a soccer tournament. The study data will be collected through questionnaires, measurements, and observations of the different soccer matches. Data will be collected during a major league in their 2022 season (i.e., the ABC Motsepe League - comprising 16 matches over eight weeks by 16 male university-level soccer players forming part of the North-West University (NWU) Potchefstroom team.

1.1.2 Participants

A convenient sampling technique will be used in the proposed study. The study is part of a service project, and only NWU players (Potchefstroom Campus) will form part of the study. Consequently, the study population will be used, and there is no need for sample size calculations. Based on data from previous studies, a statistical power analysis was carried out for sample size estimation (Bonato *et al.*, 2020; Fullager *et al.*, 2016a; Fullager *et al.*, 2016b, Vitale *et al.*, 2019; Whitworth-Turner *et al.*, 2017). The effect sizes (ES) of the different studies ranged from 0.6 to 4.3 and used Cohen's (1988) criteria. With an $\alpha = 0.5$ and $1 - \beta = 0.8$, the projected sample size needed with $ES = 1.5$ is approximately $n = 16$ for this between-group comparison. The sample size is in line with previous research done on sleep hygiene in soccer teams (Nedelec, 2015:1549), where the whole team are examined (between 10 and 20 players) (Bonato *et al.*, 2020; Fullager *et al.*, 2016a; Fullager *et al.*, 2016b, Vitale *et al.*, 2019; Whitworth-Turner *et al.*, 2017). 16 Male university-level soccer players will form part of the study. The players will represent the NWU at a major competitive league (i.e., the ABC Motsepe League). The participants of this project will be limited to NWU teams (Potchefstroom Campus), and the coaching staff will pick the starting line-up and bench for the matches.

1.1.2.1 Inclusion Criteria

The study will include all the NWU university team players in a major league (i.e., the ABC Motsepe League) from the Potchefstroom campus. Soccer players will only be allowed to participate in the study if their informed consent forms have been signed and submitted beforehand. Furthermore, soccer players who are injured or ill at the time of testing will not be

included. As the team will be analysed in whole, all data of the respective matches will be used, irrespective of the match time played by each player.

1.1.2.2 Exclusion Criteria

In cases where participants become ill, injured or do not adhere to at least ten (10) of the sleep hygiene recommendations, their results will be excluded from the study. The same intervention period and testing will be allocated to excluded soccer players if any of the requirements mentioned above are not met; this will happen during another match of the same league or future competitive league. This will ensure that the squad of 15 players will be analysed for the matches.

1.2 Measuring instruments and equipment

1.2.1. Anthropometric measurements

A calibrated BFW 300 Platform scale (Adam equipment Co. Ltd., UK.) will be used to record body mass to the nearest 0.1 kg, with the player wearing no shoes and minimal clothing. A Harpenden portable stadiometer (Holtain Ltd., UK) will be used to record body stature to the nearest 0.1cm, with the soccer players standing upright and the head in the Frankfort plane. These measures will only serve to provide a profile of the cohort examined and will take place in their team locker room prior to a physical testing session (refer to larger study previously mentioned).

1.2.2 Questionnaires

1.2.2.1 Demographic and general information questionnaire:

Before testing, the soccer players will complete an online demographic and general information questionnaire (age, playing experience, injuries, ethnicity, competing for level, sleep behaviour and exercise routines).

1.2.2.2. Sleep questionnaires:

a. *The Pittsburgh Sleep Quality Index Questionnaire (PSQI)*

The PSQI is a 19-item survey that questions sleep quality (including sleep duration and latency) and examines sleep behaviour. Habits are thought to be common areas of concern (Buysse *et al.*, 1989). Within the sleep section, participants will recall their sleep habits over the past month and answer 19 individual questions which are related to the following seven main components: sleep

