THE USE OF RECOVERY METHODS BY PROFESSIONAL SOCCER TEAMS IN SOUTH AFRICA

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DECLARATION

I, Dustin Maree, hereby declare that the work on which this dissertation is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is submitted for another degree at this or any other university.

Signed by candidate

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Signature

Date: 5 February 2019

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LIST OF ABBREVIATIONS

AFL	American Football League
ANOVA	Analysis of Variance
ASSQ	Athlete Sleep Screening Questionnaire
CASP	Critical Appraisal Skills Programme
CG	Compression garments
CHO	Carbohydrate
CK	Creatine Kinase
CMJ	countermovement jump
CWI	Cold-Water Immersion
CWT	Contrast Water Therapy
DOMS	Delayed Onset Muscle Syndrome
EIMD	Exercise induced muscle damage
EMS	Electromyostimulation
ESS	Epsworth Sleepiness Scale
FIFA	International Federation of Association Football
FIFPRO	International Federation of Professional Footballers
g	Grams
GI	Glycaemic Index
Gmbh	Gesellschaft mit beschränkter Haftung (German for 'company with limited liability')
H	Hour
HIMS	Heart rate interval monitoring system
HR	Heart rate
Hz	Hertz
J/cm2	Joule per centimeter

Kcal	Kilocalorie
kHz	Kilohertz
Km	Kilometre
M	Metre
MEQ	Morningness Eveningness Questionnaire
Min	Minute
Mn	Millimeter
mM	Muscle Strength
MRI	Magnetic Resonance Imaging
NFD	National First Division
NREM	Non-Rapid Eye Movement
NSAIDS	Non-Steroidal Anti Inflammatory Drugs
POMS	Profile of Mood States
PRISMA-P	Preferred Reporting Items of Systematic Reviews and Meta-Analyses Protocol
PSG	Polysomnography
PSL	Premier Soccer League
PSQI	Pittsburgh Sleep Quality Index
RCTs	Randomised control trials
REM	Rapid Eye Movement
RPE	Rate of Perceived Exertion
s	Seconds
SAFA	South African Football Association
SATED	Satisfaction, Alertness, Timing, Efficiency and Duration of sleep
SE	Sleep Efficiency
SHS	Sleep hygiene strategies
SOL	Sleep onset latency

SSA	Self-Assessment of Sleep and Awakening Quality scale
VO2 max	Maximal Oxygen Uptake
YYIRT	YoYo Intermittent Recovery test

ABSTRACT: STUDY 1

Background

Frequently, soccer players are in search of methods to speed-up recovery post-exercise due to fixture congestion. Players and staff have limited reliable evidence regarding the most effective recovery methods post-exercise. Vast differences in infrastructure, staff and finances exist between teams in South African soccer leagues. Monitoring the implementation of recovery methods by each team presents a significant challenge. The purpose of the present study is to describe the recovery methods, frequency of use, barriers to implementation and factors influencing potential decision makers. The findings could assist medical staff and players to select evidence-based methods.

Methods

A descriptive observational cross-sectional study was employed. Staff responsible for recovery methods throughout three professional soccer leagues in South Africa were purposively recruited. A customised questionnaire was designed to obtain data on the recovery methods implemented by South African soccer teams, as well as to investigate barriers to implementation of these methods. A panel of experts reviewed and validated the questionnaire. The majority of the questionnaires were completed online, and several face-to-face interviews were conducted. Confidentiality of the data was ensured, and informed consent was obtained from each participant.

Results

A total of 48 questionnaires were completed, 16 from each of the three leagues. Two questionnaires were excluded as participants indicated that they did not use recovery methods and one questionnaire was incomplete. The majority of respondents were fitness trainers or physiotherapists with an average of 8 ± 4 years' working experience in soccer. Five different recovery methods were used most frequently. Rehydration (n= 45, 94%), nutrition (n= 41, 85%), and stretching (n= 41, 85%) post-exercise, were reportedly used most frequently. The majority of participants (n= 38, 79%) considered the recovery methods to improve performance. There was no statistical difference in the average number of recovery methods utilised by teams in the Premier Soccer League (PSL) and National First Division (NFD; PSL 7 ± 2 vs. NFD 6 ± 1, $p = 0.24$). However, National Second Division (NSD) teams used significantly fewer recovery methods than PSL teams (PSL 7 ± 2 vs. NSD 5 ± 1, $p < 0.003$). The greatest barriers staff reported were a lack of player interest and insufficient funds.

Conclusion

The findings of this study suggest that the use of recovery methods occurs at all professional levels of South African soccer. Teams are implementing recovery methods without sufficient evidence to justify its use (i.e. stretching, massage, active recovery or cold water immersion). While nutrition and hydration are very well utilised across South African soccer, sleep interventions remain under utilised. Most teams sourced protocols based on anecdotal evidence, therefore recovery method implementation should be re-examined. Teams in the top tiered league used more recovery methods compared to lower tiered teams, most likely due to the greater resources available. However, a lack of player interest was one of the biggest barriers to implementation. It is recommended that staff and players receive improved and focused educational interventions regarding the efficacy of various recovery methods, which may also assist in altering behaviour towards more evidence-based recovery methods.

ABSTRACT: STUDY 2

Background

Sleep is widely considered to play a pivotal role in an athlete's development, health and potential performance. Various studies have reported that poor sleep quality and/or quantity negatively affects athletic recovery and performance. Despite these findings, an overwhelming number of athletes still experience sub-optimal sleep, preventing them from reaching their full potential. Information on sleep interventions remains poorly systematised in the literature. A lack of consensus exists as to which sleep interventions best assist athlete recovery and performance.

Aims

The aim of the present study was to complete a systematic review, following an outlined and described protocol, based on non-pharmacological sleep interventions to enhance recovery and performance in athletes.

Methods

Studies relating to sleep involving participants described as 'athletes' as well as studies which included recovery and performance outcomes were located through a systematic search of eight research databases, namely: Academic Search Complete, MEDLINE, CINAHL, SportDiscus, Biomedical Reference collection, AMED, PsycINFO, PsycARTICLES; and included studies published until October 2017. A Critical Appraisal Skills Programme (CASP) checklist was employed to assist with analysing the included studies' methodological quality. The systematic review was carried out in accordance with the PRISMA-P guidelines.

Results

The search revealed 1286 articles, however after removing duplications, screening titles and abstracts and adhering to the inclusion and exclusion criteria, only eight articles remained chronologically from years 2011 – 2017. The quality of evidence reviewed was generally low. Approximately 70% of the participants were male and the mean participant age ranged between 16 to 23 years. Sleep extension interventions significantly improved performance, recovery and sleep outcomes. Brainwave entrainment and red-light therapy reported improvements in sleep indices, without significantly effecting performance or recovery outcomes. Sleep education and behavior changes reported mixed results, improving sleep duration without improving performance

outcomes. Naps reported negative results on sleep indices and removal of devices did not elicit any significant differences.

Conclusion

The current review observed that improved sleep improved psychological wellness and recovery, which in turn could translate to improved performance. Interventions which had a longer duration seemed to have a more beneficial effect on sleep indices and, in turn, improved recovery and performance results. The researchers acknowledged the limited number of high quality studies reviewed and the difficulty in generalising results towards various athlete populations. The efficacy of interventions to benefit sleep indices, such as sleep extension, education and behavior changes and relaxation strategies, appear to be valuable; however, further situation and sport specific studies, including greater in-depth sleep measurements are required.

CHAPTER 1: INTRODUCTION AND SCOPE OF THE DISSERTATION

1.1 Introduction

Soccer is arguably the most played sport in the world. The latest large scale survey carried out by the International Federation of Association Football (FIFA), showed more than 250 million active players globally (Kunz, 2007). Since the 2010 FIFA World Cup, soccer has been launched into a frenzy in South Africa. SuperSport, a local television producer, signed a one billion Rand television rights deal with the Premier Soccer League (PSL) and National First Division (NFD) to televise South African soccer around the world, creating substantial financial reward and, in turn, increased competition for local players (Egbamuno, 2013).

Soccer is associated with complex physiological and cognitive requirements due to various interactions within the game, which include sprinting, change of direction, tackling, shooting, technical skills and decision making (Ali, 2011). The demands of each busy soccer season, increased competition and congested match schedules often leads to fatigue and potential injury (Dellal et al., 2013, Dupont et al., 2010). These increased demands often result in the athlete not recovering before the next game, leading to underperformance and a further decline in recovery (Dupont et al., 2010, Nédélec et al., 2012). This has led to a shift in actively attempting to expedite recovery time with several recovery methods (Reilly et al., 2008).

To date, there is very little scientific evidence supporting the efficacy of recovery methods post-exercise for athlete recovery and performance. Many of these proposed benefits are centered around anecdotal evidence based on poor studies (Nedelec et al., 2013). As a result, recovery methods are often implemented in club environments without a full understanding from either the team staff or the individual athletes on the proposed benefits or risks. Educational measures should aim to allow athletes and staff to make use of recovery methods with the full understanding of their effects (Crowther et al., 2017b).

A number of recovery methods including cold water immersion (CWI), compression garments (CG), massage, stretching and active recovery, although widely used in soccer, are supported by little scientific evidence supporting the claim that they aid in recovery post-exercise (Nedelec et al., 2013). Adequate rehydration, satisfactory nutrition and sufficient sleep demonstrated reliable evidence in improving recovery and reversing the effects of exercise fatigue (Nedelec et al., 2013). While practitioners using recovery methods list nutrition, hydration and sleep as the most effective

recovery methods post-exercise (Venter, 2014, Nedelec et al., 2013), their patterns of use, especially amongst South African soccer teams, is not known. Sleep interventions were one of the most underused recovery methods amongst elite South African team athletes (Venter and Grobbelaar, 2017, Van Wyk and Lambert, 2009).

Improving sleep has been inadequately linked to athlete health and recovery (Halson, 2008, Samuels, 2008). Previous studies have reported that a large proportion of athletes experience sleep disturbances or problems (Erlacher et al., 2011, Juliff et al., 2015b, Lastella et al., 2015b, Tuomilehto et al., 2017). Nedelec et al. (2015a) outlined a variety of acute and chronic stressors facing athletes, which affect their ability to experience good sleep. While the negative effects of sleep loss on athletic health, recovery and performance have been previously reviewed (Fullagar et al., 2014), there remains a lack of evidence supporting interventions which benefit sleep indices and, in turn, improve athlete recovery and performance. Previous reviews (Simpson et al., 2017, Nedelec et al., 2015b) have provided several recommendations such as sleep extension, naps, sleep hygiene strategies (SHS) and avoidance of harmful behaviours to enhance sleep indices; however, these are general reviews based on scarce literature.

The purpose of the present study is to describe which post–exercise recovery methods are used by professional South African soccer teams. Furthermore, due to the importance of sleep on health, recovery and potentially on exercise performance (Bird, 2013, Halson, 2008, Nedelec et al., 2015a) a systematic review was conducted to investigate the most effective evidence-based sleep interventions that may assist athletes to improve their sleep, enhance recovery and improve athletic performance.

1.2 Aim and objectives

1.2.1 Aim

Study 1: The first study aimed to investigate the use of post-exercise recovery methods in South African professional soccer teams during 2013/2014.

Study 2: The second study aimed to undertake a systematic review, following an outlined and described protocol (Appendix VII) of non-pharmacological interventions to improve sleep to enhance recovery and performance in athletes.

1.2.2 Specific objectives

Study 1:

1. To describe post exercise recovery methods used by the staff in South African professional soccer teams.
2. To compare differences between the South African soccer leagues, regarding recovery methods use by the staff.
3. To explore potential barriers that staff members faced with implementation of post-exercise recovery methods.

Study 2:

1. To establish the evidence base concerning non-pharmacologic sleep interventions, which aim to benefit athlete recovery and/or performance indices, in isolation. This will be established through a systematic review of peer-reviewed journals and abstracts in this field.
2. To establish how these interventions affect recovery and performance indices primarily and sleep indices secondarily.
3. To identify underlying causes negatively affecting athlete sleep quality and quantity and how we can address these issues to improve sleep indices.

1.3 Significance of the research

At present, there is a lack of substantive information regarding recovery methods use across the three tiered professional soccer leagues in South Africa. Inconsistencies across the leagues regarding funding, facilities and staff leave a varied approach to the use of recovery methods post-exercise. Grasping a clear understanding of the current barriers facing South African soccer staff, will allow an attempt to effect change through the implementation of effective intervention programmes (Grol, 1997). The findings of the present studies are intended to improve knowledge regarding the prevalence of the use of recovery methods in South African soccer teams. Developing a set of recommendations may support staff and players to make simple, informed and practical decisions regarding post-exercise recovery methods (Leape, 1990).

Sleep interventions are under-valued and under-utilised amongst South Africa athletes (Venter and Grobbelaar, 2017; Van Wyk and Lambert, 2009) and should form an integral part of recovery methods. While sleep interventions are perceived to assist in athlete recovery, there is currently a lack of evidence to attest to this. Findings from the systematic review should aid athletes in selecting the most effective sleep interventions for post-exercise recovery. The objectives stated above will be

fully investigated to improve knowledge and awareness regarding recovery methods, with specific reference to sleep interventions, to improve overall athlete recovery.

1.4 Structure of the research

The following work is organised into five chapters, which demonstrates the progression of the dissertation. In preparation for the investigational phase, Chapter Two offers a comprehensive literature review addressing post-exercise recovery methods in sport. This is followed by a descriptive questionnaire-based study (Chapter Three) designed to determine which recovery methods staff in South African soccer teams are making use of across each of the three professional leagues. Chapter Four presents a systematic review, conducted to investigate which sleep interventions would facilitate optimal recovery for athletes. The aims and objectives of each study will be described in the respective chapters. A detailed summary of the findings is presented in Chapter Five and locates the significance of these findings within the existing literature. The chapter concludes with a consideration of possible intervention programmes and a discussion of directions of future research.

CHAPTER 2: LITERATURE REVIEW - RECOVERY METHODS POST-EXERCISE APPLICABLE IN SOCCER

The literature review will broadly explore different recovery methods, throughout a range of sports, that are applicable to soccer. This literature review takes the form of a narrative review.

2.1 Introduction

Following the FIFA World Cup held in South Africa in 2010, soccer has increased in popularity and professionalism. A competitive season is almost year round and stresses the immune, musculoskeletal, nervous and metabolic systems (Reilly and Ekblom, 2005). Fatigue post-exercise, caused by the competitive season in soccer, can lead to under-performance and potential injury (Dupont et al., 2010, Nédélec et al., 2012), therefore support staff are constantly trying to find the best recovery methods to improve recovery in-between the players' training and match schedules (Reilly and Ekblom, 2005).

The lack of epidemiological studies provides poor context into the nature of soccer injuries and training/competition loads within South African soccer leagues (Constantinou, 2010). Future studies are recommended to assess the epidemiology and cause of injuries among soccer players in South Africa, so solutions can be generated to improve player recovery and injury prevention strategies. Before exploring the recovery methods currently used by South African soccer teams, an overview of the relevant recovery methods used in soccer should be considered. Therefore, the purpose of this review will be to outline the components of potential recovery methods used by professional sports teams and to describe the recovery process of each of these recovery modalities.

The literature search was guided by a structured process. Database searches were conducted using Cinahl, EBSCO, Google Scholar, Pedro and Science Direct. The list of titles and abstracts obtained from each of the database searches were reviewed for relevance. Following, selected full-text articles were obtained and thoroughly examined. Finally, reference lists of articles were reviewed, and the relevant citations were used. Additional articles were also obtained from the research supervisors. The following keywords were used: "Recovery in soccer", "Recovery in football", "Recovery post-exercise", "Recovery methods", "Training schedules in football", "Cold-water immersion", "Sleep cycles", "Hydration", "Protein and carbohydrates", "Caffeine", "Vitamins", "Active recovery",

"Passive recovery", "Stretching", "Massage", "Compression garments", "Fatigue post-exercise", and "Best-practice guidelines".

2.2 Recovery Post-Exercise

Recovery should form an integral part of any successful training and performance optimization programme (Barnett, 2006, Bishop et al., 2008). Before this review investigates specific recovery methods, a brief outline on Exercise Induced Muscle Damage (EIMD) post-exercise, including the physiological and mental effects and time frames of recovery, will be described.

2.2.1 Exercise-Induce Muscle Damage post-exercise

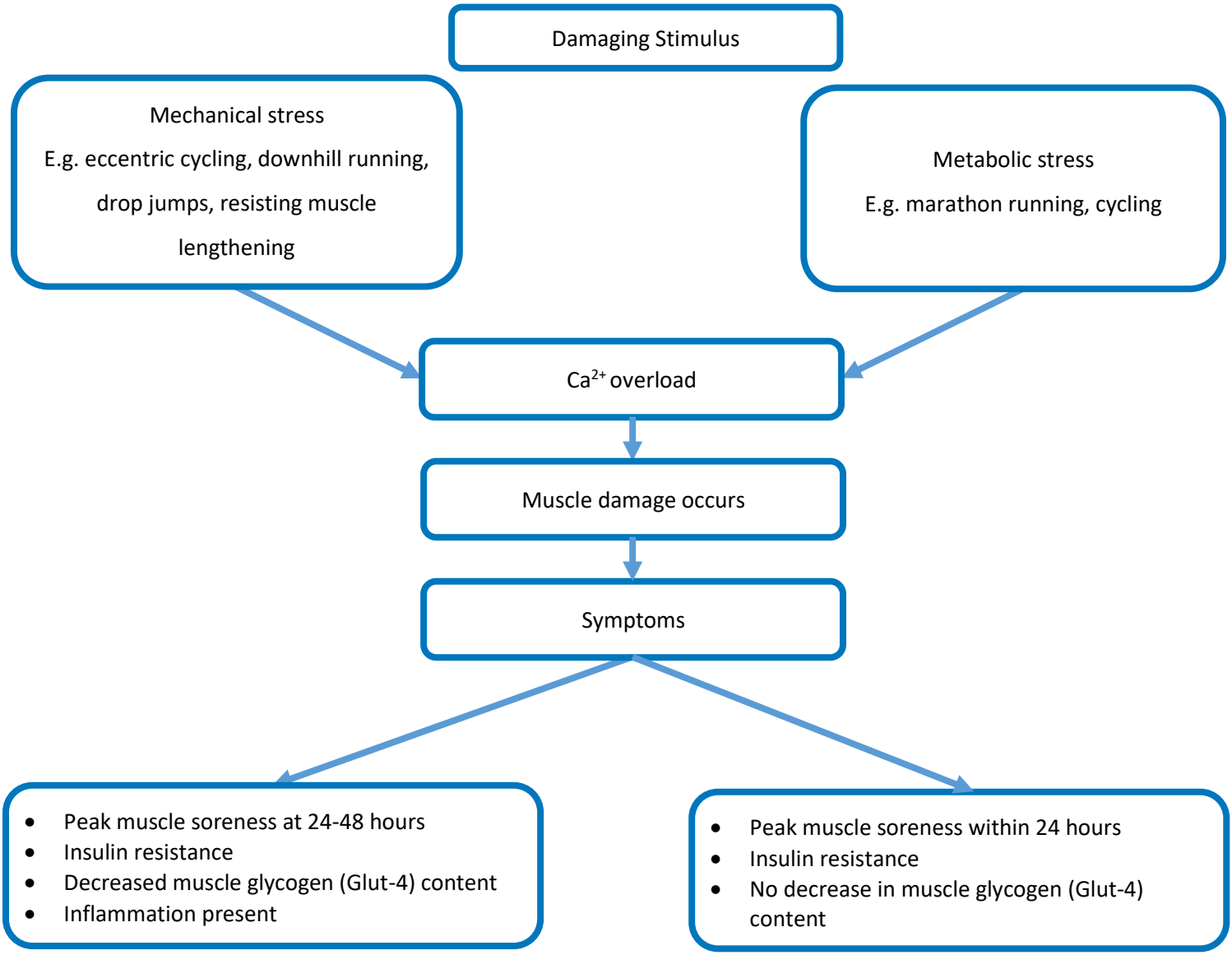
During soccer, a player undergoes many actions including: sprinting, acceleration, deceleration, tackles, jumps, etc., over an extended period (Andersson et al., 2008, Nédélec et al., 2012). These actions result in muscle damage (Douglas et al., 2017). It is important to consider EIMD because of the detrimental effects it has on short-term performance and recovery (Doma et al., 2018, Twist and Eston, 2005). Two pathways to EIMD which have been previously described (Fatouros et al., 2016, Tee et al., 2007) will be briefly outlined below (see Figure 1; Tee et al., 2007).

A 'damaging' exercise stimulus can lead to muscle damage, tissue inflammation, delayed onset muscle soreness (DOMS) and an increased perceived fatigue (Dupuy et al., 2018). Initially post damaging stimulus, Ca^{2+} levels are disrupted and a process of Ca^{2+} overload begins (Armstrong et al., 1991). The myofibre membrane as well as myofibre proteins are degraded due to this overload (Kuipers, 1994) and a process of inflammation begins, which removes the damaged tissue and regenerates the muscle fibres (Warhol et al., 1985). Muscle damage blood markers (creatine kinase; CK) and inflammatory biomarkers are increased in the blood and are somewhat responsible for DOMS (Stacey et al., 2010). The damage can lead to a temporary decrease in sport-specific performance (Doma et al., 2018, Twist and Eston, 2009), muscle power (Dabbs and Chander, 2018, Goodall and Howatson, 2008), perceived recovery (Dugué, 2015), perceived power output (Karasiak and Guglielmo, 2018) and a potential increased injury risk (Barnett, 2006).

Exercise Induced Muscle Damage can either be caused by a mechanical stress, metabolic stress, or a combination of the two leading to different symptoms (see Figure 1). The mechanical stress model is explained by the increased use of eccentric, rather than concentric or isometric contractions, which result in increased damage (McCully and Faulkner, 1986). The metabolic stress model suggests EIMD is caused by metabolic deficiencies in the muscle which can cause muscle damage or increase the

susceptibility of the muscle to mechanical stress (Tee et al., 2007). Soccer training and/or match-play is a combination of both mechanical and metabolic stress (Gaudino et al., 2014, Krustrup et al., 2006, Nédélec et al., 2012). Therefore, the ideal experimental protocols would use simulated soccer training to best replicate EIMD. Most literature available exploring recovery have used lab-based exercise protocols (i.e. drop jumps, resisted muscle lengthening training) to induce EIMD. The question remains as to whether we are able to adequately compare the results of studies using different exercise protocols to soccer training or matches. The following literature review will separate the reviewed studies' exercise protocols according to mechanical or metabolic classifications as best as possible.

Figure 1: EIMD classification and symptom characteristics
(adapted figure from (Tee et al., 2007)



2.2.2 Physiological and mental effects of recovery

Recovery aims to reverse the effects of post-exercise fatigue (i.e. dehydration, glycogen depletion, EIMD and mental fatigue; (Dupuy et al., 2018, Nédélec et al., 2012), decrease predisposition to injury (Barnett, 2006) and return the players' metabolic and physiological systems to homeostasis (Hausswirth and Le Meur, 2011). This is considered achieved when the player can perform activities, which match or exceed pre-training/competition levels (Bishop et al., 2008; Nédélec et al., 2012).

Recovery is a complex regenerative process relative to time, where physical, psychological and social factors must be considered (Kellmann et al., 2018). Although recovery can be viewed as a passive process; for players to cope with constant training/match loads and stresses, post-exercise recovery methods are essential to restore homeostasis, accelerate recovery and prepare the player for the following game (Reilly et al., 2008). Recovery methods attempt to accelerate the recovery process, reducing the time away from sporting training and competition (Halson, 2013).

2.2.3 Recovery outcome measures in the literature

In the literature, recovery has generally been assessed by examining three main outcome measures - physical performance, biochemical markers and perception of recovery (Doeven et al., 2018, Nédélec et al., 2012). A variety of different physical performance tests are used to asses and monitor recovery (i.e. countermovement jump [CM]), sprint, strength, flexibility, aerobic simulations, etc.) of which CMJ height was the most consistently measured in team ball sports (Doeven et al., 2018).