disturbance, sleep duration, habitual sleep efficiency, sleep quality, sleep latency, use of sleep medication and daytime dysfunction (Buysse *et al.*, 1989). All components (except for the number of hours in bed and habitual sleep efficiency, which is open questions) will be answered on a four-point Likert scale, ranging from zero, which indicated the positive extreme (not during the past month), to three, which is reflective of a negative extreme (Three or more times a week). A global PSQI score will be calculated after summing the seven components, with a final score ranging between 0-21. The higher the score, the more indicative it is of poor sleeping behaviours. A score of > 5 is indicative of poor sleep quality (Buysse *et al.*, 1989:205). The seven component scores of the PSQI have demonstrated high overall internal reliability scores (Cronbach's $\alpha = 0.83$) (Buysse *et al.*, 1989:197). This questionnaire will only be done before the testing period for the baseline and the intervention periods prior to, and at the end of the intervention period. This will be completed in their team locker room before commencing with their respective training sessions.

Sleep and Sporting Activity Questionnaire (SSAQ)

Soccer players will use their own laptops or smartphones to complete the questionnaire online by gaining access through individual case-protected links. This questionnaire will be completed at night before sleeping and in the morning after waking before the match day and on match day (Fullagar *et al.*, 2016:1334). The soccer players' perceptual fatigue, sleep habits, and stress will be evaluated every morning. Closed-response questions will be used in the evening to determine how the soccer players feel; these questions will consist of how "relaxed" and "exhausted" the soccer players feel if they took naps during the day (naps: not part of the total sleep time at night), how their general performance was during the day, and report any additional stress or non-exercise loads in open-response that they experienced during the day. The morning section will be used to ascertain information about the previous night's sleep, including questions relating to "restfulness" (sleep quality: one = very restful, five = not at all restful), "reasons for unrestfulness", details about sleep disturbances (if they were present), the duration of total sleep time and a short scale of general perceptual recovery (zero = not recovered at all, six = fully recovered; Kölling *et al.*, 2015). Fullagar *et al.* (2016:1334) also reported a (ICC = 0.93-0.95) with time in bed, and (ICC = 0.90-0.92) for total sleep time. This will be completed in their team locker room before commencing with their respective training sessions.

1.2.3. Match performance measures

Internal- and external match demands (RPE, GPS, HR, and match performance indicators) will be analysed during the competitive matches. Thirteen matches will be analysed for these purposes. Ten matches will be used for baseline measures, with three matches set out for SHP. The additional

two matches are set out if any errors might occur (players get injured, sick, or any reason for them not to complete all the league games) during any of the previous matches. A player and team profile will be developed for the data obtained from the ten baselines and three experimental matches. No additional load will be added on the soccer players as the data will be collected during the match. Facilities where the matches will take place are decided by the South African Football Association (SAFA), with halve of the matches taking place at the participants' home ground (therefore in Potchefstroom, at the NWU sport grounds, field A). All the facilities are considered suitable as SAFA has set-out the venues.

1.2.3.1 GPS derived variables

A GPS unit sampling at 10 Hz (MinimaxX V4.0, Catapult Innovations, Victoria, Australia) will be fitted on each player's upper back before each match by using the manufactures harness. Results from Johnston *et al.* (2014:1649) reported on the validity ($p > 0.05$) and reliability (% TEM = 1.3%) of the 10 Hz GPS unit to measure total distance covered. The GPS units will provide data regarding the repeated efforts, distance, accelerations, decelerations, velocity, and heart rate. During each match, each player's heart rate will be traced through the Fix Polar Heart Rate Transmitter Belt (Polar Electro, Kempele, Finland) at one-second intervals. The GPS unit and heart rate recordings will be downloaded on a laptop with appropriate software (Logan Plus V4.7.1, Catapult Sports, Victoria, Australia) to analyse the recordings.