Biochemical markers (CK, cortisol, testosterone, lactate, etc.) can assist in identifying the underlying physiology of recovery and can assist with the time course of recovery post-exercise (Nédélec et al., 2012). Creatine Kinase was the most consistently measured biochemical marker among the reviewed literature and whilst there is inevitably an increased effect on CK levels post-exercise, there also exist a variability between athletes showing the individual nature of recovery profiles (Roe et al., 2016, Doeven et al., 2018). Perceived recovery, self-reported measures and questionnaires (DOMS scores, Profile of Mood States questionnaire, Recovery Stress Questionnaire, etc.) have been noted as very relevant to measure athlete recovery (Saw et al., 2016, Twist et al., 2012). Self-reported measures have big variability according to the individual athlete's preferences, rather than evidence-based outcomes (Crowther et al., 2017b) and often survey results can be influenced by peers and not entirely accurate (Venter, 2014).

For the purposes of this review, recovery based on a return to previous performance will be considered the best level of evidence for the efficacy of recovery methods. This decision was made

due to the high degree of ecological and practical validity of these outcomes for professional football settings. Unfortunately, the majority of the reviewed literature either did not measure performance or showed no improvement in performance as a result of the recovery aid. Therefore, as a secondary level of evidence for the efficacy of recovery methods, biochemical markers and perceived recovery are considered. Due to the high levels of inter-individual variability typical of these measures, these results are interpreted with a degree of caution.

2.2.4 Time frames of recovery

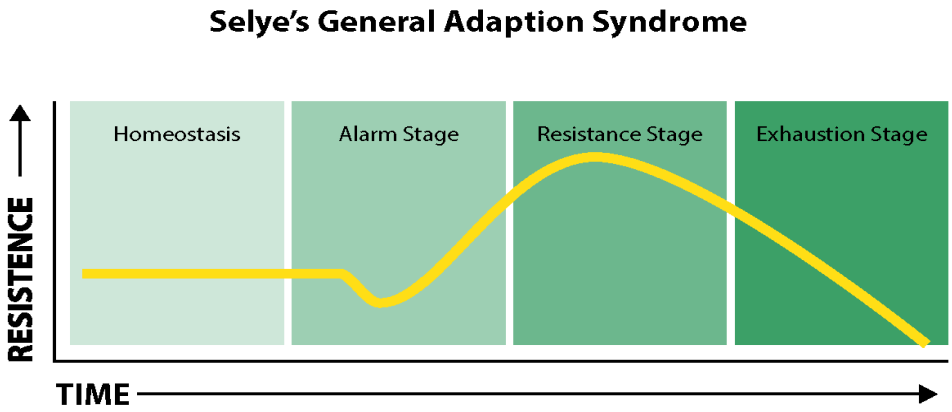
Bishop et al. (2008) outlined three stages of recovery, namely immediate recovery, short-term recovery and training recovery. Immediate recovery occurs between rapid efforts, that is, in the stride phase, one of the player's legs will be in recovery. The second phase of recovery is short-term recovery, which occurs between sprints or intense exertions, whereas the third phase of recovery, or training recovery, occurs between training sessions or competitions. The third phase of recovery will be the focus of the recovery methods in this review.

Time-frames for recovery vary depending on the individual player and the type and intensity of the exercise (Bishop et al., 2008). A study carried out on 192 participants observed that full recovery occurred approximately 132 hours after eccentric exercise (Sayers and Clarkson, 2001). A recent systematic review looking at post-match recovery outcomes in team ball sports showed that physical performance measures needed 48 hours and biochemical measures needed at least 72 hours before returning to baseline (Doeven et al., 2018). Due to the constant training in soccer and player adaptation over seasons, 72 hours post-intense exercise is considered sufficient time for the full recovery of a player (Andersson et al., 2008, Ascensão et al., 2008). Should a player demonstrate a decrease in performance beyond this timeframe, they could still not have reached full recovery or possibly are overreached or fatigued (Kenttä and Hassmén, 1998). Training during the recovery period will delay the recovery process, prolonging fatigue, and potentially leading to lack of adaptation and injury (Kuipers and Keizer, 1988).

Figure 2, re-drawn below, is based on the original work form Selye, (1950). Figure 2 shows the body's physiological response to any sort of stress (mental, exercise training, etc.; (Selye, 1956). The three to four phases which occur can be applied to exercise training which can help explain the fatigue-recovery-adaptation process. The alarm phase shows the initial reaction to the match or training which is depicted by a decrease in the performance graph due to potential fatigue, EIMD or training stress (Turner, 2011). The resistance phase begins initially with recovery of the body back to homeostasis or previous performance levels and then to newly adapted performance levels

(supercompensation) in which the performance graph moves higher than before (Turner, 2011). Improving performance depends on a balance between training and recovery, to prevent potential negative effects of the physiological and psychological exercise load (Meeusen et al., 2013, Soligard et al., 2016). In the absence of adequate rest or recovery, if further stress or training occurs, the exhaustion phase is likely to occur causing overtraining syndrome and potentially leading to injury, extended fatigue and a decrease in performance (Sands et al., 2007).

Figure 2: Selye's general adaptation model (re-drawn; Selye, 1950).



As the competitive nature of the South African soccer leagues increase, so do the number and intensity of training sessions and matches. Effective recovery strategies are required to compensate for this and are considered an important determinant of performance (Odetoyinbo et al., 2008).

2.3 Prioritizing Post-Exercise Recovery Methods in Soccer

A variety of recovery methods are currently being used to accelerate the recovery process and can generally be split into three categories: active recovery, passive recovery and additional interventions (Bompa and Haff, 2009, Rey et al., 2012). Active recovery includes water or land based sub-maximal exercises aimed at reducing muscle pain, increasing relaxation and improving thermoregulation (Tessitore et al., 2008). Passive recovery follows the natural course of recovery post-exercise, where the athlete would be in a relaxed posture (i.e. sitting, lying, etc.) without exerting themselves or employing additional recovery interventions (Strejcová and Konopková, 2012). Additional recovery interventions include hydration, nutrition, sleep interventions, hydrotherapy (i.e. CWI and contrast water therapy [CWT]), stretching (also used in active recovery), massage, compression garments (CG) and electromyostimulation (EMS). Previous reviews have questioned the efficacy of certain additional recovery interventions (i.e. massage, stretching, CG,

EMS and hydrotherapy), but have lauded other interventions (i.e. hydration and nutrition) as imperative in an athlete's recovery programme (Barnett, 2006, Nedelec et al., 2013). It is therefore important that the implementation of these recovery methods is evidence-based in order to maximize the effectiveness and resourcefulness of each recovery method. The following sections aim to describe each recovery method used in soccer post-exercise and demonstrate the impact on recovery using the available literature.

The recovery methods outlined below were included for discussion based on findings from a previous study conducted by (Nedelec et al., 2013), which reported on the most commonly used recovery methods in European soccer. This was cross-referenced with a South African study assessing the recovery methods used in rugby (Van Wyk and Lambert, 2009), as no local study considering recover methods in professional soccer teams was available.

2.3.1 Nutrition

Muscle glycogen is one of the most important substrates for energy production in soccer players (Nédélec et al., 2012) and It has previously been shown that adequate carbohydrate reserves are important for optimal performance (Sherman and Wimer, 1991). Muscle glycogen has been observed to be depleted after a soccer match or intense exercise (Mohr et al., 2003). Performance, psychological and physiological impairments were noted for judo athletes who restricted their food and energy intake prior to competition compared with athletes who maintained an unrestricted diet (Degoutte et al., 2006). Although different exercise intensities and therefore glycogen depleting consequences occur other than in soccer, a low CHO diet and low CHO availability was shown to impair performance in elite race-walkers compared with a high CHO availability (Burke et al., 2017). Whilst recent research has alluded to a potential benefit to training with a low CHO availability and an increased CHO consumption prior to competition to improve performance, the research is still being validated (Bartlett et al., 2015, Close et al., 2016). This 'train low, compete high' theory is beyond the scope of this review, however it can be noted that CHO availability seemed to still be the most important macronutrient for optimal performance; and physical performance would likely be poorer in a glycogen depleted state (Close et al., 2016, Ranchordas et al., 2017). Diets with a high CHO content and therefore glycogen availability seemed to improve soccer performance (Caruana Bonnici et al., 2019). Carbohydrate ingestion post-exercise will be explored in more detail due to its importance in soccer nutrition (Nedelec et al., 2013) with reference to Table 1 below.

Table 1: Summary of nutrition studies using metabolic EIMD protocols

Summary of nutrition studies using metabolic EIMD protocols								
Author	**Study design**	**Exercise/muscle damaging protocol**	**Subjects**	**Recovery methods**	**Recovery protocol**	**Outcome measures**	**Measurement times**	**Main finding**
Krustrup et al., 2011	Control trial	Competitive soccer match	7 high-level male soccer players	High CHO diet	High CHO diet for 5 days post-match	HR, weight and fluid intake. Muscle biopsies (muscle glycogen and Ca2+ uptake) and blood samples (CK levels, myoglobin); Yo–Yo test, repeat sprint test, MS, MVC (quadriceps) and SR function	Muscle biopsies and blood samples were measured 0, 24, 48 and 72 h post-game. MVC force was measured at 0, 24 h post-exercise	Glycogen resynthesis was impaired post-soccer game with a normal or high CHO diet. MVC and SR Ca2+ uptake were impaired and MS was elevated post-game, with faster recovery of SR function in comparison with other outcomes
Gunnarsson et al., 2013	Randomised control design	Soccer match (60 min or 90 min)	16 elite soccer players	CHO and whey PRO (high in CHO and whey	Immediately post-match	HR, Muscle glycogen (type I, type IIA, type IIB fibres)	Baseline, Post-match and for 48h post-match	Glycogen resynthesis 48 h post-soccer match was not elevated by ingestion of a high CHO diet. Glycogen resynthesis was not impaired with physical contacts
Ivy et al., 1988	Counter-balanced, crossover design	Cycle ergometer for 70 min at 68% VO2max interrupted by six 2 min intervals at 88% VO 2max, on two occasions.	12 male cyclists	CHO solution	CHO solution ingested immediately post-exercise and 2 h post-exercise	Muscle glycogen and blood samples (plasma insulin, glucose, free-fatty acids)	Muscle biopsies from the vastus lateralis at 0, 2, and 4 h post-exercise. Blood samples at 0, and 15, 45, 120, 135, 180, and 240 min post-exercise	A reduced glycogen storage rate was noted when administering delayed CHO ingestions, when compared with providing the CHO supplement immediately post-exercise.
Zawadski et al., 1992	Randomised counter-balanced design	Cycle ergometer for 2 h at the work rates established during the practice ride to deplete muscle glycogen stores lower blood glucose.	9 male subjects	CHO; PRO; CHO and PRO beverage	Immediately post-exercise and again 2 h after exercise	Plasma glucose, insulin and Bla. Muscle glycogen and PRO concentrations, CHO oxidation	Baseline, post-exercise and 4h post-exercise	The rate of muscle glycogen storage during the CHO-PRO treatment was significantly faster than during the CHO treatment and even more significant than PRO alone

Table 1 (continued): Summary of nutrition studies using metabolic EIMD protocols

Author	Study design	Exercise/muscle damaging protocol	Subjects	Recovery methods	Recovery protocol	Outcome measures	Measurement times	Main finding
Van Loon et al., 2000	Randomised, double-blind trial	Glycogen depletion protocol (intense cycle ergometer test)	8 trained cyclists	CHO only, CHO together with an amino acid and PRO mixture, or an isogenic amount of CHO (50% glucose and 50% maltodextrin)	Beverages consumed at 0, 30, 60, 90, 120, 150, 180, 210, 240, and 270 min post-exercise	Muscle glycogen, blood glucose, plasma insulin	Baseline, post-exercise and 5h post-exercise	Muscle glycogen synthesis and plasma insulin responses were higher in both CHO combination trials than in the CHO beverage alone. Addition of a PRO and amino acid or additional CHO can aid in accelerating glycogen synthesis

ABBREVIATIONS: h – hours; min – minutes; s - seconds; MS – muscle soreness, m – metre; ACT – Active recovery; Bla – Blood lactate concentration; d – day, HR – heart rate, Pass – passive recovery; VO2 max – Maximal oxygen uptake; rpm – reps per minute; g –gram; kg – kilogram; CHO – carbohydrate; ml – millilitre; PRO – protein; MVC – maximal voluntary contraction, SR - sarcoplasmic reticulum; Ca2+ - Calcium; mmol – millimoles ; Na+ - sodium; K+ - potassium; Cl- - chloride; HWI – hot water immersion

a) Carbohydrate doses when used as recovery strategy

Depending on the extent of the glycogen depletion and the intake of CHOs, it is possible for glycogen stores to be restored within 24 hours (Casey et al., 1995). Initially, CHO replacement is essential to replace the glycogen stores and re-fuel the body to bring about homeostasis (Burke, 1997, Nedelec et al., 2013).

The consumption of large amounts of CHO (1.0–1.85 g/kg/h) immediately post-exercise and at 15 to 60 minute intervals thereafter for up to five hours post-exercise, was the most efficient way to re-synthesize muscle glycogen (Burke et al., 2004, Jentjens and Jeukendrup, 2003). Further, it was concluded that when CHO ingestion was delayed by several hours post-exercise, muscle glycogen synthesis was approximately 50% lower (Ivy et al., 1988, Jentjens and Jeukendrup, 2003, Alghannam et al., 2018). Re-supplementation every two hours, for up to six hours, is recommended to maintain storage levels and adding protein to a CHO supplement may increase the rate of glycogen storage (Burke, 1997, Ivy, 1998). An average soccer player body type of around 75-80 kg should consume 90g CHO per hour for a couple hours post-exercise (Ranchordas et al., 2017).

Blom et al. (1987) examined the effect of various post-exercise sugar diets on the rate of muscle glycogen synthesis. After cycling to exhaustion, participants were allocated to groups ingesting different amounts of glucose (0.35, 0.70 or 1.40 g/kg/h) immediately, and at two and four hours post-exercise. Although glycogen storage was low when taking less than 0.35 g/kg/h of CHOs, it increased by 150% when increasing CHO consumption from 0.18 to 0.35 g/kg/h (Blom et al., 1987). However, no significant increase was observed when the participants raised the CHO consumption from 0.35 to 0.70 g/kg/h, thereby concluding that a threshold exists at 0.35 g/kg/h. Further, the abovementioned study reported very high glycogen synthesis rates at 0.35 g/kg/h, leaving little room for an improvement when increasing the CHO consumption to 0.70 or 1.40 g/kg/h. The glycogen levels reported, and the biopsy methods used should have been more thoroughly monitored and reviewed, therefore the results must be interpreted with caution.

Conversely, a study by van Loon et al. (2000) reported that the glycogen threshold observed by Blom et al. (1987) at 0.35 g/kg/h, did not exist in their study. Van Loon et al. (2000) observed that when increasing CHO consumption from 0.8 to 1.2 g/kg/h, glycogen synthesis rates improved by more than 100%. The study also showed that consumption of CHO multiple times within the hour accelerates glycogen resynthesis compared to a single ingestion within the hour (van Loon et al., 2000). Glycogen synthesis has been shown to be increased when a larger amount of CHO is consumed (up to approximately 1.2 g/kg/h), immediately post-exercise and in short-intervals (Alghannam et al., 2018).

Therefore, the differences between the two studies can be potentially explained due to the Blom et al., (1987) study using less CHO consumption, some groups delayed consumption and only used one ingestion time compared with the study by van Loon et al., (2000). Therefore, CHO should be consumed in adequate quantities immediately post-exercise in short intervals. Staff supporting the soccer players should provide food that the players enjoy and will consume to encourage optimal recovery (Ranchordas et al., 2017).

b) Types of carbohydrate used as recovery strategy

The glycaemic index (GI) examines the glucose response after CHOs are ingested and demonstrates the rate of absorption and digestion of these CHOs (Jentjens and Jeukendrup, 2003). Fructose, a low GI CHO, produced lower levels of muscle glycogen re-synthesis when compared to glucose, a high GI CHO (Van Den Bergh et al., 1996). Kien et al. (1990) investigated various glycogen synthesis rates when comparing players who ingested either a high or low GI diet after glycogen-depleting exercise. Muscle glycogen synthesis rates were seen to be 61% higher following a high GI diet compared to a low GI diet. The authors concluded that a high GI diet is indicated post-exercise to aid in improved glycogen re-synthesis rates (Kien et al., 1990). The authors did not list the amount of CHOs ingested in the diet, leaving a poor benchmark to compare to other studies reporting specific CHO doses.

In addition, protein ingestion will aid in repairing damaged muscle and assist in increasing the skeletal muscle adaptive response (Koopman et al., 2007, Mazzulla et al., 2017, Poulios et al., 2018). More specifically, when a lower amount of CHO is ingested, the co-ingestion of protein post-exercise can assist in increasing muscle glycogen synthesis (Jentjens and Jeukendrup, 2003). Further, low glycogen synthesis rates were observed when no CHOs were consumed post-exercise (Jentjens and Jeukendrup, 2003). The rate of muscle glycogen storage was quicker in the CHO-protein group (40% higher than CHO alone, and 400% higher than protein alone), supporting the author's hypothesis that adding protein to a CHO solution would increase glycogen storage levels (Zawadzki et al., 1992). Consuming around 40g (Macnaughton et al., 2016) of protein post-exercise has shown better protein synthesis rates compared with ingestion of 20g or less (Nedelec et al., 2013, Witard et al., 2014). This can be easily consumed as milk proteins within a CM beverage as discussed above, or as sports protein bars and protein powders (Ranchordas et al., 2017).

Interestingly, muscle glycogen re-synthesis at 24 and 48 hours post-match revealed no significant difference, whether the players ingested a normal or a protein- and CHO-rich diet (Gunnarsson et al., 2013, Krustrup et al., 2011). Most likely that by replacing the calorie deficit incurred from exercise, regardless of the food specifics, will re-establish similar previous muscle glycogen levels. Liquid CHO

options should be considered instead of solid CHO options immediately post-exercise, as fluid absorption and delivery are faster with liquid CHOs, improving rehydration (Jentjens and Jeukendrup, 2003).

Although no significant recovery benefits were observed when adding creatine in addition to CHOs (Krustrup et al., 2011), previous studies observed benefits for post-exercise glycogen storage with a diet combining CHOs and creatine (Cribb et al., 2007, Robinson et al., 1999). Additional research is required to isolate the effect of creatine on glycogen re-synthesis post-exercise, as well as the dosage and timeframes of consumption.

The consumption of amino acids post-exercise are essential due to their anti-inflammatory properties (Ferrucci et al., 2006). Leucine, an essential amino acid, assists in muscle protein synthesis post-exercise and can easily be found in sources of chicken, fish or in protein powders (Atherton et al., 2017, Ranchordas et al., 2017). However, a lack of research observing the benefits of amino acids to assist in post-exercise recovery still prevails (Houghton and Onambele, 2012, Nedelec et al., 2013, Pedroso et al., 2015). No differences were observed in recovery markers post-exercise when participants ingested a CHO beverage compared to a CHO and amino acid beverage (Kephart et al., 2016). Although conflicting data exists regarding the benefits of fish oil on decreasing DOMS and inflammation (Lenn et al., 2002, Phillips et al., 2003), it has recently been suggested that 2-3g of fish oil post-exercise can decrease DOMS and inflammation (Ranchordas et al., 2017). However, further research is required regarding amino acids and post-exercise recovery. A balanced diet is imperative for soccer players post-exercise and while further details considering protein, fat and amino acid ingestion are beyond the scope of the present review.

c) Summary of literature: Nutrition post-exercise

Nutrition is considered a major influence in a player's recovery period and should be optimized to gain the maximum recovery effect. *Moderate dehydration has been* is imperative to make sure the player has enough CHOs to fuel training, recovery and match schedules (Caruana Bonnici et al., 2019). Carbohydrate consumption should take precedent immediately post-exercise in replenishing the lost fuel, followed by the ingestion or co-ingestion of protein to aid in muscle repair (Ranchordas et al., 2017). The post-exercise diet should also consider other nutrients and dietary additions to improve a player's recovery (i.e. omega 3 fatty acids, tomato juice and tart cherry juice). However, additional research is required to produce reliable evidence for these nutrients and their effect on recovery and performance in professional soccer players.

2.3.2 Rehydration

a) Dehydration post-exercise in soccer

A decrease in fluid balance is common after a soccer match, specifically as players may only rehydrate during the half time interval of a 90-minute match. Fluid loss can vary; however, a 2% loss of body mass was most commonly observed across most environmental conditions (Edwards and Noakes, 2009, Phillips et al., 2014, Mohr et al., 2010). Dehydration can negatively affect metabolic, cardiovascular, nervous and thermoregulatory systems (Cheuvront et al., 2003). Moderate dehydration has been observed to negatively affect soccer-specific skills (Cariolo et al., 2019). There is a lack of scientific research available which show a direct correlation with fluid loss and strength or performance outcomes, however it has previously been noted that a decrease of around 3% body mass can decrease strength and high-intensity endurance, without effecting sprint performance (Judelson et al., 2007). Endurance performance remains unchanged with less than 2% body mass loss in temperate environmental conditions, however conditions which are very hot and/or body mass loss exceeds 2%, than endurance performance is negatively affected (Cheuvront et al., 2003). Therefore fluid intake should aim to minimize dehydration to less than 2% body mass loss (Cheuvront et al., 2003) to prevent performance deficits (Burke, 2003). Fluid intake is beneficial and can be accomplished by re-hydrating during half-time (Phillips et al., 2011, Nicholas et al., 1999) and post-match.

b) Rehydration post-exercise in soccer

Rehydration post-match is fundamental to the recovery process; stimulating glycogen and protein synthesis due to high cell volumes, while low cell volumes (decrease in hydration) lead to a reduced rate of glycogen and protein synthesis (Keller et al., 2003). Depending on the fluid, rehydration intake post-exercise can replace water and electrolytes lost during sweating and provide CHOs to restock glycogen stores from the liver (Jentjens and Jeukendrup, 2003). It is imperative to replace more fluid (water and sodium) than the body has lost during exercise to account for continuous water-loss post exercise and optimise recovery (Shirreffs et al., 2004). Players should be aware that excessive consumption of plain water may cause diuresis and negatively affect the body's water balance; therefore, including electrolyte and sodium solutions should be considered (Evans et al., 2017, Maughan and Shirreffs, 2004). However, consuming water alone (in sufficient quantities greater than body mass loss), is still better than nothing at all (Shirreffs, 2009).

Combining rehydration with the addition of CHOs and sodium post-exercise further maintains the water balance due to the influence of the ingested fluids absorption and distribution and accelerates recovery (Coyle, 2004, Evans et al., 2017). Effective hydration post-exercise should include

approximately 50-60 mmol/l of sodium (Shirreffs, 2009, Shirreffs et al., 1996). Sodium assists sugar and water absorption in the small intestine and maintains plasma osmolality by increasing the drive to drink (Maughan and Shirreffs, 1997, Noakes et al., 1985). Most sports drinks consumed today, predominantly consisting of water, also have a range of between 25-30 mmol/l of sodium and 6% carbohydrates, which is adequate for immediate rehydration and recovery of the athlete post-exercise (Shirreffs, 2009). Players in a congested match/training schedule should prioritise rehydration with CHO to improve subsequent athletic performance (McCartney et al., 2018).

Various beverages have previously been considered for post-exercise recovery as an addition to adequate hydration because of their high quantities of nitrate and anti-oxidants, such as tart cherry juice (Bell et al., 2016, McCormick et al., 2016), tomato juice (Ramaswamy and Indirani, 2011) and beetroot juice (Clifford et al., 2016). However, the lack of abundant evidence for the benefits of these beverages, particularly in soccer, requires further research. In addition, it is unlikely athletes would consume these beverages in high enough volumes alone to reach efficient hydration statues, therefore they should be considered as accessory hydration beverages. Flavoured milk has been reported to be beneficial as a beverage post-soccer; it is easily accessible, inexpensive and contains adequate CHOs and proteins required for recovery (Amiri et al., 2018, Nedelec et al., 2013).