The GPS Doppler data will be used to analyse the GPS-specific variables. The movement categories for male soccer players from Dwyer and Gabbett (2012:820) study will be used; the values for the different categories that will be used is: stand (0.0 - 0.1 m/s), walk (0.2 - 2 m/s), jog (2.1 - 3.7 m/s), run (3.8 - 6.0 m/s), and sprint (> 6.1 m/s), for the movement to be recorded as an effort the players must maintain the velocity for at least one second. The soccer players need to maintain the effort for at least 0.5 seconds for the acceleration and deceleration efforts to count. The following values: high deceleration (< -4.0 m/s²), medium deceleration (-2.5 to - 4.0 m/s²), high accelerations (> 4.0 m/s²), and medium acceleration (2.5 to 4.0 m/s²) from Wehbe *et al.* (2014:836) study will be used to determine the acceleration and deceleration values. Acceleration velocity values between 0 to 2.4 m/s² will be recorded as low-intensity accelerations, and deceleration velocity values between -2.4 and 0 m/s² will be recorded as low-intensity decelerations. Members of the research team has undergone training in setting up and analysing the GPS derived data. A training and recap session will be scheduled for all the members to familiarise themselves with the equipment.

1.2.3.2. Heart rate monitoring

The soccer players will each receive a Fix Polar Heart Rate Transmitter Belt and monitor (Polar Electro, Kempele, Finland, model: H10) the day before the match to wear during the night and during the match. The monitor will measure the heart rate at one-second intervals. The HR values will be set at <75% HR_{max}, 76-84% HR_{max}, 85-89% HR_{max}, and >90% HR_{max}, the soccer players based on their HR_{max} measured during a previous Yo-Yo IR-1 test (Casamichana & Castellano, 2010:1617).

1.2.3.3. Match performance indicators

Performance indicators (PIs) is defined as "*the selection and combination of variables that define some aspects of performance and help achieve athletic success*" (Lago-Peñas *et al.*, 2011:136). Video analysis will be used to determine the following match PIs that is categorised into the following three groups: contextual variable (match location), offensive variables (passes, successful passes (%), passes in the opposite half, total shots, shots on target, shots inside the penalty box, dribbles (attempt to beat an opponent), crosses (made into the penalty box), corners (corners taken by the team after the ball went into touch), offsides committed, and fouls received), and defensive variables (corners against, crosses against, fouls committed, red cards, and yellow cards) (Errekagorri *et al.*, 2020:810; Harrop & Nevill, 2014:912; Kubayi & Toriola, 2020:215). Depending on where the team will be playing, the location will be marked as "home" or "away". As in Harrop and Nevill (2014:911) study, data will be collected for the whole 90-minute with the injury time included.

Sportscodes video analysis software (SportsCode v. 8.9, Sportster, Australia) will use two analysts to analyse all the recorded games using tagging and will be collected from the ascribed video analyst of the respective teams (Mr. C. Nienaber). The tagging of the PIs will take place after they are identified and defined. Percentage errors will be used to conduct both intra-observer and inter-observer reliability suggested by Hughes *et al.* (2002:6). The principal analyst will assess intra-observer reliability by re-analysing three random matches to guarantee a sufficient degree of reliability. A second qualified analyst with the same familiarity and experience with the software will re-analyse all the matches to assess inter-observer reliability. The original test (A) will be compared with the retest (B) of inter and intra-analysis to calculate the percentage differences. According to research, the expected limit of agreement is 5%. Suppose the intra and inter-analysis results show an error bigger than 5%. In that case, an external analyst should repeat the analysis process (Hughes *et al.*, 2002).

1.2.3.4. Rating of perceived exertion (RPE)

The players will provide their RPE verbally 15 minutes after each match. The RPE is an effective way to determine a player's effort and exertion, (Stelios, 2011:420). A significant moderate correlation ($r = 0.506$) was found between the two indicators of internal load (RPE and %HRmean) when measuring small sided games (SSG) (David & Julen, 2015:122). Each player will be asked, “How do you rate the level of exertion of the game you just completed, from 6 to 20?”. Rating of six on the Borg scale would indicate “no exertion at all”, 7.5 “extremely light”, 9 “very light”, 11 “light”, 13 “somewhat hard”, 15 “hard (heavy)”, 17 “very hard”, 19 “extremely hard” and 20 referring to “maximal exertion” (Williams, 2017:404). The same investigator will be used to record the rating after each match. During the familiarisation session, the players will be familiarised with the question mentioned above.