Table 2: Summary of rehydration studies using metabolic EIMD protocols

Author	Study design	Exercise/muscle damaging protocol	Subjects	Recovery methods	Recovery protocol	Outcome measures	Measurement times	Main finding
Hydration								
Shirreffs et al., 1996	Repeated measures design	Intermittent cycle exercise to induce 2% body mass sweat loss. Initial HWI for10 min to increase dehydration	12 male volunteers	Two groups consisting of i) Beverage with 23 mmol NA+ or ii) Beverage with 61 mmol NA+.	Over the 4 weeks each (NA+ beverage) group consumed a different volume of fluid according to sweat loss (50, 100, 150, 200%) post-exercise	Total volume of urine (osmolality and electrolyte concentrations (Na+, K+, Cl-). Body mass loss, volume of fluid ingested and urinary volume excreted.	Baseline and for 7.5 h post-exercise	To restore correct fluid balance, a greater volume of fluids must be ingested then was lost during exercise. The Na+ content of the beverage needs to be sufficient to replace electrolytes lost; if not sufficient an increase in urinary output will occur.
Clarke et al., 2005	Double-blind repeated-measures crossover design (randomised), with subjects acting as their own controls.	Soccer-specific protocol performed on three occasions (90 min of activity)	12 soccer players	CHO and Placebo beverage (No CHO)	CHO (7 mL/kg) and placebo consumed at 0, 45 min and CHO (7 mL/kg) consumed at 0, 15, 30, 45, 60, and 75 min	HR, VO2 max, Peak power output, rate of fatigue, blood samples (Bla, glycerol, non-esterified free fatty acids, plasma glucose, cortisol), body mass and sweat loss (volume of fluid ingested and fluid loss)	Baseline, Half-time and post-exercise	Blood measurements and CHO oxidation were not significantly different between the two CHO experiments ($P > 0.05$). If total volume of CHO consumed is equal, than changing the volume or timing of ingestion has no effect on exercise performance
Gilson et al., 2010	Randomised counter-balanced design	4 days of increased soccer training	13 Subjects	CM or CHO beverage	672 ml consumed immediately post-exercise of either CHO or CM	MS; RPE; CK levels, Myoglobin, MVC quadriceps, performance tests (Agility drill and Vertical jump height)	Baseline and at 2 and 4 days during the increased training. Performance tests were done after each training session	CM showed a significant decrease in CK levels compared to the CHO beverage. Otherwise recovery was similar in both beverages
Pritchett et al., 2009	Counterbalanced, crossover, repeated-measures study	High-intensity intermittent exercise protocol, then a performance trial at 85% VO2max to exhaustion (15-18 h later)	10 regional-level cyclists and triathletes	CM or CHO beverage	Immediately post-exercise (1st sessions), and again 2 h into the recovery period	CK levels, MS; time to exhaustion	Baseline and 15-18 h post-exercise	No significant difference between trials for time to exhaustion or CK levels

Table 2 (continued): Summary of rehydration studies using metabolic EIMD protocols

Author	Study design	Exercise/muscle damaging protocol	Subjects	Recovery methods	Recovery protocol	Outcome measures	Measurement times	Main finding
Thomas, 2009	Randomised counter-balanced order	3 experimental trials (glycogen-depleting trial, a 4-h recovery period and a cycle to exhaustion at 70% VO2max)	9 trained male cyclists	CM; CHO beverage; fluid replacement drink	Immediately post-exercise, and again 2 h into the recovery period	Endurance capacity, mood and appetite, body mass and Bla	Baseline and post-glycogen depleting trial and again post-endurance trial	Participants cycled 50% longer after ingesting CM than after ingesting CHO or fluid replacement drink
Spaccarotella & Andzel, 2011	Randomised crossover design	Soccer training session and shuttle-run to fatigue	13 athletes (8 males and 5 females)	CM or CHO beverage	Immediately after first training session	Time to exhaustion, Shuttle times, RPE	Baseline and post afternoon training shuttle runs	No significant differences in run time were noted. An increased time to fatigue with CM compared with the CHO was found in the male group only
Kalman et al., 2012	Randomised crossover design	60 min treadmill jogging	12 exercise-trained men	Water, CHO beverage, coconut water	Immediately after the training session	Hydration (body mass, plasma osmolality, thirst); performance tests (time to exhaustion); HR	Baseline, 1, 2, 3 h post-exercise and post-performance test	All beverages promoted hydration and subsequent exercise performance without any significant differences between groups.
Khanna & Manna, 2005	Control trial	Treadmill running till volitional exhaustion	10 endurance athletes	No supplementation or CHO beverage during and after exercise	During exercise and immediately after exercise every 5 min for 20 min	Performance times, HR, blood glucose and lactate, VO2 max	Baseline, before and after supplementation	CHO beverage during exercise improved performance times and CHO beverage post-exercise improved lactate removal, HR response and blood glucose levels
Van Hall et al., 2000	Randomised crossover design	Intense cycling exercise	5 healthy trained volunteers	CHO; CHO and PRO; water. All recovery drinks administered as a bolus	The first bolus was 600 ml, thereafter, 150 ml every 15 min for the next 4h	Muscle glycogen, blood glucose, plasma and insulin	Baseline, post-exercise and 5 h post-exercise	No differences could be observed between CHO/PRO and CHO ingestion. Water showed the least benefit to glycogen resynthesis

ABBREVIATIONS: h – hours; min – minutes; s - seconds; MS – muscle soreness, m – metre; ACT – Active recovery; Bla – Blood lactate concentration; d – day, HR – heart rate, Pass – passive recovery; VO2 max – Maximal oxygen uptake; g –gram; kg – kilogram; CHO – carbohydrate; ml – millilitre; PRO – protein; MVC – maximal voluntary contraction; Ca2+ - Calcium; mmol – millimoles; Na+ - sodium; K+ - potassium; Cl- - chloride; HWI – hot water immersion; RPE – rate of perceived exertion

c) Evidence for rehydration post-exercise

It has previously been established that inadequate hydration strategies leading to an insufficient fluid intake will attenuate performance (von Duvillard et al., 2008). A comparison between sports drinks (CHO beverage), water and coconut water post-exercise found little differences between hydration and subsequent exercise performance, showing that hydration in sufficient quantities will aid in recovery (Kalman et al., 2012). However significant improvements were noted with CHO beverage supplementation compared with no supplementation for time to fatigue and recovery measurements. The authors, did however agree with the previous sentiments for hydration and the importance of sodium ingestion post-exercise (Shirreffs, 2009) to maintain water balance. Water and CHO beverages therefore decrease dehydration and stabilize blood volume, which in turn improves performance and aids in recovery because it lowers heart rate and core temperature (Gisolfi et al., 2001).

Drinking a large volume of fluids post-exercise (which induced dehydration) is not adequate to achieve full hydration when the sodium content is low (Shirreffs et al., 1996). Further studies are recommended to investigate the sweat composition of players following high-intensity soccer exercise, to obtain an ideal fluid replacement composition for each individual. The different environmental conditions should also be considered when administering a rehydration strategy.

The addition of CHO to the rehydration recovery drink improves glycogen re-synthesis rates (Van Hall et al., 2000). This suggests that the rate of glycogen re-synthesis post-exercise could be controlled by the rate of muscle glucose uptake (Van Hall et al., 2000). The use of liquid CHO in recovery drinks has been proved more effective than a solid CHO diet post-exercise (Reed et al., 1989, Kuipers et al., 1987, Ivy, 1999).

d) Evidence for chocolate milk as a recovery drink post-exercise

Chocolate milk (CM) has been regularly considered as an effective recovery drink because it has adequate protein and CHO content to support recovery and is highly palatable. Several studies which have investigated the effect of CM and other CHO drinks on recovery and performance post-exercise will be reviewed (Gilson et al., 2010, Potter and Fuller, 2014, Pritchett and Pritchett, 2012, Spaccarotella and Andzel, 2011b, Thomas et al., 2009) (Table 2).

Both CM and a CHO drink provided similar benefits in terms of muscle recovery in soccer players; however, no significant performance benefits were noted (Gilson et al., 2010). The only difference between the two drinks was that CM caused a greater decrease in plasma CK levels after the four

days of intense training (Gilson et al., 2010). Pritchett and Pritchett (2012) also reported no difference between the two beverages (i.e. CM and CHO) in terms of muscle recovery or performance. As previously reported, CK levels were lower in the CM group compared to the CHO drink group, sparking an interesting debate on its effectiveness against muscle damage (Pritchett et al., 2009).

A study by Thomas et al. (2009) concluded that CM was a superior recovery aid following endurance exercises, compared to two other beverages, particularly when the player is required to complete further exercise at low intensities. Although no significant differences between CM and CHO beverages for run times were noted, there was a slight improvement in the CM group for time to exhaustion (Spaccarotella and Andzel, 2011a). It was hypothesised that the differing results may be as a result of the higher fat content in the CM, or the differences in composition when compared to a CHO drink (Spaccarotella and Andzel, 2011a, Thomas et al., 2009). Additionally, sucrose, which is found in CM and not in the other two drinks, has been reported to improve glycogen re-synthesis better than glucose, which is found in most CHO sports drinks (Casey et al., 2000). Recent studies have also supported the use of CM as a beneficial recovery aid for post-exercise mountain climbing (Potter and Fuller, 2014) and tennis (Wadey, 2017).

Pritchett et al. (2009) required their participants to rate the taste and provide feedback after consuming CM and a CHO replacement drink. Participants preferred the taste of CM and complained of stomach problems after consuming the CHO drink. Chocolate milk offers hydration with CHO, fat and protein replacements; however, it is still imperative to fully replace the glycogen stores with sufficient food. Adding CHO and protein to a diet in combination with re-hydration strategies can improve intestinal absorption of sodium and assist in water retention (Snell et al., 2010). Neglecting good nutrition and hydration may have a potential negative influence on a player's recovery as well as on other recovery strategies (i.e. sleep patterns). Sleep as a recovery method will be reviewed in the following section.

2.3.3 Sleep interventions

The importance of sleep in human health, performance and wellbeing (Altevogt and Colten, 2006) as well as in athlete performance and recovery (Samuels, 2008, Venter, 2012) has been established. The average person spends approximately 30% of their lifetime sleeping (Hirshkowitz et al., 2015). Not only is sleep a basic need but it has also been linked to improved physical and mental health, cognitive processes and metabolic function (Samuels, 2008, Stickgold, 2005). Sleep repays the neural and metabolic cost of waking (Frank and Benington, 2006). As athletes consistently push their bodies to increase learning and performance, a greater amount of sleep and recovery is required (Kellmann, 2010, Lastella et al., 2014). Sleep quality is as important as sleep duration (Fullagar et al., 2015b, Krystal and Edinger, 2008) and any disturbance to sleep quality, quantity or circadian rhythm may potentially affect recovery post-exercise (Samuels, 2008).

a) Physiology of sleep and sleep stages

The two main phases of sleep are known as Rapid Eye Movement (REM) and Non-Rapid Eye Movement (NREM). Non-Rapid Eye Movement consists of four stages characterized by slow breathing, a low heart and metabolic rate, and a large secretion of growth hormone which aids in physiological recovery, followed by a REM sleep phase (Akerstedt and Nilsson, 2003). Rapid Eye Movement sleep increases in duration as sleep progresses, with the longest duration observed during early morning (Altevogt and Colten, 2006). This may be of interest to players who train during the early morning, as this decreases the amount of time spent in the REM sleep phase. Rapid eye movement sleep has been linked to memory consolidation, particularly when acquiring new skills and complex techniques (Davenne, 2009). Sleep onset under normal conditions is through NREM sleep, altering between REM sleep (20-25%) and slow-wave sleep (75-80%) for four to six 90-minutes cycles (Carskadon and Dement, 2011, Davenne, 2009).

b) Circadian rhythm of sleep

The internal clocks that control biological rhythm periods over approximately a day (24- hour intervals) are called circadian rhythms (Venter, 2012). Genetic make-up and the environment of an individual will construct the primary foundations which emphasize the circadian phases (Viola et al., 2007). The circadian timing of sleep is linked to sleep length and sleep quality, which will be affected if circadian rhythm and sleep schedules are not aligned (Samuels, 2008). Each player will adapt their individual sleep schedules to align with their circadian phases where possible, however the timing of matches and travel schedules may result in disturbances to a player's typical sleep-wake cycle (Reilly and Ekblom, 2005). It is possible, as mentioned previously, that players who experience sleep loss

during the early morning may fail to benefit from critical REM sleep. Any disturbance of one's circadian rhythm can cause changes to the sleep cycle, thereby affecting recovery (Venter, 2012).

Studies exploring the effect of sleep deprivation on recovery indices will be briefly reviewed in the following section, followed by sleep interventions focused on improving sleep indices for recovery post-exercise.

c) Sleep issues/deprivation amongst athletes

In reality, most athletes are not meeting the criteria for a healthy night's rest and are not receiving sufficient sleep quantity and quality (Erlacher et al., 2011, Fullagar et al., 2016a, Lastella et al., 2014, Venter, 2014). Objective sleep monitoring with Polysomnography (PSG) and actigraphy have observed poor sleep quality and quantity in athletes, specifically during and before competition (Lastella et al., 2015a). Although objective data are limited, there have been various subjective reports, through sleep diaries and anecdotal self-reports, of poor athlete sleep quality and sleep patterns (Erlacher et al., 2011, Venter, 2012). Leeder et al. (2012b) reported that although sleep duration was similar between athletes and non-athletes, the sleep quality in athletes was far worse. A study on professional European soccer players found that 95% of players reported sleep problems after night matches (Nedelec et al., 2015a). This concurred with (Juliff et al., 2015a) who reported that more than 50% of elite athletes experienced sleep disturbances following training and late matches.

i) Scientific studies on sleep deprivation post-exercise.

Sleep deprivation has been shown to have detrimental effects in a dose-dependent relationship on cognition (Dunican et al., 2017), mood, daytime sleepiness, memory and certain performance and recovery outcomes (Dinges et al., 1997, Van Dongen et al., 2003). Sleep deprivation risked sleep-dependent memory consolidation and neural plasticity (Walker et al., 2005). Venter (2012) reported that REM sleep increased with sleep duration, therefore an early wake up could possibly disrupt important REM sleep.

Rugby league players' ability to recover post-exercise was hindered after sleep quality and quantity was reduced (Skein et al., 2013). Previous studies, which have observed sleep deprivation in athletes regarding recovery and/or performance outcomes, have reported that the greater the amount of sleep debt or sleep restriction, the greater the negative effect on performance and recovery indices (Blumert et al., 2007, McMurray and Brown, 1984, Jarraya et al., 2013, Sinnerton and Reilly, 1992, Skein et al., 2013, Reilly and Piercy, 1994b; Table3). The above-mentioned studies measured sleep

deprivation for an exaggerated time, which is not realistic to an athletic population; therefore, the results are not generalisable. However, even mild sleep deprivation of approximately four hours resulted in a reduction in the technical ability of tennis serving and dart throwing accuracy (Edwards and Waterhouse, 2009, Reyner and Horne, 2013). These studies all reported on acute sleep deprivation, whereas chronic sleep deprivation is more likely a prevalent issue in athletes, especially over the duration of a full season. Sleep screening tools used to account for any sleep debt and sleeping problems are suggested to be included in pre-screening medical tests, as well as at the beginning of each season (Gupta et al., 2017, Tuomilehto et al., 2017). Further insight into sleep deprivation studies is beyond the scope of the present literature review, which will primarily focus on sleep as a recovery method.

Table 3: Summary of sleep deprivation studies using metabolic and mechanical EIMD protocols

Sleep deprivation on recovery and performance outcomes								
Author	**Study design**	**Exercise/muscle damaging protocol**	**Subjects**	**Recovery methods**	**Recovery protocol**	**Outcome measures**	**Measurement times**	**Main finding**
Reilly & Piercy, 1994	Counter-balanced, crossover design	The weight-lifting tasks consisted of bicep curls, bench press, leg press, and dead lifts. For each exercise a submaximal and maximal load was determined	8 male subjects	Sleep deprivation	Sleep allowed for only 3h a night for 3 successive nights	Sub maximal and Maximal lifts for each exercise, mood states and subjective sleepiness scores	Baseline, at each test occasion in the evening and post intervention each morning	Mood states of confusion, vigour, and fatigue were affected significantly by sleep deprivation ($p < 0.001$), but no significant effect of sleep loss or anger, tension, and depression was noted. Submaximal lifting tasks were more affected by sleep loss than maximal exertion
Jarraya et al., 2013	Randomised crossover design	Handball training	12 handball players	SDB, SDE, No sleep deprivation (control)	(i) Control (subjects slept from 22:00 until 7:00 of the following day), (ii) SDB during which subjects slept from 03:00 to 07:00 h, (iii) SDE during which subjects slept from 22:00 to 03:00 h	Cognitive tasks (RT test, the Stroop test - SA, and the barrage test - CA)	Baseline and the following day post-sleep intervention	Partial sleep deprivation caused a significant increase in RT (especially SDE) and decreased level of attention (especially SDB)
Sinnerton & Reilly, 1992	Repeated measures design	Swimming protocol in a 50m pool on 4 consecutive days, morning (06:30 h) and evening (17:30 h)	8 swimmers	Sleep deprivation and normal sleep (control)	Restricted nightly sleep (2.5h sleep a night)	Grip and back strength, lung function, resting HR and mood states. Swimming performances over four trials at 50m	Baseline, post sleep intervention and post swimming exercise over the 4d	No decrements were observed with sleep deprivation in back or grip strength, lung function, or swim times. Sleep deprivation negatively affected mood states
Reilly & Walsh, 1981	Repeated measures design	91h and 45 min of 5-a-side soccer World Record attempt	10 male students	Sleep deprivation	No sleep for the duration of the game (92 h)	Subjective fatigue, grip strength, psychological state, HR, exercise, urine analysis	Baseline and every 4h throughout the game	As play was prolonged, group anxiety increased. The last two days of sleep deprivation showed increased behavioral abnormalities

Table 3 (continued): Summary of sleep intervention studies using metabolic and mechanical EIMD protocols

Sleep extension on recovery and performance outcomes								
Author	**Study design**	**Exercise/muscle damaging protocol**	**Subjects**	**Recovery methods**	**Recovery protocol**	**Outcome measures**	**Measurement times**	**Main finding**
Schwartz & Simon, 2015	Prospective cohort	Tennis serves	Twelve (seven females and five males) university tennis players	Sleep extension	Sleep at least 9h including naps for one-week vs baseline (normal sleep routine, approximately 7h)	Tennis serving accuracy and ESS and the Stanford Sleepiness Scale (daytime sleepiness) SHS	Baseline and throughout the study	An increase in sleep (by approximately 2 h per night) significantly increased tennis performance and decreased daytime sleepiness
Mah et al, 2011	Prospective cohort	Basketball training and matches in season	11 university basketball players	Sleep extension	Sleep extension for at least 10 h a night for 5-7 weeks	Actigraphy, ESS, POMS questionnaire, timed sprint and shooting accuracy (free-throws and 3-point), reaction time via PVT	Baseline and post-intervention	Improvements in mood and sport specific exercises post-intervention
Waterhouse et al., 2007	Crossover experiment	Sleep deprivation by 4 h	10 healthy males	Nap (20-30 min)	Nap for 20 min or sat quietly (control)	Alertness, short-term memory, body temperature, HR, reaction time, grip strength, 2-m and 20-m sprint times	Baseline and 30 min post intervention	Improvements were noted for mental and physical tests post intervention (napping)
Kamdar et al., 2004	Prospective cohort	Baseline sleep advised between 6-9h	15 male students	Sleep extension	Sleep as much as possible (maximum sleep extension) for 5-7 weeks	Psychomotor vigilance task, reaction times, and POMS, actigraphy, sleep journals	Baseline, mid-intervention and post-intervention	Sleep extension leads to improvements in daytime alertness, reaction time, and mood

Table 3 (continued): Summary of sleep intervention studies using metabolic and mechanical EIMD protocols								
Nutrition and sleep								
Author	**Study design**	**Exercise/muscle damaging protocol**	**Subjects**	**Recovery methods**	**Recovery protocol**	**Outcome measures**	**Measurement times**	**Main finding**
Afaghi et al., 2007	Randomised crossover design	High-GI meal 4 h before bedtime; a high-GI meal 1 h before bedtime, and a low-GI meal 4 h before bedtime	12 healthy men	N/A	Sleep was ad libitum, with usual bedtime falling between 2145 to 0030	Blood glucose, urine analysis, subjective sleepiness measures using VAS	Blood glucose at baseline & at 15, 30, 45, 60, 90, & 120 min after the high- & low-GI meals Urine for analysis was collected in 2parts VAS assessed at 30 min & at 1, 2, 3, & 4 h after each meal	A significant reduction in sleep onset latency was observed with a high-GI meal 4 h before bedtime compared with a low-GI or hi-GI meal 1 h before bedtime
Howatson et al., 2012	Randomised crossover design	Tart-cherry concentrate or placebo twice a day for 7 days	10 healthy males and 10 healthy females	N/A	Sleep was instructed as per normal sleep behaviour	Urine analysis (for melatonin), diet recall, subjective sleep quality, actigraphy	Urine analysis in first 48h & last 48h. Sleep quality, diet recall & actigraphy daily	The ingestion of tart-cherry concentrate increased melatonin levels and improved sleep quality and duration
Sleep interventions to aid recovery and performance indices								
Fullagar et al., 2016	Randomised cross-over design	90 minute soccer match	20 amateur soccer players	SHS protocol over one night vs control group	The control group waited until 02:00am to sleep, whilst the SHS group went to sleep at 00:00	Actigraphy, sleep diary, sleep questionnaire, CMJ, Blood markers, Recovery questionnaires, Training load data, HR, RPE	Baseline, 12 and 36h post-exercise	Sleep quantity improved post SHS protocol, however no improved recovery or performance markers were noted compared to control group
Van Ryswyk et al., 2015	Prospective Cohort	Regular pre-season training (approximately 7.5 h per week)	25 male AFL senior level players	SHS over six weeks	2 x 1 h sleep education sessions (SHS recommendations)	Daily sleep diaries Actigraphy data ESS, PSQI, MEQ, POMS questionnaires PVT reaction time	Baseline and post intervention (6 weeks later) Sleep diaries - daily	Improvements in subjective sleep duration, fatigue, vigour and sleep efficiency
Zhao et al., 2011	Randomised parallel cohort study	12 basketball training sessions	18 female basketball players	Red-light therapy prior to sleep	30 minutes of irradiation from a red-light therapy instrument every night for 14 days vs control	PSQI – Chinese version. Serum Melatonin (pg/ml) Cooper 12-Minute Run test	Baseline and post intervention (2 weeks later)	Red-light therapy improved sleep quality

Abbreviations: h – hours; min – minutes; s - seconds; m – metre; d – day, HR – heart rate, Pass – passive recovery; GI – glycaemic index; RT – reaction time; VAS – visual analogue scale; ESS – Epsworth Sleepiness Scale, RPE – rate of perceived exertion; SHS – sleep hygiene strategies; PSQI – Pittsburgh Sleep Quality Index; MEQ - Morningness Eveningness Questionnaire; POMS – Profile of Mood States

d) Scientific studies on sleep interventions post-exercise

A variety of sleep interventions are explored in the current literature focusing on post-exercise recovery (Simpson et al., 2017). Sleep interventions can be separated into increasing sleep duration (Mah et al., 2011, Schwartz and Simon, 2015), improving sleep behaviours (Simpson et al., 2017) or interventions aimed to improve sleep quality and/or quantity (i.e. red-light therapy, CWI, nutrition, etc.) (Nedelec et al., 2013). Popular sleep behaviour recommendations include, routine sleep/wake schedules, no stimulants before bed, a quiet, comfortable sleeping environment (Maness and Khan, 2015) and education (Van Ryswyk et al., 2017). Several studies have reported recovery and performance improvements with sleep extension (Mah et al., 2011, Kamdar et al., 2004, Schwartz and Simon, 2015; Table 3) as an intervention. The beneficial outcomes are somewhat congruent with naps, another form of sleep extension, particularly in participants who experienced sleep loss due to demanding schedules and travelling (Fietze et al., 2009, Waterhouse et al., 2007, Davenne, 2009).

The abovementioned studies however, used small sample sizes and outcome measurements were inconsistent due to the participants' travelling schedules and/or poor reporting of the experimental procedure. Many studies used subjective measures of sleep duration/quality, but these show poor agreement with objective measures (Erlacher et al., 2011, Leger et al., 2005). A lack of utilization of the 'gold standard' measurement of sleep – polysomnography, will make it difficult to have accurate outcomes for sleep duration or quality (Halson, 2014, Samuels, 2008). Some of the participants were also sleep deprived, which could have biased the positive effect of the sleep intervention and other participants were untrained non-athletes which may have compromised generalising results to an athletic population.

Sleep hygiene strategies (SHS) have previously been implemented to treat insomnia (Stepanski and Wyatt, 2003). Recently, these have been aimed at improving sleep quality and quantity to assist athlete recovery post-exercise (Nedelec et al., 2015b, Simpson et al., 2017). Although the SHS protocol improved sleep duration among soccer players, no performance or recovery markers were improved (Fullagar et al., 2016a). A longer duration SHS study also showed no performance benefits, however found improvements in sleep and perceived recovery measurements (Van Ryswyk et al., 2017). Different measurement outcomes, familiarization protocols, intervention durations and a lack of control groups were found in these studies making it difficult to get a conclusive take-away message.

Exposure to bright light and blue light waves inhibits the secretion of melatonin, thereby decreasing sleep quality (Cajochen, 2007, Nedelec et al., 2015b, Stiller and Postolache, 2005, Waterhouse et al.,

2007). Due to athletes increased exposure to these lights it has been suggested that players should wear blue-light blocking glasses at night (van der Lely et al., 2015). Most research has not reported a correlation between red-light and melatonin secretion increase, but rather that blue-light exposure can result in melatonin suppression (Figueiro and Rea, 2010, Gringras et al., 2015). Red-light therapy prior to sleep can potentially provide a non-pharmacological and non-invasive intervention to aid sleep (Zhao et al., 2012a). To give additional options for athletes to combat sleep problems and increase sleep quality it is prudent to do further quality research on the effects of these interventions.

Although studies investigating the effects of various nutritional additions (i.e. CHO on sleep quality and quantity) are lacking and equivocal (Halson, 2014), Afaghi et al. (2007) observed that consuming a high-GI meal before bedtime reduced sleep onset latency compared with a low-GI meal. Tart-cherry juice, which has anti-inflammatory properties, also showed improved sleep duration and quality compared with a placebo (Howatson et al., 2012). While a light bed-time snack (i.e. CHO or protein based) or beverage (i.e. milk) can assist as a potential anabolic stimulus and positively influence sleep (Nedelec et al., 2015b), over hydration post-exercise can negatively affect sleep by causing players to wake up for urination (Halson, 2008).

Whilst interventions seemed to improve perceived sleep outcomes, it was not clearly linked to performance recovery. Further, these studies could not rule out that any increased recovery or performance results were the direct result of the sleep interventions and not confounding variables. The methodological quality of the above interventions seemed low; because of the small sample sizes, studies should be pooled into a meta-analysis so more conclusive outcomes can be made. An appraisal of the quality of the studies should be done with a standardized quality scoring system for allow for evidence-based outcomes. The synthesis of information will enable practical recommendations for staff in soccer club with sleep intervention guidelines and to see how the results relate specifically to soccer players.

Compression garments are often used post-exercise, while players are sleeping, to aid in recovery; however, it has been reported that CG can be uncomfortable during the night and may cause disturbed sleeping patterns due to the increased body temperature (Davies et al., 2009). Compression garments will be reviewed in the following section to assess its effects on post-exercise recovery parameters.

e) Summary of literature: Sleep interventions

The available research investigating the relationship between sleep, post-exercise recovery and performance in players reported that sleep should be taken into consideration when planning a player's recovery. Sleep deprivation has a clear negative effect on recovery and performance and should be avoided (Fullagar et al., 2015b). Whilst interventions aimed at improving sleep quantity/quality seem promising because of the variety of interventions possible, a thorough review which considers the quality of the research for each intervention is required.

2.3.4 Compression garments

a) Compression garments as a recovery strategy

Compression garments have been implemented as a means of prophylactic treatment for deep vein thrombosis after patients have been discharged from hospital, fly long-distances or have been immobilised for a lengthy period of time (Ali et al., 2007). The use of CG during sporting events are most often implemented as a recovery tool post-muscle damaging exercise (Hill et al., 2013). Compression garments can be worn as a full suit or isolated to either upper body or lower body compression. Compression garments are easy to use, safe and readily accessible, which makes it a useful recovery method when teams are travelling post-match (Davies et al., 2009). The following section will focus on studies investigating the effects of CG as a post-exercise recovery tool.

b) Mechanism and physiological effects of compression garments

Compression garments function by applying increased pressure on the extremities (i.e. ankle), and less pressure on the proximal limbs (i.e. thigh), to improve venous return and increase the femoral blood flow (Ibegbuna et al., 2003, Perrey, 2008). Compression garment pressures of approximately 17 to 20 mmHg at the calf, and 15 mmHg at the thigh have been suggested (Lim and Davies, 2014, Scanlan et al., 2008). A recent study comparing high and low CG pressures observed higher pressures of approximately 24 mmHg at the calf and 15 mmHg at the thigh were more beneficial in improving muscle function post-exercise (Hill et al., 2017).

Compression garments may attenuate muscle oscillation (Bringard et al., 2006), improve joint range of motion, alter local blood flow, diminish swelling and reduce perceived muscle soreness during post-exercise recovery (Davies et al., 2009, Hill et al., 2013, MacRae et al., 2011b). However, the review by MacRae et al. (2011) identified that wearing CG post-exercise had limited physiological or performance effects. The studies reviewed had inconsistent results and a range of different methodologies, making consensus on CG difficult; therefore, these results need to be viewed with caution when considering a soccer population (MacRae et al., 2011b). Another recent review did not

find significant effects on EIMD (Dupuy et al., 2018), however this review used a strict inclusion criterion, therefore limiting the number and quality of studies.

c) Post-exercise studies with compression garments as a recovery strategy

Few studies exist to replicate an exercise protocol similar to a soccer match, thereby eliciting poor transferability of the data to professional soccer players. The majority of studies implemented a mechanical EIMD protocol for the participants (Davies et al., 2009, French et al., 2008, Hill et al., 2017, Jakeman et al., 2010), (Kraemer et al., 2001a, Kraemer et al., 2010) while a few other studies used a metabolic EIMD protocol (Duffield et al., 2008, Gill et al., 2006, Marqués-Jiménez et al., 2017, Montgomery et al., 2008, Trenell et al., 2006; Table 4).

Table 4: Summary of compression garment studies using mechanical and metabolic EIMD protocols

Compression garments studies using a mechanical EIMD protocol								
Author	**Study design**	**Exercise/muscle damaging protocol**	**Subjects**	**Recovery methods**	**Recovery protocol**	**Outcome measures**	**Measurement times**	**Main finding**
Davies et al., 2009	Randomised crossover experimental design	5 x 20 maximal drop-jumps	11 subjects (7 trained females and 4 trained male)	CG; Pass (control)	48h of CG wear (lower limb)	Blood collection (plasma CK and LDH), mid- thigh circumference, MS and performance (sprints 5 m, 10 m, and 20 m), agility and CMJ test	Baseline and after 24 and 48h of recovery	Increase in DOMS and plasma CK levels was noted in the control group at 24 and 48h. No other significant differences were noted on any performance measurements
Kraemer et al, 2001a	A between groups design	Arm curl on Biodex isokinetic dynamometer (2x50). Including concentric, eccentric and isometric movements	15 non strength-trained men	CG (sleeve only); Pass (control)	CG sleeve wear for 3d post-exercise	Relaxed elbow angle, plasma CK levels, LDH & DOMS	Baseline and daily for 3d	Increase in plasma CK levels for both CG and control. CG showed reduced loss of elbow ROM, decreased DOMS and swelling and an increase recovery of force production
Kraemer et al., 2001b	A between groups design	Arm curl on Biodex isokinetic dynamometer (2x50). Including concentric, eccentric and isometric movements	20 non-impaired strength trained women	CG (sleeve only); Pass (control)	CG sleeve wear for 5d post-exercise	Relaxed elbow angle, plasma CK levels, LDH & DOMS	Baseline and daily for 5d	Increase in plasma CK levels for both CG and control. CG showed reduced loss of elbow ROM, decreased DOMS and swelling and an increased recovery of force production
Kraemer et al., 2010	A within-group balanced, and randomised control design	Heavy resistance exercise protocol using barbells (3 sets of 8–10 RM, 2 to 2.5-min rest) for 8 weeks	11 men and 9 women, who were all accustomed to resistance training	CG; Pass (control)	Full body CG for 24h	Sleep quality, vitality rating, resting fatigue rating, DOMS, muscle swelling, reaction movement times, bench throw power, CMJ power, and plasma CK levels	Baseline and 2 h post-exercise	Full-body CG worn during the 24h recovery period enhanced various psychological, physiological and performance markers of recovery

Table 4 (continued): Summary of compression garment studies using mechanical EIMD protocols								
Author	**Study design**	**Exercise/muscle damaging protocol**	**Subjects**	**Recovery methods**	**Recovery protocol**	**Outcome measures**	**Measurement times**	**Main finding**
Jakeman et al., 2010	Randomised control trial	10 x 10 plyometric drop jumps from a 0.6-m box	17 physically active female volunteers	CG; Pass (control)	Full leg CG for 12h post-exercise	DOMS, plasma CK levels, knee extensor concentric strength, and vertical jump performance	Baseline and 1, 24, 48, 72, and 96h post-exercise	CG wear improved CMJ, squat jump, knee extensor strength and MS but had no effect on plasma CK levels compared to control
French et al., 2008	A match-paired, between-group design with repeated measures (random assignment)	Resistance exercise: 6x10 parallel squats at 100% BW with 5s one RM eccentric squat	26 young men	CG; CWT; Passive recovery (control)	CG wear for 12h post-exercise	Baseline values of DOMS, plasma CK and Mb, joint ROM, limb circumference, 10-30m sprint, CMJ, and 5RM	Post-exercise and at 48h post intervention	Significant differences from baseline in all groups for CMJ and DOMS, however no differences noted between the recovery methods to form a hierarchy
Hill et al., 2017	Randomised control trial	100 drop jumps	45 active volunteers	CG (high pressure); CG (lower pressure); control	CG wear 72h	DOMS, MVC, CMJ, plasma CK, C-reactive protein and myoglobin	Pre-exercise and 1, 24, 48 and 72 h post exercise	CG (higher pressure) improved muscle function post-exercise compared with CG (lower pressure), however no differences was noted with plasma CK clearance
Summary of compression garment studies using metabolic EIMD protocols								
Duffield et al. 2008	Randomised counter-balanced design	10-min exercise protocol of a 20-m sprint and 10 plyometric bounds every minute.	11 participants	CG and no CG	Lower body CG during exercise and for 24h post-exercise	Peak concentric knee extension and flexion force. Bla, pH, plasma CK levels, and CRP. HR, RPE, DOMS. Sprint time and bounding performance	Baseline, post-exercise, 2 and 24h post-exercise	No significant differences were recorded for all outcome measurements between the two groups, except slightly lower DOMS reported with the CG group after 24h
Duffield & Portus, 2007	Randomised crossover experimental design	30 min repeat-sprint exercise protocol comprising 20m sprints every minute, separated by submaximal exercise	10 male cricket players	3 x CG brands (Skins, Adidas and Under Armour) and a control	Full-body CG for 24h	HR, skin temperature, changes in body mass, RPE and DOMS. Capillary blood samples (Bla, pH, O2 saturation and O2 partial pressure), plasma CK levels. Throwing tests (maximal distance and accuracy)	Baseline and 24h post-exercise	Significant differences were seen with increased skin temperature, lower plasma CK levels and improved DOMS post-exercise when wearing CG in general. No significant differences were noted with repeat-sprint or throwing performance, HR, body mass change or blood measures during exercise

Table 4 (continued): Summary of compression garment studies using metabolic EIMD protocols								
Author	**Study design**	**Exercise/muscle damaging protocol**	**Subjects**	**Recovery methods**	**Recovery protocol**	**Outcome measures**	**Measurement times**	**Main finding**
Gill et al., 2006	Randomised control trial	Four competitive rugby games over a tournament	23 elite male rugby players	CWT; CG; Pass; ACT	Lower limb CG wear for 12h	plasma CK levels	Immediately post match, 36 & 84h post match	No significant differences in plasma CK recovery were observed between the ACT, CWT, or CG interventions at any time point
Montgomery et al., 2008	Randomised control trial	Participants competed in a 3d tournament style basketball competition	29 male basketball players	CHO + Stretching; CWI; CG	CG wear for 18 h	20m acceleration, basketball line-drill and agility test, Yoyo Level 1 intermittent recovery test, vertical jump, flexibility test	Baseline and post-tournament	CG did not show any improved recovery outcomes compared to the interventions. CWI actually showed better recovery outcomes than CG
Marques-Jimenez et al., 2017	Two-stage cross-over design	Participants competed in two matches separated by 3d	18 soccer players	CG shorts; full-leg CG, full-leg stockings and control	CG were used during match and for 3d post-match (worn for 7h)	Bla, arterial oxygen saturation of haemoglobin, RPE, anaerobic power (vertical jump, sprint, change of direction) and aerobic capacity (Yo-Yo Intermittent Recovery level 2)	Baseline, post-match, 24, 48, 72h	Psychological recovery improved after 24-48h after wearing full-leg CG. No significant differences were noted in performance measurements

Abbreviations: h – hours; min – minutes; s - seconds; m – metre; d – day, HR – heart rate, Pass – passive recovery; CHO – carbohydrate; CWI – Cold Water Immersion; CG – compression garments; CWT – Contrast Water Therapy; ACT – active recovery; CK – creatine kinase; O2 – oxygen; DOMS – delayed onset muscle soreness; Bla – blood lactate; RPE – rate of perceived exertion; LDH - lactate dehydrogenase; CMJ – counter movement jump; RM – repetition maximum; Mb – myoglobin; ROM – range of motion; RM – repetition maximum

i) Evidence for compression garments and its use in metabolic EIMD protocols

No significant improvements in performance recovery were noted in any of the metabolic EIMD protocols (Duffield et al., 2008, Duffield and Portus, 2007, Gill et al., 2006, Montgomery et al., 2008, Marqués-Jiménez et al., 2017), however improvements in DOMS and decreased plasma CK levels were observed showing some signs of recovery. It was hypothesised that CG were beneficial to reduce post-exercise muscle damage (i.e. as seen in the lower plasma CK levels post-CG use (Duffield and Portus, 2007), however further studies are required to understand whether plasma CK levels are in fact an accurate measure of muscle trauma and can be consistently used with player profile variability (Doeven et al., 2018, Roe et al., 2016).

Although CG showed benefits in perceived recovery and DOMS rating, the placebo effect cannot be ruled out. This was especially relevant as one study used CG wear during and after exercise as opposed to only post-exercise (Marqués-Jiménez et al., 2017). The insignificant effects on performance recovery among players in these exercise settings possibly suggests that the sport specific protocols were not sufficiently damaging to necessitate CG use. Several studies have investigated mechanical EIMD protocols to assess whether CG might have more of an effect on performance and/or recovery.

ii) Evidence for compression garment protocols in mechanical EIMD protocols

Congruency between results in the metabolic and mechanical EIMD protocols were observed in that the most noticeable benefit of CG were the improved DOMS scores. This link could possibly be attributed to some of the studies mixed metabolic and mechanical EIMD protocols (Duffield et al., 2008, Duffield et al., 2010). However an improved performance recovery was also observed in most studies using mechanical EIMD protocols (i.e. drop jumps or heavy resistance exercises with eccentric component) (Hill et al., 2017, Jakeman et al., 2010, Kraemer et al., 2001a, Kraemer et al., 2001b, Kraemer et al., 2010), although no significant differences were noted in plasma CK levels further suggesting that looking at biochemical markers alone as a recovery outcome is not enough.

The majority of the above studies used untrained athletes, diverse exercise protocols and different compression strategies (single limb, both limbs, etc.), therefore not allowing reliable transferability of data for comparison to team sports. It has previously been noted that the majority of published literature concerning CG have not used an intense enough EIMD protocol to measure a reliable response (Bieuzen et al., 2014b, Pruscino et al., 2013). Full-body compression worn during the 24 hour recovery period post heavy-exercise seemed to enhance various psychological, physiological and performance markers in untrained participants who were not accustomed to the mechanical

EIMD protocol (Hill et al., 2017, Kraemer et al., 2010). The majority of the reviewed studies suggest that CG may aid in assisting damaged muscle during the recovery phase and improve perceived recovery, however offer no substantial physiological or performance recovery benefits in an athletic population (Davies et al., 2009, Marqués-Jiménez et al., 2017). These results should be viewed with caution in the context of a professional soccer player who is training on a consistent basis and is looking to prioritise performance recovery.

d) Summary of literature: Compression garments

There is currently a lack of evidence reporting a significant benefit in CG usage in improving performance recovery from sport specific activities (Nedelec et al., 2013). However, perceived recovery and DOMS ratings improved sporadically throughout the literature (Valle et al., 2013, Dupuy et al., 2018) and because DOMS is often experienced post-exercise in soccer there could be some value in using CG after heavy or unaccustomed periods of training when DOMS is severe. Apart from the initial expense incurred by the player or club, CG is a safe and easy method of recovery, which is continuously applied post-exercise and requires little vigilance or effort (Hill, 2016). Albeit, appropriate protocols ought to be developed and future research is once again recommended to investigate CG type, pressure, timing, duration as well as the training status of the player within their recovery time frames to convince soccer coaches and trainers to utilise this recovery method.

2.3.5 Cold-water Immersion

a) Cold-water immersion use post-exercise

Cold-water immersion is a popular recovery method (Leeder et al., 2012a, Swenson et al., 1996) to speed up the recovery process post high-intensity exercise, associated with metabolic and mechanical EIMD, which decrease performance (White and Wells, 2013). Jacuzzi's, baths, portable drums or containers are filled with a combination of ice and water and the player is immersed into the cold water immediately post-exercise in attempt to improve the recovery process (Wilcock et al., 2006). Whilst protocols for CWI are heterogeneous throughout the literature regarding temperature, duration and level (i.e. depth) of immersion (Nedelec et al., 2013); most research supports CWI benefitting perceived recovery and DOMS post-exercise (Bleakley et al., 2012, Hohenauer et al., 2015).

b) Physiological effects of cold-water immersion post-exercise

Cold-water immersion is proposed to improve recovery by minimizing swelling and inflammation post-exercise, resulting in decreased perception of muscle soreness (Cheung et al., 2003). The mechanism facilitating these effects is yet to be clearly demonstrated, however theories considering

vasoconstriction, analgesic effects of cold water, hydrostatic pressure and the effect on inflammatory pathways have been proposed to aid in the post-exercise recovery (Tavares et al., 2018).

As the body is exposed to cold, the muscle and core temperature decreases (White and Wells, 2013), which leads to vasoconstriction and therefore a decrease in swelling and inflammatory factors from muscle damage experienced post-exercise (Coté et al., 1988, Eston and Peters, 1999, Wilcock et al., 2006). Cooling of the tissue leads to a reduction in the nerve pulse transmission, causing a decrease in blood flow, nerve excitability and muscle spasm which reduces perceptual pain levels, swelling and inflammation (Lee et al., 2005, Sauls, 1999, Wilcock et al., 2006). Finally, the effects of hydrostatic pressure from water immersion have been thought to increase blood flow by causing a pressure on the periphery and moving fluids centrally increasing cardiac output (Wilcock et al., 2006). This increased blood flow was thought to increase the removal of metabolic waste built up from damaged muscle (Bleakley and Davison, 2010), however conflicting results regarding metabolic clearance exists (Ihsan et al., 2016).

While the player may experience pain-relief symptoms; attempting to resume play immediately after CWI may result in a decrease in performance due to reduced muscle function, spasticity and poor stretch reflex response (Eston and Peters, 1999, Garcia et al., 2016). Although long term strength training adaptations can be potentially negatively affected when using CWI on a regular basis, the effects are minimal (Frohlich et al., 2014, Yamane et al., 2006) and sometimes cannot be seen (Howatson et al., 2009), therefore recovery methods such as CWI should be used at appropriate times in the season and not consistently throughout. The positive effects of CWI on DOMS and perceived recovery will most likely outweigh these potential negative effects and by adapting CWI protocols to each situation (training/match/rest), player characteristics and goals there will be better outcomes and rationale for its use (Tavares et al., 2018). Considerable controversy has surrounded the correct protocols for CWI and as a result, several studies have implemented different methodologies and protocols.

c) Protocols for cold-water immersion use post-exercise

No evidence-based protocol exists for CWI concerning immersion time, depth of immersion, water temperature and when best to use CWI (Poppendieck et al., 2013, Stephens et al., 2017). The review will briefly investigate the variety of CWI protocols used amongst recovery method studies.

i) Temperatures used for cold-water immersion protocols

Nedelec et al. (2013) reported that temperatures between 9 °C and 10 °C showed the most beneficial effects for CWI, however temperatures between 10 °C and 15 °C have shown the most consistent benefits for muscle soreness post-exercise and subsequent potential player performance (Halson, 2011, Higgins et al., 2017, Machado et al., 2016, Poppendieck et al., 2013, Stephens et al., 2017). The sensation of 'cold pain' begins at temperatures below 15 °C, therefore any warmer temperatures should not be classified as CWI (Machado et al., 2016). Several studies have found that temperatures as low as 5 °C (Glasgow et al., 2014; Sellwood et al., 2007) (Glasgow et al., 2014). Glasgow et al. (2014) was also effective in reducing the effect of DOMS, as a colder protocol would reduce skin temperature more rapidly, resulting in hypo analgesia. However, due to player discomfort and no substantial evidence in using these cold temperatures, it would be better to use CWI between 10 °C and 15 °C. It has even been suggested that temperatures this low can reduce the beneficial effect of hydrostatic pressure in CWI (Tavares et al., 2018). On the other end of the spectrum, if water temperatures are above the recommended range (i.e. 10°C - 15 °C; (Halson, 2011, Robey et al., 2013), the player should be immersed for longer durations to establish any beneficial effect.

ii) Immersion times used for cold-water immersion protocols

Various studies have implemented immersion times between 5 and 30 minutes (Bailey et al., 2007, Ingram et al., 2009), (Vaile et al., 2008), while Nedelec et al. (2013) reported improvements on anaerobic recovery performances (i.e. sprint, countermovement jump and maximal strength) with 10 to 20 minutes of CWI. The review by Halson (2011) highlighted several studies that reported benefits when implementing CWI durations of approximately 15 minutes. Bleakley and Davison (2010) considered the biomechanical and physiological effects of shorter durations of CWI (5 minutes or less), and concluded that although CWI yielded minor changes on physiologic and metabolic body functions, there remained an unclear rationale for implementing CWI for this short time duration as effective skin temperature changes was unlikely to occur (Bleakley and Davison, 2010, Rech, 2013). Superficial tissues took at least 8 minutes to cool to minimum temperatures (Janwantanakul, 2009) and deeper tissues will inevitable take longer (Mawhinney et al., 2017), therefore it is suggested that at least 10 minutes is needed. The duration of CWI must also be considered against the player's body size, as muscle and fat have an insulator effect, therefore a player larger in stature may need to remain immersed for a longer duration (Halson, 2011, Stephens et al., 2017). Ten to 15 minutes seems to be an optimum duration as an effective recovery method (Halson, 2011, Machado et al., 2016).

iii) Immersion depths used for cold-water immersion protocols

Whole body immersion (i.e. excluding the head) has been reported to be the most beneficial immersion level for CWI (Halson, 2011, Poppendieck et al., 2013), while cooling only a portion of the body (i.e. only the exercised limb) did not decrease the core temperature as effectively as with whole body immersion (McDermott et al., 2009). The greater the body surface submerged in the cold water the greater the amount of heat exchange that takes place (Janwantanakul, 2009, Stephens et al., 2017). Considering hydrostatic pressure may be an important part of recovery for CWI, it is suggested that the deeper one is emerged the greater the pressure-gradient from the water pressure to decrease muscle oedema (Wilcock et al., 2006) and remove waste products (Brophy-Williams et al., 2011). Additionally, Halson (2011) recommended players' to be in a standing position when immersed, as this would increase the hydrostatic pressure.

iv) Post-exercise timing of CWI protocols

Nedelec et al. (2013) reported that CWI implemented immediately post-exercise was more beneficial than delayed CWI (i.e. either a few hours later or the following morning). While Poppendieck et al. (2013) reported that CWI should not only be applied immediately post-exercise but continuously over the following three to four days. However, due to the nature of recovery as a passive process, this could be considered as a confounding variable and not only as a beneficial effect from CWI. Water temperature, immersion depth and duration will all affect the protocol and by altering each variable, the outcome will be affected. The interactions between these variables are complex and an optimal protocol whilst not yet identified, should be developed in the most holistic way possible considering all facets of the training/match schedule and player characteristics (Stephens et al., 2017, Tavares et al., 2018).