1.2.4. Sleep hygiene period (SHP)

The soccer players' own sleep routine will be followed and act as their own control group during the no-recovery period comprising of two periods of three matches. All the soccer players will complete the SHP over three matches (containing two weeks). The specific layout will be no intervention for five matches (sham-period), followed by an SHP for three matches (two weeks) and five matches of no intervention. This is to accurately measure if any changes took place because of an SHP. For testing session one (T1), the sleep intervention will take place over a week period – starting on a Monday and ending on the following Thursday upon finishing the physical performance tests – which is similar to that implemented in previous research (Duffield *et al.*, 2014; Fullagar *et al.*, 2016:a; Lever *et al.*, 2020; O'Donnell & Driller, 2017).

During the sham period, the participants will follow their own sleep routine and act as their own control group for the entire duration. Within these conditions, players will be allowed to self-regulate their exposure to electronic equipment, pre-bed light (60 ± 12 Watts), and sleeping patterns. During the intervention period, participants will adhere to the sleep hygiene protocol as set out. During both periods, players will sleep in their own home setting.

The SHP will start a week before the first intervention, with soccer players executing the SHP in their own environment. High quality and quantity of sleep are what we aim for from the SHP intervention. The following SHP recommendations will be intended (soccer players will be requested to adhere to at least ten of the possible 16 bids), with players marking daily which were implemented:

- All electronic stimulants (television, mobile phones, and computers) should be limited or avoided from 20:00 with a cool-light setting commencing 19:00 on the devices (Bird, 2013; Griffiths *et al.*, 2021; Vitale *et al.*, 2019).

- Minimise excess light from 21:00 till 21:30 by only having a bed lamp on (Fullagar *et al.*, 2016a; Vitale *et al.*, 2019).
- Changed the bed lamp to a low-wattage globe (4 Watts) from 20:00 to create a cool lighting (Duffield *et al.*, 2014).
- Maintain a sleep routine by commencing with sleep at 21:30 (Bird, 2013; Griffiths *et al.*, 2021)
- Manipulate the room temperature to more or less 19–20°C (to decrease core temperature and thereby increase sleepiness) (Bird, 2013; Fullagar *et al.*, 2016a; Griffiths *et al.*, 2021).
- To wear the Sleepspec glasses during the evening prior to going to sleep (Bird, 2013; Vitale *et al.*, 2019).
- To wear eye masks whilst sleeping to reduce environmental light (Bird, 2013; Fullagar *et al.*, 2016a).
- To wear ear plugs whilst sleeping to reduce environmental sound (Bird, 2013; Fullagar *et al.*, 2016a).
- To take a warm bath or shower prior to going to bed (Griffiths *et al.*, 2021; Vitale *et al.*, 2019; Whitworth-Turner *et al.*, 2017).
- To consume a glass of luke-warm milk (Nédélec *et al.*, 2015b; Vitale *et al.*, 2019) OR camomile tea (Griffiths *et al.*, 2021) prior to going to bed.
- Have the last large meal at least two to three hours prior to sleep (Bird, 2013; Duffield *et al.*, 2014).
- Avoid consuming caffeine or any supplements from 17:00 (Bird, 2013; Vitale *et al.*, 2019).
- Try and remove any timing instruments (i.e., clock) from the room (Bird, 2013; Vitale *et al.*, 2019).
- Participants will be advised to obtain a thorough night rest (at least 8 hours sleep) (Bird, 2013)
- Try and avoid disruptions (i.e., bathroom timings) by being conscious of food and fluid intake prior to bedtime (Bird, 2013).
- To avoid napping from 14:00 each day, and limit it to 30 minutes (Bird, 2013; Nédélec *et al.*, 2015b).

1.2.5 Procedure

Data will be collected over a whole tournament taking place in the 2022 season (i.e., ABC Motsepe league), comprising of 13 matches. Six to ten matches are set out to collect baseline measures, with three matches set out to implement and analyse the effectiveness of the SHP. All participants will be screened daily for Covid-19 by taking their body temperatures and completing an electronic Covid-19 screening app.

Details regarding the study design, purpose of the study, procedures, and possible risks of participating will be held by an independent person to the project one week before the testing commences. The participants will then receive a hard copy of the consent form and information leaflet concerning the project to read in their own time if they are willing to take part in the study.