Logistically implementing the ideal CWI protocols for individual players can be challenging in team sports like soccer. Arranging immersion baths with different temperatures for each member, especially when travelling will be difficult. A large area with suitable baths and the transport of ice are required for CWI, which can be hard for some teams to access. Further to this a lack of knowledge with regards to CWI protocols and the physiological and performance benefits make it hard to justify its use, especially for players who dislike cold temperatures. However there still remains a potential use for improved DOMS and psychological factors after heavy training or match-play (Bleakley et al., 2012, Tavares et al., 2018). The effects of the various protocols used in the literature will be reviewed below.

d) Post-exercise studies with cold-water immersion as a recovery strategy

Various studies have observed participant's recovery response post CWI, following a soccer match or simulated exercise protocol (Ascensão et al., 2011, Bailey et al., 2007, Elias et al., 2012, Ingram et al., 2009, Rowsell et al., 2011), while other studies have observed participant's recovery response to CWI after mechanical EIMD activity (Eston and Peters, 1999, Goodall and Howatson, 2008, Jakeman et al., 2009, Sellwood et al., 2007, Skurvydas et al., 2006). These studies are summarized in Table 5.

Table 5: Summary of cold-water immersion studies using mechanical and metabolic EIMD protocols

Summary of cold-water immersion studies using mechanical EIMD protocols								
Author	**Study design**	**Exercise/muscle damaging protocol**	**Participants**	**Recovery methods**	**Recovery Protocol**	**Outcome measures**	**Measurement times**	**Main finding**
Eston & Peters, 1999	Randomised control trial	Eccentric exercise protocol for elbow flexors (8 sets of 5 contractions) on an isokinetic dynamometer	15 healthy females	CWI; control (no CWI)	Arm in CWI (15 °C for 15 min) post exercise, repeated every 12h for seven sessions	DOMS CK levels, Relaxed elbow angle, Isometric strength, Swelling	At baseline and at 24, 48, and 72 h post-exercise.	Significant increase in elbow angle and significant reduction in CK levels post CWI. No significant effects of CWI on muscle strength, swelling or DOMS
Sellwood, 2007	Prospective randomised double-blind controlled trial	Eccentric loading protocol with non-dominant leg. Concentric quadriceps contractions, 5 sets of 10 repetitions.	40 untrained participants	CWI (5 °C)and Tepid Water (24 °C)	3 x 1-min immersions (with 1-min rest in between)	DOMS, Isometric strength, Swelling, Quadriceps muscle function (one-legged hop-for-distance) and CK levels	Baseline; and at 24, 48, and 72 h post-exercise	No significant differences between groups for DOMS, isometric strength, swelling, hop-for-distance or CK levels over time. There was a significant increase in pain on sit-to-stand at 24 h in the intervention group.
Skurvydas et al., 2006	Cross-over	100 intermittent (every 20 s) drop jumps from a height of 0.75 m	20 physically active males	CWI and control (no CWI)	Immersion for 15 min, with 10 min rest period; repeated twice	CK levels, DOMS and Muscle function (MVC, Vertical jump and fatigue)	Baseline; immediately post-exercise; and at 4, 8, 24, 48, and 72 h post-exercise	Significant reductions in DOMS, CK levels and significant improvements in muscle function following CWI
Jakeman et al., 2010	Randomised control trial	10 sets of 10 counter-movement jumps	18 physically active female volunteers	CWI and control (no CWI)	single 10-min bout of lower limb CWI at 10 °C immediately post-exercise	CK levels, DOMS and MVC of the quadriceps	Baseline and at 1, 24, 48, 72 and 96 h, following the protocol	No significant difference was noted between the treatment or control groups for any of the outcome measurements
Goodall & Howatson., 2008	Randomised controlled trial	5 sets of 20 drop jumps; from a height of 0.6 m, with 2 min rest between each set	18 physically active males	CWI and control (no CWI)	12 min in 15°C ± 1°C up to the iliac crest	CK levels, MVC, DOMS, Knee flexion range, Swelling (thigh)	Pre-exercise; and at 24, 48, 72 and 96 h post-exercise. MVC recorded at 0 h	No significant differences in CK levels, MVC, ROM or swelling following CWI
Yamane et al., 2006	Experimental pre-test post-test	Lower limb: endurance training on a cycle ergometer; 25 min at 70% VO2 max. Upper limb: maximum hand-grip exercises (3 sets of 8-repetitions. Exercises performed thrice a week for 4–6 weeks	6 student males	CWI and control (no CWI)	Exercised leg CWI 5 °C for 20 min and exercised arm CWI 10 °C for 20 min administered post-exercise	Peak isometric torque, Muscle endurance, Oxygen uptake, and femoral and brachial artery diameter	Pre- and post-training	Significant training effects and increases in artery diameter were noted in the control group, compared to the CWI group

Table 5 (continued): Summary of cold-water immersion studies using eccentric/DOMS-inducing & simulated exercise protocols								
Author	**Study design**	**Exercise/muscle damaging protocol**	**Participants**	**Recovery methods**	**Recovery Protocol**	**Outcome measures**	**Measurement times**	**Main finding**
Howatson et al., 2009	Randomised controlled trial	5 sets of 20 drop jumps; from a height of 0.6 m; 10 s rest between each jump and 2 min rest between each set. Repeated 2-3 weeks later	16 males (physically active)	CWI and control (no CWI)	CWI for 12 min in 15°C water immediately post-exercise and at 24, 48, 72 h. No CWI after second exercise protocol.	CK levels, MVC (quadriceps), DOMS, Knee flexion ROM, Swelling - thigh circumference	Pre-exercise; and at 24, 48, 72 and 96 h post- exercise.	No significant differences with CWI and any outcome measures were noted and CWI did not inhibit the repeated bout effect
Frolich et al., 2014	With-in subject repeated measures experiment	Single-leg hamstring curl (8-12 repetitions) – 1RM	17 male sport students	CWI and control (no CWI)	single leg CWI for 3 x 4 min in 12°C	1RM and 12RM strength test	Baseline, familiarisation period and post-test every week for 5 weeks	The 'control leg' showed better strength measurements post-intervention over 5 weeks, suggesting CWI can negatively affect strength training adaptations
Summary of cold-water immersion studies using metabolic EIMD protocols								
Sanchez-Urena et al., 2017	Randomized counter-balanced cross-over	Three 90-minute sessions intense training sessions (technical and tactical elements, 5 minutes of active stretching, and 75 minutes of cardio training)	10 male basketball players	CWIa (single immersion), CWIb (multiple immersion), Pass	Participants rotated through the interventions: CWIa (12 min immersion with at 12 °C), CWIb (4 times x 2 min immersion at 12°C +1 min out of water at room temperature), and Pass (12 min sitting down)	CMJ, DOMS and swelling – thigh circumference	0, 24 and 48 h post exercise	Both CWI protocols effectively improved recovery outcome measures compared with Pass.
Montgomery et al., 2008	Randomised control trial	Subjects competed in a 3-day tournament style basketball competition	29 male basketball players	CHO + Stretching; CWI; CG	5x1 min in 11 °C CWI, separated by 2min	20-m acceleration, basketball agility and line-drill, Yoyo Level 1 intermittent recovery test, vertical jump, sit-and- reach flexibility test	Baseline and post-tournament	CWI was significantly better in maintaining 20-m acceleration and line-drill performance over the tournament compared to CHO and stretching or CG.
Ascensoa et al., 2011	Randomised trial	Single soccer match	20 junior male soccer players	CWI and Tepid Water (35 C)	CWI (10 °C) or thermo-neutral water (35 °C) for 10 min up to ASIS post-match	Muscle damage markers (CK levels, myoglobin), Inflammation (C-reactive protein), neuromuscular function (jump and sprint abilities and MVC-quadriceps), and DOMS	Measured at baseline, within 30 min of the end, and 24 and 48 h post-match	Significant overall improvements were shown with CWI, showing CWI to be beneficial to muscle recovery markers post-single soccer match

Table 5 (continued): Summary of cold-water immersion studies using metabolic EIMD protocols

Author	Study design	Exercise/muscle damaging protocol	Participants	Recovery methods	Recovery Protocol	Outcome measures	Measurement times	Main finding
Ingram et al., 2009	Cross-over	80 min of simulated team sports exercise followed by a 20-m shuttle run test to exhaustion.	11 male team sport players	CWI, CWT and Control (No immersion)	2min x 5min CWI (10 °C) separated by 2.5min sitting upright at room temp (22°C)	10m×20m sprints; isometric strength of quadriceps, hamstrings and hip flexors; DOMS, CK levels and CRP	Baseline, 0, 24 and 48h post-exercise.	CWI and CWT resulted in decreased DOMS ratings and improved isometric strength and sprint measurements.
Bailey et al., 2007	Randomised control trial	90-min intermittent shuttle runs	20 males	CWI and control (no CWI)	Immersion for 10 min at 10 °C	DOMS, changes in muscular function and intracellular proteins	Baseline, during treatment, and regularly for 7 days post-exercise	CWI administered immediately after exercise reduced MS at 1, 24, and 48h. MVC of the knee flexors were reduced after CWI at 24 and 48h compared with control group. CWI had no effect on the CK response, but reduced myoglobin 1 h after exercise.
Elias et al., 2012	Counter balanced crossover study	Australian football training session	14 male Australian Football players	CWI, CWT and Control (No immersion)	14 min CWI	Repeat-sprint ability, jump performance (CMJ and squat jump), DOMS and RPE	45 min pre training and post-training. MS was measured after 1h, with all measures repeated 24 and 48h	MS ratings were improved for CWI and CWT, however CWI>CWT. CWI was the most effective method in reducing RPE and repeat-sprint performance.
Elias et al., 2013	Randomised control trial	Full practice match of 75-min	24 male Australian football players	CWI, CWT and Control (No immersion)	14 min CWI	DOMS, RPE, CMJ and repeat-sprint ability	Physical performance was tested 0, 24 and 48 h post-match. MS and RPE was measured at 0, 1, 24 and 48 h post-match.	All outcome measures improved with CWI more so than with CWT or passive recovery
Rowsell et al., 2009	Control trial	Four soccer matches over four days	20 junior boys soccer players	CWI and Tepid Water (35 C)	5 x 1 min in 10 °C water, separated by 1 min seated at room temperature (22°C) after each match	CMJ, CK, HR, DOMS, and RPE	90 min pre and 22 h post-match	CWI post-match did not affect physical performance or muscle indices, however it reduced the RPE and DOMS between matches in tournaments.
Rowsell et al., 2011	Control trial	Four soccer matches over four days	20 junior boys soccer players	CWI and Tepid Water (35 C)	5 x 1min in 10 °C water, separated by 1 min seated at room temperature (22°C) after each match	High-intensity running distance (>15 km/h) and total distance covered, HR and RPE	22h after each game	CWI was more effective than tepid water immersion for reducing DOMS, fatigue, improving total distance run measures, and maintaining HR

ABBREVIATIONS: h – hours; min – minutes; s - seconds C – degrees Celsius; CWI – Cold Water Immersion; CK – creatine kinase; RPE – rate of perceived exertion; CWT – Contrast Water Immersion; CG – compression garments; DOMS - delayed onset muscle soreness; m – metre, km/h – kilometres per hour; MVC – Maximal Voluntary Contraction; CRP – C- reactive protein' ROM- range of movement; ASIS – Anterior Superior Iliac Spine; EIMD – exercise induced muscle damage; CMJ – counter movement jump; VO2 max – maximal oxygen uptake; HR – heart rate; CHO – carbohydrates; CMJ – counter movement jump; RPE – rate of perceived exertion; RM – repetition maximum.

i) Evidence for cold-water immersion protocols and its use in studies using mechanical EIMD protocols

No noticeable differences were found post-CWI for physical performances, muscle soreness, swelling or strength in most of the studies using mechanical EIMD protocols (Eston and Peters, 1999, Frohlich et al., 2014, Goodall and Howatson, 2008, Jakeman et al., 2009, Sellwood et al., 2007, Yamane et al., 2006). One study actually showed a significant increase in pain levels for the CWI group compared to the control (Sellwood et al., 2007). One possibility for this result could be the use of a lower water temperature (i.e. 5 °C) for their protocol, as water temperatures this low have previously been reported to elicit a pain response (Davis and Pope, 2002). Furthermore, Yamane et al. (2006) and Frohlich et al. (2014) suggested that consistent use of CWI had a negative effect on strength training adaptations compared to the control group.

A reduction in creatine kinase (CK) plasma levels after CWI was however found in two studies (Eston and Peters, 1999, Skurvydas et al., 2006). The reduction in plasma CK levels were contrary to evidence reported in previous simulated sports protocol studies using CWI (Bailey et al., 2007, Ingram et al., 2009), possibly due to increased muscle damage in the mechanical EIMD protocols because of the untrained participants recruited to the mechanical EIMD study. However, in general the eccentric protocols used was most likely not intense enough to bring about an adequate training stimulus, therefore no recovery would be needed, limiting any potential significant difference from the CWI intervention.

The studies all employed different cooling protocols (see Table 5), focused on different body parts (i.e. arm versus leg), had poor control groups and had differing EIMD protocols. The exercise protocol as well as the participants (i.e. untrained) used in both studies do not allow the reader to translate these results to a population of soccer players. The poor methodological quality of the above studies for CWI deem it necessary to locate further scientific evidence to see any benefit for its use and potential develop conclusive protocols (Sánchez–Ureña et al., 2017).

ii) Evidence for cold-water immersion protocols and its use on studies using metabolic EIMD protocols

Cold water immersion showed significant benefits in most performance and recovery measurements in the studies using metabolic EIMD protocols (Ascensão et al., 2011, Bailey et al., 2007, Elias et al., 2012, Elias et al., 2013, Ingram et al., 2009, Rowsell et al., 2011, Sánchez–Ureña et al., 2017). Limitations of the Elias et al. (2012;2013) studies included that no protocol specifics were provided for temperature, number of immersions or depth the of water immersion. No control group (no immersion) was used in Ascensao et al. (2011), therefore one cannot dismiss the treatment effect and further to this, all the studies above used different cooling protocols. However, the reviewed

studies clearly show a potential benefit in using CWI post-exercise after EIMD from metabolic pathways.

The exercise protocols used in the metabolic studies were similar if not more intense than a soccer match scenario and most likely more intense than the protocols used in the mechanical studies above, potentially eliciting a greater need for recovery in the metabolic protocols. Additionally, many of the EIMD metabolic studies used protocols which replicated congested match fixtures (Montgomery et al., 2008, Rowsell et al., 2009, Rowsell et al., 2011, Sánchez–Ureña et al., 2017) and not just one off-games, further exposing the participants to potentially greater EIMD exposure. This greater need for recovery might allow the CWI to show greater improvements on recovery and performance indices compared to the EIMD from mechanical studies. Delayed Onset Muscle Soreness via the metabolic pathway peaks within 24 hours (Tee et al., 2007), therefore encouraging CWI as quick as possible post-exercise, whereas DOMS via mechanical pathways only peak between 24-48 hours suggesting CWI immediately post-exercise might be unnecessary in these scenarios especially if only perceived recovery is shown to improve (Hohenauer et al., 2015).

Due to the array of study methodologies used above, meta-analyses are imperative to gain perspective. A recent meta-analysis on the influence of CWI on recovery parameters post-exercise in team sports concluded that, although improved perceptions on fatigue existed after CWI, a lack of amalgamated supporting evidence was available to draw definitive conclusions for its use (Higgins et al., 2017).

e) Summary of literature: Cold-water immersion post-exercise

Cold-water immersion is frequently used as a recovery modality from strenuous exercise. Evidence suggests that CWI should be used post EIMD caused from intense metabolic training to assist with perceived recovery and potential performance parameters. No evidence exists for any recovery or performance improvement in using CWI from mechanical EIMD protocols. The most effective protocol for CWI has been postulated by various reviews, using a duration of full-body immersion of approximately 12 to 15 minutes, in 10 to 15 °C water (Leeder et al., 2012a, Machado et al., 2016, Stephens et al., 2017). Full body immersion allows for increased hydrostatic pressure which may be a beneficial effect of CWI. The hydrostatic pressure effect exists in most hydrotherapy models, including CWT, which will be reviewed in the following section. Protocols need to be individualised, taking into consideration body size and dermal restrictions to cold exposure (Stephens et al., 2017). Future studies on chronic use of CWI should be reviewed to assess any potential negative effects of training adaptation and recovery of the player.

2.3.6 Contrast Water Therapy

a) Contrast water therapy as a recovery method post-exercise

An additional form of hydrotherapy offered to players as a recovery tool is CWT. Contrast water therapy is the alternating between hot and cold water respectively (Vaile et al., 2007). Contrast water therapy has been commonly used in the sporting community as a recovery method; however, there remains a lack of evidence supporting these protocols (Bieuzen et al., 2013) and poor standardization of protocols exist (De Nardi et al., 2011). Various applications of cold (e.g. CWI, showers or cold packs) and heat (e.g. hot baths, showers or heat packs) are used in an alternate fashion to create contrasting temperatures; however, hot and cold immersions or showers seem to be the most commonly utilised CWT method post-exercise (Cochrane, 2004).

b) Physiological effects of contrast water therapy post-exercise

Vasoconstriction of the blood vessels occurs when the body is exposed to cold temperatures (Cochrane, 2004). Once the blood vessels constrict, the metabolism slows down reducing swelling and inflammation, thereby limiting injury (Cochrane, 2004). The application of heat has been shown to increase tissue temperature and cause dilation of the blood vessels, known as vasodilation (Hing et al., 2008). Vasodilation causes an increase in blood flow and circulation, which increases the supply of oxygen and antibodies, and aids in the clearance of metabolic waste built up by the cells (Cochrane, 2004). It is hypothesized that CWT assists in recovery by promoting vasoconstriction and vasodilation causing a 'pumping effect,' increasing the peripheral circulation and improving waste removal from fatigued muscles (Calder, 1996).

Myrer et al. (1994) hypothesized that the 'pumping effect' caused by CWT would have to be accompanied by significant sub-dermal and muscle temperature changes. The authors immersed participant's right leg into a hot (40 °C) whirlpool for four minutes, followed by a cold (15 °C) whirlpool for one minute; repeated four times (Myrer et al., 1994). However, this protocol did not produce any significant differences in intramuscular temperature. In a later study by the same authors, the medium of the CWT was altered to cold and hot packs and the protocol duration for both hot and cold periods was increased (Myrer et al., 1997). Once again, no change in intramuscular tissue temperature was observed, confirming the results of previous studies (Higgins and Kaminski, 1998, Myrer et al., 1994). In contrast, Fiscus et al. (2005) demonstrated a significantly increased arterial blood flow in the lower leg with CWT for a duration of 20 minutes, implementing a 4:1 hot to cold ratio of water immersion, compared to 20 minutes of no immersion (i.e. the control). However, the authors proposed that the fluctuations in blood flow were due to changes in cutaneous

circulation rather than intramuscular circulation, therefore questioning this 'pumping effect' (Fiscus et al., 2005). Equivocal evidence exists regarding changes in intramuscular temperature fluctuation and it remains unclear as to the exact mechanism by which CWT benefits athlete recovery (Bieuzen et al., 2013).

Additionally, it has been reported that CWT immediately improved clearance of lactate build-up (Forghani et al., 2015, Morton, 2007), decreased muscle swelling and re-energised the psychological state post-exercise (Bieuzen et al., 2013). In a recent systematic review, CWT was described as beneficial for perceptual recovery, but no benefits were noted for the recovery of DOMS in team sport (Higgins et al., 2017). Due to the frequent use of CWT as a recovery strategy, enhanced research is required to understand the exact mechanisms by which it functions to aid in recovery (Barnett, 2006).

c) Contrast water therapy protocols post-exercise

The varying results reported across the use of this method, creates significant uncertainty as to the best available protocol. Wilcock et al. (2006) suggested that the hydrostatic pressure exerted on the body while immersed in water causes a fluid movement shift thought to enhance the ability of a player to recover. Positive results for the use of full-body immersion CWT on DOMS after a fatiguing cycling protocol (Vaile et al., 2007, Vaile et al., 2008) are in accordance with a review by Halson (2011), which suggested the best CWT protocol to aid in recovery would be full immersion to the neck in a standing position. However, no differences were noted between utilising alternating showers or immersions in elite netball players for performance or recovery outcomes (Juliff et al., 2014). Logistically different temperature immersion baths are not always available; therefore, showers will be an easy and accessible replacement.

Cold water temperatures are similar to that in the CWI protocol of 11-15° C (Bleakley et al., 2012), whereas the contrasting warm water is suggested at around 36-38° C (Stanley et al., 2012, Wilcock et al., 2006). Temperatures above 36° C were seen to alter core temperature and therefore suitable for use as hot water in CWT (A B Craig and Dvorak, 1966). Contrast water therapy duration did not seem to have a dose–response effect on performance recovery from high-intensity cycling (Versey et al., 2011, Versey et al., 2013). This is an interesting study, as there are limited available studies investigating the effects of different exposure times of CWT in a sporting environment. That being said, the majority of research has used total recovery times of around 15 minutes, alternating each minute between hot and cold water (Bieuzen et al., 2013, Versey et al., 2013).

d) Post-exercise studies with contrast water therapy as a recovery strategy

Various studies have observed participants' recovery response to CWT after mechanical EIMD studies (Argus et al., 2017, French et al., 2008, Robey et al., 2009, Vaile et al., 2007, Vaile et al., 2008). Further studies have investigated recovery response to CWT following metabolic EIMD protocols (Elias et al., 2012, Gill et al., 2006, Ingram et al., 2009, Kinugasa and Kilding, 2009, Versey et al., 2011). Studies summarized in Table 6 below.

Table 6: Summary of contrast water therapy studies using mechanical and metabolic EIMD protocols

Summary of contrast water therapy studies using mechanical EIMD protocols								
Author	**Study design**	**Exercise/muscle damaging protocol**	**Subjects**	**Recovery methods**	**Recovery protocol**	**Outcome measures**	**Measurement times**	**Main finding**
Vaile et al., 2007	Randomised crossover trial	DOMS-inducing leg press protocol (5 x10 eccentric contractions at 140% of 1RM, with 3 min recovery between sets. Two trials were completed1 separated by 6 weeks	13 athletes	CWT; Pass (control)	1 min CWI (8–10°C); 2 min HWI (40–42 °C) for total 15 min	CK levels, DOMS, thigh volume, isometric squat strength, and weighted jump squat	Baseline, immediately post recovery, and at 24, 48, and 72h	Quicker recovery of muscle strength and power was observed with CWT. No significant differences in CK levels or DOMS between treatments were found
French et al., 2008	A match-paired, between-group design with repeated measures (randomised)	Resistance exercise: 6x10 parallel squats at 100% BW with 5s 1RM eccentric squat	26 young men	CWT; CG; Pass	1 min CWI (8–10 °C); 3 min HWI (37– 40 °C) for total 12 min	DOMS, CK and Mb levels, joint ROM, limb circumference, 10-30m sprint, CMJ, and 5RM	Baseline, immediately and 48h post-intervention	No performance recovery differences were noted between the recovery methods, however CWT showed minor improved DOMS ratings post-exercise
Robey et al., 2009	A semi-randomised repeated measures design (participants as own controls)	Strenuous stair running	20 rowers	CWT; Pass; stretching	Hot shower (40 °C) for 2 min and CWI (12 °C; waist deep) for 1 min, repeated five times.	DOMS, CK levels, blood samples, Peak torque, rowing ergometer trial post-stair run	Baseline and immediately post-exercise, as well as at 24, 48, and 72h	No significant strength or performance differences existed between the three recovery interventions
Argus et al. 2017	Randomised controlled design	Heavy resistance exercise	13 males	CWT; CWI; Pass	1 min CWI (15 °C); 1 min HWI (38°C) for total 14 min	perceptual recovery, MVC of the knee extensors, CMJ	Baseline, 0, 2 and 4h post-recovery	CWT had no significant effect on perceptual or performance recovery within 4h compared with CWI or Pass
Ingram et al., 2009	Cross-over	80 min of team sports exercise followed by a 20m shuttle run test to exhaustion	11 male team sport athletes	CWI, CWT and Control (No immersion)	2 min CWI (10 °C); 2 min HWI (40 °C) for 3 repetitions.	10m×20m sprints, lower limb isometric strength, DOMS, CK levels and CRP	Baseline, 0, 24 and 48h post-exercise.	CWT resulted in decreased DOMS compared with control

Table 6 (continued): Summary of contrast water therapy studies using metabolic EIMD protocols								
Author	**Study design**	**Exercise/muscle damaging protocol**	**Subjects**	**Recovery methods**	**Recovery protocol**	**Outcome measures**	**Measurement times**	**Main finding**
Crowther et al., 2017	Randomized controlled trial	Simulated team-game fatiguing circuit	34 active males	CWI, CWT, Pass (No immersion), ACT and combined CWI + ACT	Alternated HWI (38 °C) and CWI (15 °C) every min for 14 min total	Repeat-sprint ability, CMJ, sit and reach flexibility test, DOMS score	Baseline, 1, 24 and 48h post-exercise	CWT elicited the best results for short term perceptual recovery
Elias et al., 2012	Counterbalanced crossover study	Australian football training session	14 male Australian football players	CWI, CWT and Control (No immersion)	14 min CWT (No Protocol specifics)	Repeat-sprint ability, jump performance (CMJ and squat jump), DOMS and RPE and fatigue	Pre and post-training. MS and RPE were measured after 1h, all measures repeated 24 and 48h post-training	MS ratings were improved for CWI and CWT, however CWI>CWT. CWI was the most effective method in reducing RPE and repeat-sprint performance
Gill et al., 2006	Randomised controlled trial	Four competitive rugby games over a tournament	23 elite male rugby players	CWT; CG; Pass; ACT	1 min in CWI (8–10 °C) and 2 min HWI (40–42 °C) for 3 cycles	CK levels	0, 36 & 84h post-match	CWT showed 85% recovery after 84 hours (2nd fastest). No significant differences in CK recovery were observed
Versey et al., 2011	Randomised, counter-balanced crossover design	Four trials of a 75 min cycling protocol containing six sets of five 15 s sprints and three 5 min TT	11 trained male cyclist	CWT (6 min), CWT (12 min), CWT (18 min), Pass	Alternated HWI (38 °C) and CWI (14 °C) every min for 18 min total	Cycle performance (work, power), core temperature, HR, RPE, thermal sensation, whole body fatigue and DOMS	Performance, temperature and HR measured after each sprint or exercise bout, while fatigue and MS measured pre and post-exercise	All CWT conditions improved thermal sensation, fatigue and MS compared with control, but no significant differences existed between conditions. CWT up to 12 min was seen as beneficial
Hamlin, 2007	Randomised crossover design	Repeated sprint test (10 repeated maximal effort sprints every 30 s), completed again 1 h post-intervention	20 junior rugby players	CWT; ACT (6 min slow jog)	CWT: 6 min [3 x 1-min hip-immersions in CWI (8—10 °C) alternated 3 x 1 min HWI (38 °C) showers]	Repeated sprint ability, Bla, HR	3 min post-sprint trials and 3 min post-recovery.	CWT decreased Bla and HR compared to ACT, but had no significant effect on repetitive sprint performance

Table 6 (continued): Summary of contrast water therapy studies using metabolic EIMD protocols								
Author	**Study design**	**Exercise/muscle damaging protocol**	**Subjects**	**Recovery methods**	**Recovery protocol**	**Outcome measures**	**Measurement times**	**Main finding**
King and Duffield, 2009	Repeated measures study	Four netball exercise circuit sessions on consecutive days.	10 female netball players	CWT, CWI, ACT, Pass	1 min CWI-iliac crest (10°C) and 2 min hot shower (39 °C)	Performance test, Bla, PH, Bicarbonate, HR, RPE and DOMS	Baseline, post warm-up. post-exercise, and post-recovery	CWT demonstrated a decrease in Bla post-intervention. The 1 d recovery period between exercise bouts maintained performance for all interventions
Juliff et al., 2014	Rnadomized cross-over design	Three randomized trials of netball specific circuit	10 female netball players	CWT (showers); CWT (immersion); Pass	14-minute recovery (a) CWT (1 min 38 °C and 1 min 15 °C immersion), (b) contrast showers (1 min 38 °C and 1 min 18°C)	Repeated agility, skin and core temperature, and perception scales	Baseline, 0, 5 and 24 h post-exercise	No differences between any outcomes for CWT immersion or showers were noted. Both CWT interventions had a significantly better perceptual recovery than Pass.
Kinugasa and Kilding, 2009	Randomised crossover design	3 soccer matches on 3 separate days	26 young soccer players	CWT; CWI; Pass; Combined (CWI and ACT)	1 min CWI (12 °C); 2 min hot shower (38 °C) repeated 3 times	vertical jump height, HR and RPE	Pre match, 10 min post-match, after each intervention, and after 24 h	CWT did not show any significant benefits in performance or recovery outcomes compared to other interventions or Pass
Vaile et al., 2008	Randomised crossover trial	105 min cycle (including 66 maximal effort sprints) over 5 consecutive days	12 endurance trained male cyclists	CWT; CWI; HWI; Pass	1 min CWI (15 °C) and 1 min HWI (38 °C) for total 14 min. Full body immersion protocol	Core temperature, HR RPE, TT performance, Peak power, average power and total work.	At end of each sprint, pre-post recovery. Power and work measured during exercise	Performance was enhanced in all tasks across the 5d following CWI and CWT compared to HWI and PAS.

ABBREVIATIONS: 1RM – one repetition maximum; h – hours; min – minutes; s - seconds C – degrees Celsius; CWI – Cold Water Immersion; CK – creatine kinase; RPE – rate of perceived exertion; CWT – Contrast Water Immersion; MS – muscle soreness, m – metre; CRP – C- reactive protein; EIMD – exercise induced muscle damage; CMJ – counter movement jump; ACT – Active recovery; Bla – Blood lactate concentration; d – day, HR – heart rate, Pass – passive recovery; CG – compression garments; RM – repetition maximum, Mb – myoglobin; BW – body weight; TT- time trial; HWI – Hot Water Immersion

i) Evidence for contrast water therapy protocols and its use on mechanical EIMD protocols

No significant differences in performance recovery or biochemical markers were noted in the reviewed mechanical EIMD protocols (Argus et al., 2017, French et al., 2008), (Robey et al., 2009, Vaile et al., 2007). Most variables returned to baseline levels by 72 hours post-exercise, which indicated that passive rest alone assisted to regenerate the physiological parameters of the body post-exercise (Robey et al., 2009). Contrast water therapy did however slightly improve DOMS scores, but when compared to any other recovery method it was not superior (Bieuzen et al., 2013, French et al., 2008). Most of the above studies reviewed had poor methodological quality; some participants were used as their own controls, others used single limb immersion only (thereby limiting any potential benefits from hydrostatic pressure), there was short washout periods and varying CWT protocols were administered.

While a previous review reported CWT as a more effective recovery option than passive recovery alone (Bieuzen et al., 2013), a recent study having both mechanical and metabolic EIMD effects found CWT to be no more superior for perceptual or performance measures four hours post resistance training compared to a control (Argus et al., 2017). This supports the abovementioned studies' conclusions that CWT does not have enough evidence to be justified as a recovery method for EIMD caused through mechanical only pathways.

ii) Evidence for contrast water therapy protocols and its use on metabolic EIMD protocols

Contrast water therapy consistently showed improvements in DOMS and perceptual recovery throughout most of the reviewed studies without showing any significant improvements in performance outcomes (Crowther et al., 2017a, Elias et al., 2012, Ingram et al., 2009, Juliff et al., 2014), (Versey et al., 2011). Blood lactate was seen to decrease quicker post-CWT in a few studies when considering biochemical markers of recovery (Hamlin, 2007, King and Duffield, 2009). Both these studies used the same CWT protocol of CWI and hot showers, which could potentially explain the similar results. The absence of a passive control group in Hamlin et al. (2007) did not allow the authors to confidently conclude that the findings were due to CWT and not the passive nature of recovery. Whilst lactate clearance was significantly improved immediately post-exhausting exercise amongst a student population, after two hours no differences were noted with lactate levels or subsequent performance (Forghani et al., 2015). Previously, lactate build-up was noted as the most important cause of muscle fatigue (Allen et al., 2008) and associations between quicker lactate clearance and improved athletic performance believed (Bangsbo et al., 1996, Monedero and Donne, 2000). However, now lactate is only considered as one of many measures causing fatigue, and also

not strongly enough correlated to muscle function and recovery to be measured in isolation (Bond et al., 1991, McCallum, 2017). Therefore, emphasis should not be placed on lactate clearance results.

No studies showed any performance recovery benefits, bar a single study looking at endurance cyclists who found CWT assisted in maintaining performance compared to passive recovery (Vaile et al., 2008). Maintaining endurance performance would be different to recovering from an intense soccer match, and without substantial data these results should not be transferred across athletic populations. The main definition for recovery was to prioritise performance recovery, which CWT has shown to have no beneficial effect on. Whilst CWT had a minor effect on biochemical markers (lactate clearance), there was positive connotations with perceptual recovery.

However, if options are available for hydrotherapy post-exercise, it seems CWI should be prioritized over CWT (Bieuzen et al., 2013). The reasons revolve around the shorter CWI durations for CWT compared to CWI; therefore limiting the effects of cold water on decreasing the inflammatory factors (Tavares et al., 2018), as well as decreased immersion durations limiting the hydrostatic pressure effect. In addition, further research is needed to show the benefits of heating the muscle for post-exercise recovery (McGorm et al., 2018).

e) Summary of literature: Contrast water therapy post-exercise

Contrast water therapy is a cost-effective strategy which is readily available to most sporting teams post-training and post-match. The positive effects related to perceptual recovery and soreness should be considered (Crowther et al., 2017a, Bieuzen et al., 2014a)(Bieuzen et al., 2014; 2013, Crowther et al., 2017a; 2017b) even though no performance recovery effects was observed. The positive effects using CWT protocols with water temperatures of 10–15 °C for cold and 38–40 °C for hot, 15 minute session duration, full body immersion up to the neck and a ratio of hot: cold to be 1:1 have been highlighted (Halson, 2011, Higgins et al., 2017). In light of no other evidence-based recovery methods, CWT should be considered as superior to passive recovery post-soccer exercise for the perceptual effects of recovery, however if CWI is available it should be used in preference. A further recovery method, which relies on the theorem of a 'pumping effect', is active recovery, which is often likened to the proposed mechanism of CWT (Cochrane, 2004, King and Duffield, 2009) and will be reviewed in the following section.

2.3.7 Active recovery

a) Active recovery as a recovery post-exercise

Active recovery is a common form of recovery in soccer and is currently performed by more than 80% of French professional teams (Nedelec et al., 2013). It is believed that active recovery enhances the recovery process by accelerating the return to homeostasis following a soccer match (Andersson et al., 2008). Active recovery is commonly referred to as a 'warm down' or 'cool down', and this strategy typically includes a low-intensity exercise (e.g. pool exercise, jog or cycle) of approximately 15 to 30 minutes (Nedelec et al., 2013).

b) Physiological effects of active recovery post-exercise

Active recovery has been utilised to assist players in adapting to training loads and enhance post-exercise performance (Barnett, 2006). Active recovery immediately following exercise assists in progressively reducing the bodies core temperature and blood flow (Reilly and Brooks, 1986). Active recovery has also been linked to assisting in stabilising activity in the central nervous system, potentially promoting sleep and relaxation, which is considered another important recovery tool (Reilly and Ekblom, 2005). It has been postulated that active recovery aids in the clearance of blood lactate that has accumulated during exercise (Andersson et al., 2008, Koizumi et al., 2011). The increase in lactate removal has been correlated to the intensity of the exercise performed (Bond et al., 1991, Monedero and Donne, 2000, Ohkuwa et al., 2009). Previous studies (Bond et al., 1991), (Dupont et al., 2003, Gupta et al., 1996, Koizumi et al., 2011) have reported that active recovery performed at intensities of between 30 to 60 percent of VO2 maximum for a minimum duration of 15 minutes, enhances lactate removal and pH recovery when compared to passive recovery. The efficacy of active recovery as indicated by lactate removal capabilities has been utilised in the past (Bond et al., 1991, Monedero and Donne, 2000). However, lactate removal should not be the only marker used to assess the quality of recovery, as faster lactate removal does not ensure improved performance post-exercise (McCallum, 2017).

The rate of blood lactate disappearance was significantly greater during active recovery compared to passive recovery (Bond et al., 1991). Despite these significant differences, there was no difference in isokinetic measures of maximal strength, work output and muscle fatigue between recovery modes, further indicate that lactate is unrelated to muscle function (Bond et al., 1991). As discussed with CWT, lactate measures should not be measured in isolation when assessing recovery (Barnett, 2006) and biochemical markers in general are peripheral measurement outcomes to performance recovery. It should also be considered that active recovery has been reported to fatigue participants

faster than passive recovery, as it requires the utilisation of greater levels of oxygen and energy, thereby negatively affecting the recovery process (Koizumi et al., 2011).

c) Post-exercise studies with active recovery as a recovery strategy

The majority of studies investigating the effects of active recovery post-exercise have utilized metabolic EIMD protocols (i.e. cycling, match or game environment; (Andersson et al., 2008, Bond et al., 1991), (Dupont et al., 2004, Gill et al., 2006, Gupta et al., 1996, King and Duffield, 2009, Koizumi et al., 2011, Lane and Wenger, 2004, Tessitore et al., 2007, Suzuki et al., 2004). Limited studies were reviewed assessing mechanical EIMD protocols (Sayers et al., 2000). Studies summarized in Table 7 below.

Table 7: Summary of active recovery studies using metabolic and mechanical EIMD protocols

Summary of active recovery studies using metabolic EIMD protocols								
Author	**Study design**	**Exercise/muscle damaging protocol**	**Subjects**	**Recovery methods**	**Recovery protocol**	**Outcome measures**	**Measurement times**	**Main finding**
Dupont et al., 2004	Repeated measures test	Two graded intermittent exercises (15 s) to exhaustion alternated with recovery periods (15s)	12 males	ACT; Pass	Cycle ergometer at 40% of VO2max for 15s between sets	Bla; Time to exhaustion	Bla (3 min post-exercise); Time to exhaustion (s)	No difference in Bla readings between the groups. Time to exhaustion after Pass was longer compared with active recovery
Bond et al., 1991	Crossover	mechanical brake cycle ergometer at 150% VO2max for 60s (two exercises)	5 males	ACT; Pass	Cycling at 30% VO2max for 20 min	Peak torque, total work output and fatigue (dominant quadriceps muscle), Bla	Baseline, post-intervention	The rate of Bla removal was significantly greater during active recovery than Pass. No significant differences were seen in any isokinetic between recovery modes
Lane and Wenger, 2004	Randomised crossover trial	Two intermittent cycling sessions; 18 min of varying work intervals separated by 24h	10 physically active men	ACT; Massage; CWI; Seated rest (Pass)	Cycling at 30% VO2max for 15 min	Total work (kj), total number of pedal revolutions in each work bout	Baseline, post-intervention and post-exercise	Only the control condition showed a decrease in total work completed between the first and second exercise sessions. All other recovery methods including active recovery facilitated recovery between the session in no hierarchal order
Choi et al., 1994	Cross-over	High-intensity cycle ergometer (1 min exercise at 130% VO2max with a 4 min rest period between)	6 untrained males	ACT; Pass	30 min cycle at 40-50% VO2max plus 30-min seated rest	Bla, Muscle glycogen	Baseline and throughout intervention	Muscle glycogen after 60 min of Pass increased, whereas it decreased after active recovery. A greater decrease in Bla was observed during ACT than during Pass and significantly different at 10 and 30 min of the recovery period
Koizumi et al., 2011	Randomised control trial	30s maximum cycling followed by a 20 min recovery and 30s maximum cycling again	10 males	ACT; Pass; Immobilization	Cycling at 30% VO2max for 20 min	Work and Power output, Respiratory gas exchange variables, Bla, Oxygen saturation of muscle	Baseline and 5, 10, 20 min post-exercise	The total work of the 2nd Exercise was higher in active recovery compared to Pass. After interventions muscle oxygenation level and Bla were lower in active recovery compared to Pass

Table 7 (continued): Summary of active recovery studies using metabolic EIMD protocols								
Author	**Study design**	**Exercise/muscle damaging protocol**	**Subjects**	**Recovery methods**	**Recovery protocol**	**Outcome measures**	**Measurement times**	**Main finding**
Andersson et al., 2008	Randomised control trial	Two 90-min soccer games separated by a 72h	17 elite female soccer players	ACT; Pass	Submaximal cycling and resistance training at <50% 1RM	CMJ, sprint performance, maximal isokinetic knee flexion and extension, CK levels, urea, uric acid, and DOMS	Baseline, 0, 5, 21, 45, 51, and 69h after a first match, and after second match	The neuromuscular and biomechanical changes were similar after the first and second games. No significant differences for active recovery or Pass groups were noted for recovery
Andersson et al., 2010	Randomised control trial	Two 90-min soccer games separated by a 72h	10 elite female soccer players	ACT; Pass	submaximal cycling at 60% HRpeak; resistance training at <50% 1 RM	Leukocyte count and several plasma pro- and anti-inflammatory cytokines	Baseline, 0, 21, 45 and 69h after the first game and within 15–20 min after the second game	A pro- and anti-inflammatory cytokine response occurred after the first but not the second soccer game. No difference was observed between active recovery or Pass on the inflammatory response post-exercise
Tessitore et al., 2007	Randomised crossover	Four football games, scheduled on a twice-weekly basis for a period of 2 weeks	10 male futsal players	Pass; water-exercises; ACT (land-based exercises); EMS	20 min ACT [16 min jog and 4 min stretching]	Anaerobic performance (CMJ, bounce jumping, 10m sprint) Hormones (salivary cortisol, urinary catecholamine's). Subjective ratings (RPE, DOMS, RESTQ), sleep duration	Baseline, pre/post exercise and pre/post intervention	No significant effect was found on anaerobic performances, hormones, rating of MS, recovery-stress state, and amount of sleep for any recovery interventions
Gill et al., 2006	Randomised control trial	Four competitive rugby games over a tournament	23 elite male rugby players	CWT; CG; Pass; ACT	Cycle (80–100 rpm, 150W) for 7 min	CK levels	0, 36 & 84h post-match	No significant differences in CK recovery were observed between the interventions at any time point. CWT, CG and active recovery showed quicker recovery response compared to passive recovery
Fairchild et al., 2003	Randomised counterbalanced trial order	Cycling for 2.5 min at 130% VO2 peak followed by a 30s sprint	8 endurance athletes	ACT; Pass	Pedaling for 45 min at 40% VO2max	VO2max, Bla, pH, muscle glycogen	Baseline, 0, 45 and 75 min post-exercise	Bla and pH returned more rapidly after active recovery compared to Pass. However, muscle glycogen levels increased post Pass compared to ACT
Suzuki et al., 2004	Randomised control trial	Rugby match (80-min)	15 Japanese rugby players	ACT; Pass	1h of low-intensity aquatic exercise	POMS; CK levels, neutrophils, lactate	Baseline, post-match and 24 and 48h post-match	Significant improvements in POMS with ACT, however no physiological measurements changes

Table 7 (continued): Summary of active recovery studies using mechanical EIMD protocols

Author	Study design	Exercise/muscle damaging protocol	Subjects	Recovery methods	Recovery protocol	Outcome measures	Measurement times	Main finding
Sayers, 2000	Randomised control trial	50 maximal eccentric contractions of the elbow flexors of the non-dominant arm.	26 male volunteers	ACT; Pass	50 bicep curls with a 2kg dumbbell daily	Relaxed arm angle, flexed arm angle, maximal isometric force, and DOMS	Baseline, 0, and for 8d post-recovery	Active recovery and immobilization improved recovery in muscle strength (maximal isometric force). While recovery from DOMS improved with active recovery and was delayed with immobilization

ABBREVIATIONS: h – hours; min – minutes; s - seconds C – degrees Celsius; CWI – Cold Water Immersion; CK – creatine kinase; RPE – rate of perceived exertion; CWT – Contrast Water Immersion; MS – muscle soreness, m – metre; CRP – C- reactive protein; CMJ – counter movement jump; ACT – Active recovery; Bla – Blood lactate concentration; d – day, HR – heart rate, Pass – passive recovery; CG – compression garments; EMS- Electromyostimulation; VO2 max – Maximal oxygen uptake; RM – repetition maximum; rpm – repetition per minute; W -Watt; POMS – Profile of Mood States questionnaire

i) Evidence for active recovery and its use on metabolic EIMD protocols

Active recovery between two exercise sessions was more beneficial than passive recovery for subsequent performance and recovery indices (Koizumi et al., 2011, White and Wells, 2015). It was hypothesized that the benefits observed were due to active recovery aiding in the increase in delivery of oxygenated blood to the muscles, thereby improving recovery and performance during the second exercise. A further study, in agreement with the above findings, conducted by Lane and Wenger (2004), reported that active recovery (30% maximal oxygen uptake [VO2 Max]), CWI and massage all facilitated the recovery process between two high-intensity, intermittent exercise sessions separated by 24-hour periods. Contradictory to the findings of the above studies (Koizumi et al., 2011, Lane and Wenger, 2004, White and Wells, 2015), post-exercise active recovery had no effect on the recovery time of neuromuscular and biochemical factors in female soccer players after 72 hours (Andersson et al., 2008, Andersson et al., 2010). Most intense training or matches are followed by a long rest period; therefore, the above findings may only be useful if you have to perform subsequent exercise within 24 hours or in a tournament setting or congested fixtures.

In somewhat agreement with active recovery's short term effects, it was also noted that active recovery had a short term improvement on DOMS, however no improvement on muscle recovery (Zainuddin et al., 2006) or anaerobic performances (Tessitore et al., 2007). No substantial performance or perceived recovery was described in the reviewed studies, barring the improved POMS scores in one study (Suzuki et al., 2004) Only some biochemical markers (lactate and CK levels) improved when compared to passive recovery alone (Bond et al., 1991, Choi et al., 1994), (Fairchild et al., 2003, Gill et al., 2006), however as shown above these measurements are not sufficient to show significant recovery benefits. The ACT protocol needs to be standardized; different durations could have a different effect, as seen in CK concentrations. Gill et al (2006) used a 7-minute ACT protocol and found improved CK clearance compared to a one-hour protocol used in Suzuki et al (2004).