Five days after the information session, the participants who are willing to participate in the study will sign the informed consent forms in the presence of a person independent from the project, followed by a familiarisation session during which all the physical, physiological and psychological measurements will be demonstrated and explained to them. The participants will be requested to complete a general information questionnaire regarding their training habits, best performances over the last two years, and injury history. This will only be done once throughout the testing period and will take 30 minutes to complete. Following this session, they will receive instructions on the sleep recommendations to incorporate from the following Monday.

Over the 8 weeks, players will complete the sleep protocols: five matches of no sleep intervention, 3 matches incorporating the SHP, and again five matches of no sleep intervention, totalling 13 matches. A week of no-intervention or measurements will be organised following the intervention period to serve as a wash-out period.

Week 1 – 3 and 6 - 8 (10 matches, five weeks):

During the sham weeks, participants will adhere to their own sleeping regime and patterns.

Week 4 – 5 (3 matches, two weeks):

Participants will complete the SHP recommendations during the intervention week and mark which recommendations were adhered to daily. Recommendations will include setting a cool temperature and low Watt-light and removing alarms or clock appliances. Each participant will receive sleepspectacles glasses from wearing during the night before sleeping to minimise light exposure. They will receive an eye mask and earplugs too, if they wish, to wear them to minimise light and noises. In addition, they will be asked to minimise exposure to electronic media by 20:00 in the evening. They will also be requested to go to bed at 21:30 following a hot bath or shower. This will be done to ensure a good night's rest of at least eight hours of uninterrupted sleep. Participants will adhere to the SHP recommendations set out starting a week before the first match for the entire week. This will take place at their own homes. They will be requested to adhere to at least ten of the 16 listed recommendations and mark what recommendations were adhered to daily. The participants will be requested to abstain from ingesting any drugs or participating in

strenuous physical activity that may influence the physical or physiological responses of the body for at least 48 hours before the scheduled tests.

Wednesdays and Saturdays (match-days): Upon waking, the participants will be asked to complete the electronic questionnaires on their previous night's quality and quantity of sleep (*SSAQ*). Participants will then adhere to the same Covid-19 precautionary measures upon entering the competition arena. This will be followed by fitting them with the Polar monitor and belt. Following this, each participant's body mass and stature will be recorded in a private room. In addition to this, a Catapult GPS unit will be fitted to the upper back ten minutes before the start of each match using a harness supplied by the manufacturer. This will be used to evaluate their internal and external match loads (HRs, accelerations, decelerations, time spent in various intensity zones, etc.). Again, 15 minutes after the match, their rating of perceived effort (RPE) will be collected.

The participants will complete their own soccer-specific warm-up protocol; the execution of this protocol will be used throughout the study for the matches. A manufacturer's vest will be used to fit the Catapult GPS sampling unit on the upper back of the players just before each match, together with the fixed Polar HR monitor and belt to measure HR intervals. Through the Catapult GPS sampling unit, we will evaluate different internal and external match loads, decelerations, accelerations, and time spent by the players in various intensity zones. Fifteen minutes after the match, the soccer players will record their RPE. This will be repeated over the entire 14 matches taking place.

Participants' own playing load profile will be compiled through data collected over the entire league; this profile will consist of variables like the average time spent in low-, medium-, high-intensity HR zones; average time spent in low-, medium-, high-intensity activities; distance covered during matches. Furthermore, participants PIs will be compiled in the following 3 groups: contextual variable (match location), offensive variable (passes, successful passes (%), passes in the opposite half, total shots, shots on target, shots inside the penalty box, dribbles, crosses, corners, offsides committed, and fouls received), and defensive variables (corners against, crosses against, fouls committed, red cards, and yellow cards). The collected data during the no-intervention period and data found in literature (normative) will be used as baseline data to compare the SHP data with and to conclude if the SHP has a significant impact on PIs and internal and external match demand. By gathering data over the entire league, changes and relationships between the different match, physical, and physiological PIs can be examined.

Suppose the soccer players have any questions or are uncertain about the protocol. In that case, they will have an opportunity to consult with the research team.