Passive recovery was shown to improve recovery during intervals compared with active recovery. 'Time to exhaustion' for intermittent exercise alternated with passive recovery was significantly longer compared to active recovery, while metabolic power during intermittent exercise alternated with passive recovery was significantly lower when compared to the active recovery group (Dupont et al., 2004). Active recovery required a higher energy output than passive recovery, as during active recovery less oxygen becomes available for cell nourishment and regeneration (Dupont et al., 2004, Dupont et al., 2003).

A recent survey investigating athletes' perceptions of effective recovery methods, showed land based active recovery as the least effective recovery method (Crowther et al., 2017b). There is lack of concrete evidence supporting the use of active recovery strategies and support staff should consider alternate evidence-based approaches for recovery (Barnett, 2006, Dupuy et al., 2018).

ii) Evidence for active recovery protocols and its use on mechanical EIMD protocols

Recovery from DOMS was improved with active recovery and worsened when immobilized (Sayers et al., 2000). Immobilization is an unlikely form of recovery post-exercise, unless a more severe injury is suspected. This study differed from most studies in that it implemented an upper limb protocol for EIMD (Sayers et al., 2000). It has previously been reported that upper limbs are often more susceptible to EIMD than lower limbs (Chen et al., 2011, Paschalis et al., 2010), therefore the study's results should be viewed with caution.

d) Summary of literature: Active recovery post-exercise

Evidence that active recovery enhances post-exercise recovery is currently limited. The various protocols, exercise choices and exercise intensities employed in previous studies have left a grey area regarding the appropriate guidelines. Whilst performing low-intensity exercise immediately post-exercise may have some benefits in performance within 24 hours, few other benefits exist with using active recovery as a recovery method in soccer. Therefore, support staff should consider alternate evidence-based recovery methods post-exercise.

2.3.8 Massage

a) Massage as a recovery strategy

Another popular recovery tool post-exercise is massage, which has seen widespread use among players of various sporting codes (Crowther et al., 2017b). Massage is defined as 'mechanical manipulation of body tissues with rhythmical pressure and stroking for the purpose of promoting 'health and well-being' (Dryden et al., 2004). Nedelec et al. (2013) found that approximately 80% of French soccer teams used massage as a recovery technique post-exercise to promote recovery.

b) Mechanism and physiological effect of massage

Massage by a therapist, uses a variety of techniques to stimulate and manipulate body tissue (i.e. effleurage, vibration, petrissage, friction and tapotement). Most treatments begin slower and with less pressure using effleurage, which is a continuous gliding motion to stimulate relaxation (Gasibat and Suwehli, 2017). Following, petrissage involves picking up the muscle and tissue in a kneading motion while softly squeezing and wringing to reach deeper muscles, stimulating local circulation and blood flow (Benjamin, 2010). Friction is then specifically applied to focus on adhesions, trigger points

and muscle spasms to loosen the tissue and increase range of motion and blood flow to the muscle (Goats, 1994). Tapotement is a quick striking motion in which direct force to the tissue stimulates local responses and often completes the treatment session (Benjamin, 2010). The proposed benefits of massage includes neurological and psychological benefits, such as increased local blood flow and improved relaxation, as well as decreased muscle tension, inflammatory reactions and pain response (Braverman and Schulman, 1999, Weerapong et al., 2005).

Although massage has been hypothesised to increase blood flow in muscle tissue (Hovind and Nielsen, 1974, Hansen and Kristensen, 1973), research has demonstrated otherwise (Gasibat and Suwehli, 2017, Tiidus and Shoemaker, 1995), citing previous studies to have poor methodological quality, small sample sizes and no/inadequate control groups. Tiidus and Shoemaker (1995) found the mean blood velocities and artery diameters of both the brachial (forearm) and femoral (quadriceps) arteries remained unchanged after each of the massage treatments, indicating that manual massage did not elevate muscle blood flow regardless of massage type or the muscle mass receiving the treatment. These findings are in agreement with another study which reported that massage did not significantly elevate blood flow in massaged muscle tissue post-muscle damaging exercise (Shoemaker et al., 1997).

Gupta et al. (1996) reported that massage was ineffective in removing lactate post-exercise and observed that participants who received massage post-exercise consumed oxygen at a much greater rate compared to other recovery methods used (i.e. active and passive recovery), indicating that massage may potentially hinder recovery. Hinds et al. (2004) reported that, while arterial blood flow remained unchanged post-massage treatment, skin blood flow over the quadriceps was significantly increased, resulting in a potential diversion of blood flow away from recovering muscles (Hinds et al., 2004). However recent evidence alludes to massage as effective in alleviating DOMS and improving perceptions of fatigue, while showing limited signs of improved performance or muscle function recovery (Dupuy et al., 2018, Gasibat and Suwehli, 2017, Guo et al., 2017, Hilbert et al., 2003, Torres et al., 2012).

Table 8: Summary of massage studies using mechanical EIMD protocols

Summary of massage using mechanical EIMD protocols								
Author	**Study design**	**Exercise/muscle damaging protocol**	**Subjects**	**Recovery methods**	**Recovery protocol**	**Outcome measures**	**Measurement times**	**Main finding**
Hilbert et al., 2003	Randomised Control Trial	6 sets of 10 maximal eccentric contractions (right hamstring)	18 male and female volunteers	Massage; control (no massage)	1 session; 20 min, 2h post-exercise (effleurage, tapotement, petrissage)	PT, DOMS, Range of motion	2, 6, 24, and 48h post-exercise	Massage post-exercise reduced DOMS 48h post-exercise, but did not significantly improve hamstring function
Jonhagen et al., 2004	Prospective randomised clinical trial	300 maximal eccentric contractions of the quadriceps (bilaterally)	8 active men and 8 active women	Massage (one leg); Internal control - no massage (other leg)	First session within 10 min post-exercise for 12 min and then once daily for 2 days	Max strength and functional tests based on 1- leg long jumps. Pain using VAS scale.	Baseline, immediately post-exercise and 2ds post-exercise	Massage did not significantly affect pain, strength or function post-exercise
Tiidus and Shoemaker, 1995	Prospective randomised clinical trial	7 sets of 20 maximum quadricep contractions (180 degrees and 90 degrees)	9 healthy university volunteers (5 men and 4 women)	Massage (one leg); Internal control - no massage (other leg)	10-min massage post-exercise and repeated at 24 and 72h (Superficial and deep effleurage strokes)	(PT) - quadriceps at 0, 60, and 180 degrees and DOMS	Baseline, 0, 24, 48 and 72h post-exercise	DOMS reduced at 48h, however no significant effect on muscle strength 96h post-exercise
Zainnudin et al., 2005	Prospective clinical trial	10 sets of 6 maximal elbow flexion contractions (bilaterally), separated by 2 weeks	Ten healthy subjects (5 men and 5 women)	Massage (one arm); Internal control - no massage (other arm)	10 min of massage (effleurage, petrissage and friction) 3h post-exercise	MVC elbow flexor, ROM, upper arm circumference, CK levels, and MS	0 and 30 min post-exercise, and on 1, 2, 3, 4, 7, 10, and 14d post-exercise	Massage improved DOMS by 30%, but had no effect on muscle function
Kargarfard et al., 2015	Randomized controlled trial	5 x 10 squats at 75% 1RM + 5 x 10 leg press at 75% 1RM + maximal isometric quadriceps contraction	30 bodybuilders	Massage; control (no massage)	30 mins of massage (effleurage, petrissage, kneading) performed 2h post-exercise	plasma CK, agility test, vertical jump test, isometric torque test, and DOMS	Baseline, immediately post-exercise, immediately post massage, 24, 37 and 72h post exercise	Massage Improved CK clearance, DOMS and maintained performance better compared to the control group

Table 8 (continued): Summary of massage studies using metabolic EIMD protocols								
Author	**Study design**	**Exercise/muscle damaging protocol**	**Subjects**	**Recovery methods**	**Recovery protocol**	**Outcome measures**	**Measurement times**	**Main finding**
Summary of massage using metabolic EIMD protocols								
Robertson et al., 2004	Randomised crossover design	6 x standardized 30s high intensity exercise bouts on cycle ergometer	9 male players	Massage; Pass (supine rest)	massage applied after 5 min post-exercise for 20 min (effleurage)	Bla, mean power, peak power HR, and fatigue ratings	Baseline, during exercise and pre/post intervention	No significant physiological effects compared with Pass. However, fatigue ratings were improved with massage
Hemmings et al., 2000	counterbalanced design	Two interventions separated by one week. 80 straight punches per round. Total of 10 rounds (5 rounds per performance)	8 male amateur boxers	Massage; Pass (supine rest)	Massage post-exercise for 20 min (effleurage and petrissage)	Boxing ergometer output, HR, and RPE	Baseline, during and after performances	Massage observed to have psychological benefits, but no significant benefits on boxing performance
Lane & Wenger, 2004	Randomised crossover trial	Two intermittent cycling sessions; 18 min of varying work intervals separated by 24h	10 physically active men aged 18–30	1. ACT 2. Massage 3.CWI 4. Seated rest (Pass)	Massage post-exercise for 15 min (Deep effleurage, compressions, deep muscle stripping, jostling, frictions)	Total work, total number of pedal revolutions in each work bout	Baseline, post-intervention and post-exercise	Only the control condition showed a decrease in total work completed between exercise sessions. All other recovery methods including massage facilitated recovery between the session in no hierarchal order
Ogai et al., 2008	Crossover trial	Two intermittent cycling sessions (separated by 35 min): 8 sets of 5s sprints	11 healthy female students	Massage; control	10 min of petrissage	Blood lactate, muscle stiffness, perceived fatigue, muscle power	Baseline, after EX1, during the 15th to 20th min, before EX2, and immediately after EX2	The massage group showed improved power in subsequent exercise and improved perceived fatigue and muscle stiffness. No effects were noted for blood lactate
Viitasalo et al., 1995	Randomized controlled trial	5 sessions of mixed strength, performance and sport-specific training over a 1-week	14 track and field athletes	Underwater massage jets; control	3 sessions of 20-30 min of warm underwater (37°C) massage jets during the week	DOMS, jumping parameters (contact time, height), isometric strength, blood lactate, CK, myoglobin	Biochemical markers (every mon-fri morning); Jump and strength parameters (3 times per week) DOMS (4 times per week)	Small improvements in jumping outcomes post water jet massage, however significant increases in CK and lactate levels after massage jets compared with control

Abbreviations: h – hours; min – minutes; s - seconds; HR – heart rate, Pass – passive recovery; CWI – Cold Water Immersion; ACT – active recovery; CK – creatine kinase; MS – muscle soreness; RPE – rate of perceived exertion; DOMS – delayed onset muscle soreness; VAS – visual analogue scale; MVC – maximal voluntary contraction, Bla – blood lactate; ROM – range of motion; PT – peak torque; d - day

c) Evidence for massage following mechanical EIMD protocols

The majority of the reviewed studies showed improvements with DOMS only, following the massage intervention (Hilbert et al., 2003, Kargarfard et al., 2016), (Shoemaker et al., 1997, Zainuddin et al., 2005) (Table 8). However, a placebo effect cannot be excluded from the sham massage (Hilbert et al., 2003) or no massage with the controls, as the patient might feel that something received (massaged limb) is better than nothing (control limb; (Kargarfard et al., 2016, Shoemaker et al., 1997, Zainuddin et al., 2005).

Improvement in plasma CK levels were noted in two studies (Kargarfard et al., 2016, Zainuddin et al., 2005). It was hypothesised that the decrease in plasma CK levels may be due to the increased blood flow resulting from the massage, flushing it away from the damaged muscle and into the blood circulation (Smith et al., 1994); however, as previously shown, massage had no significant effect on arterial blood circulation (Shoemaker et al., 1997, Tiidus and Shoemaker, 1995). One study showed that following a water jet massage, plasma CK levels actually increased (Viitasalo et al., 1995).

Whilst massage had no effect on performance recovery (Barlow et al., 2007, Gupta et al., 1996, Hinds et al., 2004, Jönhagen et al., 2004, Robertson et al., 2004), bodybuilders were able to maintain performance and improve recovery markers post-massage (Kargarfard et al., 2016). Muscles that had a bigger girth undergoing a DOMS inducing protocol were likely to show improved recovery from massage (Chua et al., 2016). However, whilst bigger legs would be common amongst body-builders, this would not necessarily apply to soccer players running around 10km per session (Ekstrand et al., 2004).

d) Evidence for massage in metabolic EIMD protocols

Some studies have demonstrated positive effects of massage on performance recovery (Lane and Wenger, 2004, Ogai et al., 2008) (Table 8). Massage was shown to increase power output when two intermittent cycling trials were separated by 35 minutes (Ogai et al., 2008). Massage was also shown to promote recovery of performance to a greater extent than passive recovery, but was no more effective than other recovery methods (Lane & Wenger, 2004). Improved recovery was observed after shorter duration massage sessions (i.e. 5 to 12 minutes), compared with sessions more than 12 minutes in duration, especially on untrained participants (Poppendieck et al., 2016). Other studies observed that whilst no significant physiological performance effects were observed; fatigue indices were lower in the massage group indicating at least a perceptual recovery benefit (Hemmings et al., 2000, Hilbert et al., 2003, Ogai et al., 2008, Zainuddin et al., 2005) (Table 8). Reduced DOMS may be due to the massages effect on improved sleep patterns, increased endorphin and serotonin levels

from touch and pressure points, and lowered stress levels associated with performance (Cafarelli and Flint, 1992, Hilbert et al., 2003). Recent systematic reviews have concurred with the improvements observed for perceived recovery of massage post-exercise (Dupuy et al., 2018, Guo et al., 2017, Torres et al., 2012).

Most studies failed to register the type and intensity of strokes of the massage and did not always include the techniques used. Each therapist has a different style and technique, resulting in a variety in the massage treatment provided throughout these studies (Nelson, 2013). Other methodological issues include failure to standardize exercise and dietary intake in the days preceding the visits to the laboratory and a lack of field experiments (Moraska, 2007, Robertson et al., 2004). Due to the wide usage of anecdotal massage prescription most likely due to the perceived recovery benefits, future studies should assess the correct duration, pressure and technique to enhance recovery post-exercise (Gasibat and Suwehli, 2017). Although not reviewed in depth, no performance benefits were also noted with a foam-roller used as a massage technique instead of a therapist (Jones et al., 2015). Benefits were also noted when massage was combined with stretching as a post-exercise recovery method among basketball players (Delextrat et al., 2014). Stretching as a recovery method will be reviewed in the following section.

e) Summary of literature: Massage

Massage post-exercise appeared to be an effective and safe technique to address DOMS (Dupuy et al., 2018, Torres et al., 2012) in both metabolic and mechanical EIMD protocols without having any practically applicable effects on physiological performance recovery within a soccer context. The majority of studies reporting on the recovery effects of massage post-exercise have a number of flaws in their methodologies, leaving inconsistent data on the consensus of the effects of massage. If subsequent performance is necessary, massage should be considered only as a method to address perceived fatigue.

2.3.9 Stretching

a) Stretching as a recovery method

Stretching has been a popular recovery tool post-exercise for many sports codes (Crowther et al., 2017b). In addition, some soccer teams have dedicated as much as 40% of total training time (pre, post and during training) to stretching protocols (Dadebo et al., 2004). It was hypothesised that stretching decreased injury proneness amongst military trainees (Hartig and Henderson, 1999). However, a systematic literature review assessing the impact of stretching on injury prevention could not find sufficient evidence to support or refute routine stretching before or after exercise to prevent

injury, leaving an uncertain consensus on this matter (Thacker et al., 2004). Stretching pre-exercise has also been linked with a decrease in explosive power during subsequent training, therefore providing no convincing evidence to utilise stretching before a match or training session (Shrier, 2004). The inclusion of stretching in the present review will only be as a recovery tool post-exercise. A recent survey investigating the perceptions of team sport athletes found stretching to be perceived as the most effective recovery method (Crowther et al., 2017b). Stretching was also the most used recovery method in a survey among national and international athletes (Crowther et al., 2017b) and many soccer clubs utilise stretching as part of their recovery protocol (Nedelec et al., 2013).

b) Mechanisms and physiological effects of stretching

The primary purpose of stretching is to increase joint range of motion and decrease stiffness of musculotendinous tissue (Bandy et al., 1997, Thacker et al., 2004). Bandy et al. (1997) suggested that a 30 second static stretch is an effective amount of time for a hamstring muscle to increase range of motion and that any increase in duration of the stretch will not show improved benefits. Nedelec et al. (2013) reported that most clubs are implementing static stretching of 31 seconds, with two to five repetitions per session. Stretching concentrates on increasing the musculotendious unit length (Page, 2012) and it is thought that stretching contributes to decreased oedema following muscle-damaging exercise (Bobbert et al., 1986). However, vigorous stretching post-muscle damaging exercise could also lead to further damage of the muscle tissue (Lund et al., 1998). Implementation of stretching needs to be justified, as the potential negative effects on recovery can hinder athlete performance; therefore, studies assessing the effects of stretching post-exercise will be reviewed below.

Table 9: Summary of stretching studies using mechanical and metabolic EIMD protocols

Summary of stretching studies using mechanical EIMD protocols								
Author	**Study design**	**Exercise/muscle damaging protocol**	**Subjects**	**Recovery methods**	**Recovery protocol**	**Outcome measures**	**Measurement times**	**Main finding**
Lund et al., 1998	Crossover design	eccentric exercise until exhaustion in right quadriceps (isokinetic dynamometer, in two different experiments, with 13-23 month interval)	Seven healthy untrained women	stretching; control (no stretching)	passive stretching (3 x 30 s with 30s rest) of right quadriceps muscle	PCr/Pi ratio, dynamic muscle strength, CK levels and MS	Measurements were obtained at baseline and daily for 7d post-exercise	Stretching did not have any significant influence on any outcome measures
Jayaraman et al., 2004	Randomised control trial	Intense eccentric knee extension MVC trials	32 untrained males	1. Heat 2. Stretch 3. Heat + stretch 4. No treatment	Daily stretching of hamstrings and quadriceps (20 s x 3 sets with 30s rest)	Isometric strength, MS, and MRI of the thigh	Baseline and 2,3,4,8 and 15d post-exercise	Stretching did not significantly reduce MS, swelling or muscle damage
Mika et al., 2007	Randomised crossover trial	Three sets of dynamic leg extension and flexion (20–110 degrees) at 50% of MVC	10 healthy male	ACT; Pass; Stretching	Static stretching and PNF of quadriceps (hold 5 s)	EMG, MVC	Baseline and post exercise and post-recovery	ACT was superior for all outcome measures compared to Pass and stretching
Wessels & Wan, 1994	Prospective Clinical trial	3 sets of 20 maximal eccentric and concentric hamstring exercises on both legs	10 healthy, sedentary subjects (2 woman and 8 men)	Static stretching (one leg); Internal control - no stretching (other leg)	10 x 1min seated hamstring stretch on one leg	MS, SLR	Muscle pain (VAS) measured every 12 h for 72h. SLR measured at 0 and 48h	There was a significant difference in the VAS over time for both experiments but not between legs. Stretching post-exercise did not reduce DOMS

Table 9 (continued): Summary of stretching studies using metabolic EIMD protocols								
Author	**Study design**	**Exercise/muscle damaging protocol**	**Subjects**	**Recovery methods**	**Recovery protocol**	**Outcome measures**	**Measurement times**	**Main finding**
Beckett et al., 2009	Counterbalanced (Latin-square design)	3 sets of 6 sprint repetitions (4 min recovery between sets)	12 male team-sport players	stretching; control (no stretching)	6 static lower limb stretches held for 20s	RSA, mean sprint, fastest sprint and COD	Baseline and post-intervention	Lower limb stretching during recovery periods between efforts may compromise RSA performance but has less effect on COD performance
Pooley et al., 2017	Crossover	80 min competitive soccer match	10 professional youth soccer players	Static stretching; control (passive seating)	Two 15 s stretches (gastrocnemius, hamstrings, quadriceps, glutes, hip flexors, adductors and abductors)	Muscle oedema, CK, CMJ and MS	Baseline, 0 and 48h post-match	No significant differences between static stretching or control was observed for any performance or recovery outcomes
Smith et al. 1993	Randomized controlled trial	5 min marching	20 active university students	Static stretching; ballistic stretching	17 stretches (static stretching – hold for 1 min; ballistic stretching – continuous bouncing 60/min)	DOMS, CK levels	Baseline, 0, 24, 48, 72, 96, 120h post-stretching	Both stretching (static and ballistic) significantly increased DOMS and CK levels. Static more so than ballistic for DOMS

Abbreviations: h – hours; min – minutes; s - seconds; d - days; PCr/Pi - inorganic phosphate to phosphocreatine; MRI –magnetic resonance imaging; Pass – passive recovery; ACT – active recovery; CK – creatine kinase; MS – muscle soreness; RPE – rate of perceived exertion; DOMS – delayed onset muscle soreness; VAS – visual analogue scale; MVC – maximal voluntary contraction; COD – change of direction; RSA – repeat sprint ability; SLR – straight leg raise; PNF – proprioceptive neuromuscular facilitation; EMG – electromyography; CMJ – countermovement jump

c) Evidence of stretching studies using mechanical and metabolic EIMD protocols

No performance, physiological or perceived recovery benefits were noted with using stretching as a post-exercise recovery method in the reviewed studies using mechanical or metabolic EIMD protocols (Jayaraman et al., 2004, Lund et al., 1998, Mika et al., 2007, Pooley et al., 2017, Smith et al., 1993, Wessel and Wan, 1994) (Table 9). Furthermore, it was suggested that stretching between bouts of exercise (Beckett et al., 2009) or post-exercise can potentially decrease performance and increase DOMS and muscle damage (Lund et al., 1998, Smith et al., 1993). However, the small sample sizes, use of untrained participants, unaccustomed exercise protocols and varying stretching protocols, in conjunction with lengthy hiatus' between the trials (increasing exposure to confounding variables) most likely affected the results, therefore limiting these research conclusions.

The studies reviewed in a Cochrane paper investigating the effect of stretching on muscle soreness post-DOMS inducing exercise, produced inconsistent findings (Herbert et al., 2011). The authors observed little or no effect of stretching on the muscle soreness experienced one week after exercise (Herbert et al., 2011). Dadebo et al. (2004) observed that in most professional soccer clubs, the stretching protocols were diverse, inconsistent and depended on the experience of the staff involved in administering these protocols, leaving a varied, anecdotal approach with limited available guidelines. The above findings concurred with a recent study showing no effect of studies exploring stretching in basketball players (Calleja-González et al., 2016). At the very least players should be advised not to partake in static stretching compared to ballistic stretching in between exercise sessions (Beckett et al., 2009). Additionally, a recent systematic review confirmed that stretching had no positive effect on DOMS and any stretching within 6 hours post-exercise could further increase DOMS (Dupuy et al., 2018).

d) Summary of literature: Stretching

Currently, there is no evidence confirming stretching to effectively assist in post-exercise recovery, leaving practitioners with further uncertainties regarding guidelines going forward. Unless new research shows benefits to justify its use, stretching post-exercise should not be recommended to soccer players.

2.3.10 Electromyostimulation

Electrical stimulation is an additional recovery aid employed by various sporting teams. However, only 13% of French teams employ this method for recovery in professional soccer (Nedelec et al., 2013). The high cost, complicated use, and lack of convincing evidence for recovery has deemed it an unnecessary item in many medical departments, although it is easily portable for use while travelling.

Electromyostimulation is often included in rehabilitation protocols when neurological damage or inadequate involuntary contractions of the muscles are able to take place (Maffiuletti et al., 2000). Electromyostimulation essentially replaces the natural muscle contraction mechanism by the transmission of electrical impulses to stimulate the motor neurons peripherally (Maffiuletti et al., 2000). In the present review, EMS will only be discussed as recovery tool post-exercise.

a) Mechanism of electromyostimulation

It has been suggested that muscle contractions may be beneficial to recovery and tissue healing post-exercise, due to the increased blood flow resulting from the 'pumping effect' (Barnett, 2006). A review reported that EMS, stimulating muscle contractions, reduced post-exercise blood lactate compared to passive recovery (Malone et al., 2014). It is hypothesised that the increased blood flow due to the contractions will 'remove the metabolites of muscle damage' (Bieuzen et al., 2014a). Post-exercise recovery by means of EMS focuses on implementing submaximal skeletal muscle contraction that mimics active recovery (Malone et al., 2014). Electromyostimulation delivers an electric current from a device through surface electrodes placed on the skin adjacent to the muscles' motor point (Seyri and Maffiuletti, 2011). The physiological effects of EMS vary depending on the frequency used (Sharma et al., 2017). A low frequency (i.e. 4Hz) EMS increased cutaneous blood flow greater than a higher frequency (i.e. 110Hz) EMS applied to the forearm flexor (Cramp et al., 2000). Similar lower frequencies were found to be beneficial as an analgesic effect, blunting the pain sensation and improving DOMS scores (Walsh et al., 1995). The mean impulse frequency used in an EMS protocol for post-exercise recovery was 4.7 ± 2.4 Hz (Malone et al., 2014). The intensity and amplitude can be altered according to the specific requirements of each protocol. Most reviewed studies employed a combination of different recovery methods, including EMS, when assessing recovery responses (Cortis et al., 2010, Jajtner et al., 2015, Lattier et al., 2004, Pinar et al., 2012, Tessitore et al., 2007, Zarrouk et al., 2011). A single study by Taylor et al. (2015) considered the sole use of EMS for post-exercise recovery.

Table 10: Summary of electromyostimulation studies using mechanical and metabolic EIMD protocols

Summary of electromyostimulation studies using mechanical and metabolic EIMD protocols								
Author	**Study design**	**Exercise/muscle damaging protocol**	**Subjects**	**Recovery methods**	**Recovery protocol**	**Outcome measures**	**Measurement times**	**Main finding**
Lattier et al., 2004	Randomised crossover	High-intensity uphill running. An all-out running test was also performed 80 min post-exercise	Eight well trained male subjects	EMS (Low Hz), Pass, ACT (sub-maximal running)	EMS of both lower limbs for 20 min in a supine position.	Evoked twitch and MVC of knee extensor muscles and EMG of the quadriceps	Immediately post-exercise, 10 min post-recovery and 65 min post-exercise	EMS, Pass or ACT recovery interventions had no significant effect on the MVC of the quadriceps post-exercise protocol
Cortis et al., 2010	Randomised crossover	Sub-maximal running test	8 males	Low-intensity water exercises, EMS, and Pass (sitting rest)	EMS (in supine) starting on 9 Hz and going down to 1 Hz over time for 20 min	physiological (oxygen consumption, Bla and hemoglobin saturation), psychological (RPE, DOMS), and CMJ	Baseline, after morning and afternoon exercise sessions	EMS was the second most effective intervention for improving the DOMS and RPE
Tessitore et al., 2008	Randomised crossover	Four football games, scheduled bi-weekly for 2 weeks	10 male futsal players	Pass; water-exercises; ACT (land exercises); EMS	20-min EMS on the quadriceps. EMS staring on 9 Hz and going down to 1 Hz over time	CMJ, bounce jumping, 10-m sprint. Hormones (salivary cortisol, urinary catecholamine's). RPE, DOMS, Questionnaire of recovery stress for players, sleep duration	Baseline, pre/post exercise and pre/post intervention	No significant effect of EMS was found on any performance measurements. Participants perceived increase benefits from EMS and water exercises compared to Pass and ACT
Tessitore et al., 2007	Randomised crossover	100 min soccer training session (2d rest between experimental sessions)	Twelve young professional soccer players	Pass (sitting); low-intensity land exercises (jogging, running and stretching); water-aerobic exercises; and EMS (lying supine)	20-min EMS on the quadriceps. EMS staring on 9 Hz and going down to 1 Hz over time	CMJ, bounce jumping, 10-m sprint, RPE, DOMS	Baseline, pre/post exercise and pre/post intervention	Dry-aerobic exercises and EMS were more beneficial than water-aerobic exercises and Pass for improving DOMS
Zarrouk et al., 2011	Crossover	5 sets of 10 concentric knee extensions at 80% PT at 120°/s, with 3 min recovery between sets	Eight male elite judo players	ACT; Pass; EMS	EMS low-frequency (10 Hz) to quadriceps for 3 min	The PT and maximal EMG activity from the knee extensors were quantified at isokinetic velocities of 60, 120, and 180, with 5 repetitions at each velocity	Baseline, during exercise and 3 min post-intervention	EMS decreased neuromuscular fatigue in quadriceps isokinetic protocol

Table 10 (continued): Summary of electromyostimulation studies using mechanical and metabolic EIMD protocols								
Author	**Study design**	**Exercise/muscle damaging protocol**	**Subjects**	**Recovery methods**	**Recovery protocol**	**Outcome measures**	**Measurement times**	**Main finding**
Heyman et al., 2009	Randomised crossover	Two climbing tests until exhaustion, separated by the recovery intervention	13 female well-trained climbers	ACT, Pass, EMS, CWI	EMS on bilateral forearm muscles (bisymmetric current) for 20 min	HR, Bla, RPE, thermal stress, and handgrip strength as well as technical difficulty with climbing	Before warming up, before and after tests and after 10 min of recovery	ACT and CWI interventions maintained performance whereas EMS and Pass impaired performance
Martin et al., 2004	Randomised crossover	intermittent one-legged downhill running on a treadmill	Eight healthy males	ACT; Pass; EMS	EMS was applied to the femoral nerve for 30 min on low frequency	MVC quadriceps, Pain levels, muscle fatigue and muscle contractile properties	Baseline, 30 min, 24, 48, and 96h post-exercise	No significant effect on recovery for any method, including EMS
Taylor et al., 2015	Randomised counter-balanced	60m x 50m maximal sprints	28 professional rugby and football players	EMS (for 8 h); Pass	EMS on the peroneal nerve, a frequency of 1 Hz	DOMS, CMJ, Bla and CK and saliva (testosterone and cortisol)	Baseline, 2 and 24h post-exercise	Improvements were noted with CMJ recovery, CK reduction and MS for the EMS group compared to the control
Pinar et al., 2012	Randomized counter-balanced crossover trial	6x30s cycle sprints and then a Wingate cycle test post-intervention	12 male sport players	Massage; EMS; Pass	EMS on quads and hamstring for 24 min using frequency range of 1-9 Hz	Lactate, HR, peak and mean power, RPE	Baseline, post-exercise, post-recovery intervention, post-Wingate test	No difference between any of the interventions on recovery markers
Jajtner et al., 2015	Randomized controlled trial	High volume lower body resistance workout	30 resistance trained men	EMS; CWI; Pass	EMS on quads and hamstring for 24 min using frequency range of 1-9 Hz	DOMS, performance measures (peak and mean squat power), myoglobin, CK values, hemoglobin	Baseline, pre-exercise, 0, 30 min, 24 and 48h post-exercise	No benefits on recovery parameters were observed from EMS

Abbreviations: h – hours; min – minutes; d - days; Pass – passive recovery; ACT – active recovery; CK – creatine kinase; DOMS – delayed onset muscle soreness; RPE – rate of perceived exertion; Hz - hertz ; MVC – maximal voluntary contraction; EMG – electromyogram; EMS – electromyostimulation; m – metre; Bla – blood lactate; CWI – cold water immersion; HR – heart rate; CMJ – counter movement jump; PT – peak torque

b) Evidence of electromyostimulation post-exercise

Performance improvements were noted in some studies using EMS as a recovery method (Lattier et al., 2004, Taylor et al., 2015, Zarrouk et al., 2011) (Table 10), while other studies showed no (Heyman et al., 2009, Jajtner et al., 2015, Martin et al., 2004, Pinar et al., 2012) (Table 10) or limited performance benefits (Malone et al., 2014, Babault et al., 2007). Further, some studies showed increased perception of recovery following EMS (Cortis et al., 2010, Tessitore et al., 2008, Tessitore et al., 2007). This perceived recovery benefit from the EMS noted may explain the improved subsequent performance (Lattier et al., 2004). On the other hand, reduced perception of pain or DOMS post-EMS was not correlated to any performance improvements in soccer (Tessitore et al., 2007, Tessitore et al., 2008) or sub-maximal running (Cortis et al., 2010).

In concurrence with the above, a review assessing the effects of EMS on strength recovery, athletic performance and DOMS post-exercise found 90% of the studies reported no benefit on any performance parameters (Babault et al., 2011). One benefit, which remained consistent throughout most of the studies, was the subjective benefit experienced by the participants and the increased feeling of well-being following the intervention compared to other interventions (Babault et al., 2011, Malone et al., 2014). However, the authors raised concerns regarding the methodologies of the various studies on correct electrode placement, duration and intensity of the EMS, and different healthcare providers administering the intervention (Babault et al., 2011, Malone et al., 2014).

c) Summary of literature: Electromyostimulation

In conclusion, there is limited beneficial evidence to warrant the use of EMS as a recovery intervention, to improve or maintain performance parameters. However, EMS can provide positive effects to decrease DOMS and improve psychological well-being (Babault et al., 2011, Malone et al., 2014) and EMS could provide a simple recovery option when travelling.

2.4 Conclusion

The ever-growing popularity of soccer in South Africa, in addition to the competitive nature of professional leagues compels players and medical staff to discover means to increase recovery time before each match. Current research highlights the negative effects of inadequate recovery strategies on performance and injury risk (Dellal et al., 2013, Dupont et al., 2010); therefore, optimal utilization of recovery methods by soccer teams is crucial. As highlighted, the literature revealed a huge variety of recovery methods currently employed in soccer and other team sports (Nédélec et

al., 2012, Venter, 2014). The question remains as to the most effective and efficient method to achieve optimal recovery.

There is ample and convincing evidence supporting the roles for nutrition and hydration in enhancing recovery post-exercise by addressing dehydration and glycogen depletion following athletic performance (Halson, 2014, Nedelec et al., 2013). However, evidence supporting the benefit of other popular recovery methods (i.e. CWI, CWT, massage, stretching, CG, active recovery and EMS) on post-exercise recovery indices was inconclusive (Barnett, 2006, Nédélec et al., 2012). Additionally, the importance of sleep has also been highlighted in this review, and findings suggest that sleep should be explored further in connection with player recovery (Fullagar et al., 2015a, Nedelec et al., 2015a, Simpson et al., 2017). Although previous studies have reported that a combination of recovery methods can improve recovery and performance indices (Duffield et al., 2014), justifications are still required before administering each method (Cheung et al., 2003, Hill et al., 2017, Nedelec et al., 2015b). Therefore, recovery methods (i.e. CWI, CWT, massage, stretching, active recovery or CG), which do not have an adequate evidence base, should only be employed as required to interact and improve the key evidence-based recovery methods (i.e. nutrition, hydration and potentially sleep interventions).

Overall, a major limitation across the literature was the lack of standardised exercise protocols when investigating the effect of specific recovery methods. Future research should focus on developing standardised measurement outcomes and protocols in athletic environments. Furthermore, detailed and standardised exercise protocols would ensure replication and comparisons across studies. Further analyses of combined interventions and the effect of individual preferences on recovery methods would be useful for future studies to benefit player recovery. The prevalence of recovery method uses and practices among professional South African soccer teams is yet to be fully examined. Before recommending best practice for recovery methods in South African soccer, it is important to understand current practice and recovery implementation methods. In order to achieve this aim, a questionnaire has been developed and implemented. This will be reviewed in the following chapter.

CHAPTER 3: THE USE OF RECOVERY METHODS IN SOUTH AFRICAN SOCCER

3.1 Introduction

Competitive soccer provides a full body workout, placing considerable stress on several systems within the body (Bradley et al., 2009, Reilly & Ekblom, 2005). Training from week to week, including matches, causes fatigue that results in a decrease in recovery and subsequent performance levels (Ali, 2011, Ekblom 1986, Nédélec, 2012).

Recovery functions to reverse the effects of fatigue and is seen as complete when the player is able to match or exceed pre-training/competition performance levels (Jones et al., 2017). Recovery can be viewed as a passive process; however, for players to cope with constant training/match loads and stressors, post-exercise recovery methods are used to accelerate the restoration of homeostasis and prepare the player to be able to perform high-quality work during training and matches (Reilly et al., 2008). Neglecting appropriate recovery methods could negatively affect the athlete and team's performance, resulting in a possible injury or burnout (Reilly & Ekblom, 2005).

Despite the variety of recovery methods (i.e. CWT, massage, stretching, active recovery and CG) used by sports teams, there is a lack of evidence to suggest the most appropriate and effective recovery method (Coffey et al., 2004, Lane & Wenger 2004). However, sleep interventions, nutrition and hydration were found to be potentially beneficial in reversing the effects of post-exercise fatigue and improving recovery (Nedelec et al., 2013).

Regardless of the lack of empirical evidence examining the effects of recovery modalities, soccer teams in South Africa continue to invest in recovery strategies aimed to improve recovery and performance. Therefore, further research is required to understand which recovery methods are currently being used as well as how these are applied in professional soccer in South Africa. The findings of the present study will assist South African soccer teams in identifying effective recovery methods to cope with the physical demands of the soccer season. The aim of this study was to determine the use of post-exercise recovery methods in professional South African soccer teams through these objectives: describe post exercise recovery methods used by staff of South African professional soccer teams; to compare differences between the staff of South African soccer leagues, regarding recovery method use and to explore potential barriers that staff members faced with implementation of post-exercise recovery methods.

3.2 Methods

3.2.1 Study design

A questionnaire-based cross sectional descriptive survey was used to collect responses from Premier Soccer League (PSL), National First Division (NFD) and National Second Division (NSD) club staff. Responses were obtained through face-to-face interviews, telephonic interviews or via an online survey portal.

3.2.2 Participants

Staff from 16 teams from each of the top three professional leagues in South Africa were invited to participate (48 participants). Purposive sampling was used to recruit the club staff (e.g. doctor, physiotherapist, biokineticist, fitness trainer, or coach) who were directly responsible for overseeing recovery modalities in their respective teams. Participants were required to be registered with either a PSL, NFD or NSD team for the 2013/2014 season. Participants must have had at least one year's experience working with a professional soccer team. Staff members were excluded if they previously worked for a different soccer club within the 2013/2014 season or had been transferred from another club within the last six months.

As more teams played in the NSD, staff from only 16 teams were selected from this league as it allowed a weighted comparison with the staff from 16 teams in both PSL and NFD. Teams from this division were randomly selected from the overall population. If a staff member from a team was unable to be contacted, another team was randomly selected from the remaining teams to be contacted. If more than one staff member was involved with recovery methods, the most senior member was interviewed.

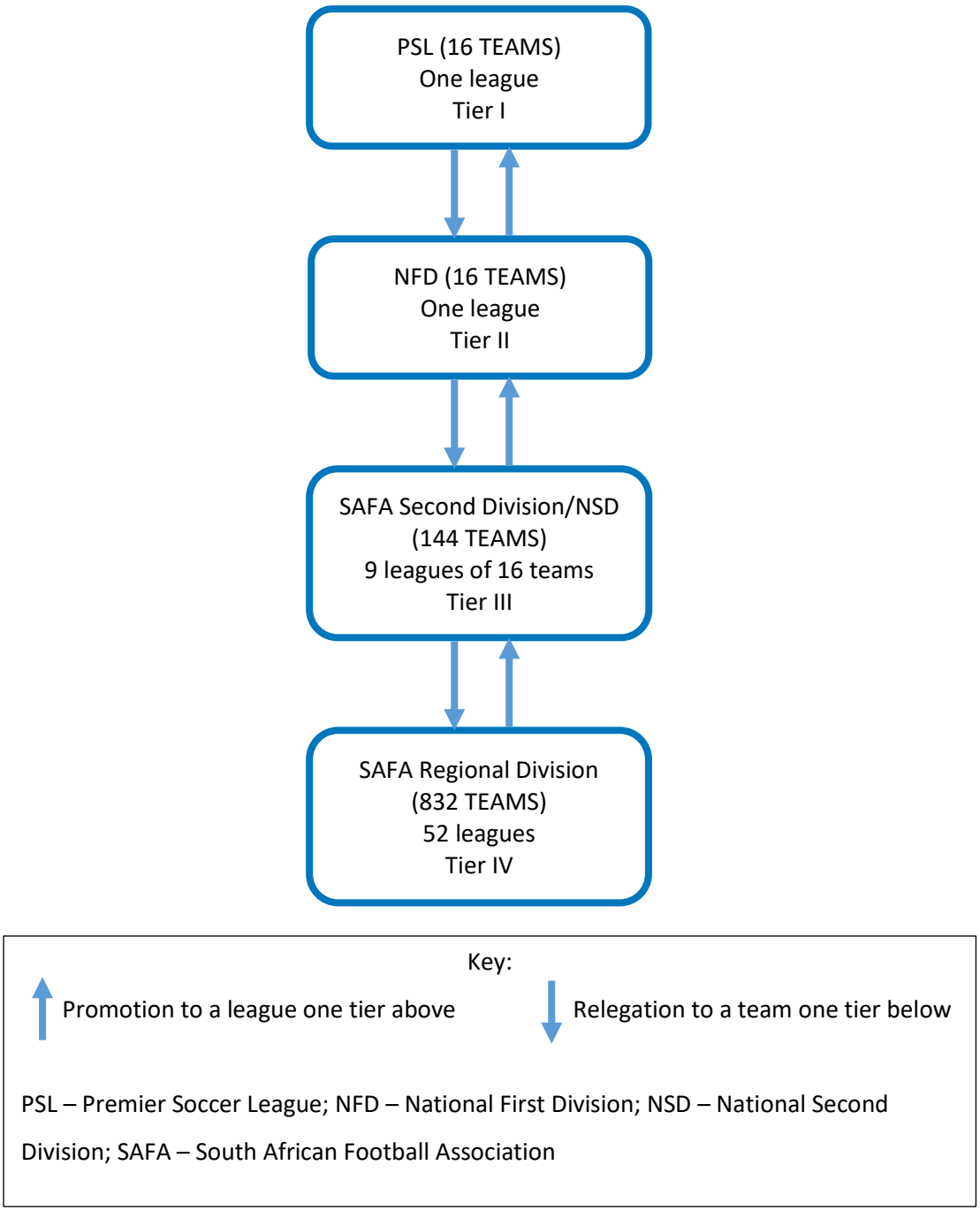
3.2.3 Ethical consideration

The study was performed in accordance with the principles of the Declaration of Helsinki (October, 2013). Ethical Approval to conduct the study was obtained from the Faculty of Health Sciences Human Research Ethics Committee at the University of Cape Town (HREC/Ref- 044/2014; see Appendix III). Prior to completing the questionnaire, each participant was presented with an information sheet and informed consent form. The aims of the study, as well as information relating to privacy and confidentially were included in the information sheet. Participants were also informed of their right to withdraw from the study at any moment without prejudice or reason. Informed consent was then obtained from each participant. Only the researchers involved in the study had access to the raw data. There were no identifiable risks to participating in the study and participants were informed that they would have access to the findings.

3.2.4 Study setting

The South African soccer league consists of four tiers (see Figure 3). The PSL (first tier) was established in 1997 and is comprised of 16 teams. The NFD (second tier) is also comprised of 16 teams. These leagues include teams from various provinces within South African. The third tier is administered by the South African Football Association (SAFA) and is known as the SAFA Second Division (referred to as the NSD in this dissertation). Previously known as the Vodacom league (between 1998-2012), this division is comprised of 144 teams, equally divided into nine provincial leagues. At the end of each season, two teams are promoted while a further two teams are relegated from each league. The SAFA regional league (tier four) is not considered a professional league (Koonyaditse, 2010).

Figure 3: South African professional soccer tiers with promotion and relegation arrows



3.3 Procedure

3.3.1 Data sources

The study utilised a purpose designed questionnaire. The questionnaire was developed in accordance with the available literature pertaining to post-exercise recovery methods (Nédélec et al., 2012, Nedelec et al., 2013). Participants were asked which of the 11 post-exercise recovery methods they implemented in their respective teams and were only asked further questions which pertained to the recovery methods they used. The questionnaires were therefore more efficient, quicker to answer

and prevented participants being presented with irrelevant questions. The questionnaire consisted of multiple choice questions, where participants were required to select the most relevant answer, as well as 5-point ordinal Likert Scale questions with descriptors (strongly agree, moderately agree, undecided, moderately disagree, strongly disagree), where participants had to rate the importance, frequency, and/or quantity of each item (see Appendix II).

The questionnaire used in this study can be viewed (see Appendix II). Initially the questionnaire attempted *to investigate the knowledge, attitudes and beliefs of the participants and to note any* correlations between these categories. However, it was realized that there were not enough knowledge questions in each category to be effectively analysed and it was decided to keep the data analyses simple and find out when and what recovery methods the participants were using. Therefore, each section has a few knowledge questions which were not analysed.

3.3.2 Validation of the questionnaire

Prior to providing the study participants with the aforementioned questionnaire, a pilot study was conducted on five youth medical staff from Ajax Cape Town Football Club, who were each provided with a copy of the questionnaire to complete and asked to provide feedback on its design. Responses to the pilot study were used to assess content and face validity and were not used for data analysis. Further, a panel of experts in the field of sports recovery reviewed the questionnaire and provided feedback. Relevant suggested changes were made before the final questionnaire was made available to study participants (see Appendix II).

3.3.3 Data collection

Staff members (participants) responsible for each teams' recovery methods were contacted through details obtained from the team managers of the respective clubs. The investigator contacted the potential participants to inform them of the study and arrange an interview. The most senior staff member responsible for recovery in the club was contacted, however if this was not possible, the next most senior staff member was approached. Each interview (approximately 40 minutes in duration) took place at either the clubs' facility, at a travelling team's hotel, via skype or telephonically. Due to financial constraints and logistical issues, several participants completed an electronic questionnaire made available on FluidSurvey. All interviews were conducted in English and no translation was required. Sixteen face-to-face interviews were conducted, and 32 participants completed the online survey.

3.4 Statistical Analyses

Statistical analyses were performed using Statistica statistical software (version 12, StatSoft, Inc. 2012). Chi-square measures of association and percentages were used for descriptive information. On the Likert scale, 'strongly agree, and 'moderately agree' were considered as positive responses and the rest of the responses were considered negative. All data was presented as the mean ± standard deviation. Statistical significance was accepted as $p < 0.05$. The three-tiered soccer leagues were compared using a one-way analysis of variance (ANOVA) and post-hoc tests.

3.5 Results

3.5.1 Participants

Forty-eight surveys were completed and comprised of responses of staff from 16 teams from each of the three leagues. One respondent (representing a team in the NSD) submitted an incomplete questionnaire, therefore only certain data responses were available for this team. The majority of participants were either team fitness trainers or physiotherapists. The average age of participants was 31 ± 5 years (range 23 to 48 years). On average, participants had worked within various soccer leagues for 8 ± 4 years (range 1 to 19 years), and 3 ± 3 years (range 1 to 15 years) with the same team. Table 11 details the profession of each participant per league.

Table 11: Study participant's profession per league

	Premier Soccer League (n=16)	**National First Division** (n=16)	**National Second Division** (n=16)	**Total** (n=48)
Fitness Trainer	5 (31%)	8 (50%)	5 (31%)	18 (38%)
Biokineticist*	2 (13%)	1 (6%)	1 (6%)	4 (8%)
Physiotherapist	7 (44%)	4 (25%)	4 (25%)	15 (31%)
Doctor	-	1 (6%)	1 (6%)	2 (4%)
Coach	-	2 (13%)	4 (25%)	6 (13%)
Other	2 (13%)	-	1 (6%)	3 (6%)

'Other' included one exercise physiologist, one head of youth and one exercise and rehabilitation specialist.

*A biokineticist is a specialized exercise therapist who works alongside allied health professionals. A biokineticist is recognized and registered with the Health Professions Council of South Africa.

3.5.2 Teams' access to medical and support staff

Within the PSL, seven teams (44%) employed one physiotherapist, six teams employed two physiotherapists (38%), and three teams (18%) did not employ a physiotherapist. Within the NFD, 12 teams (75%) employed a physiotherapist, and each of the remaining four teams (25%) employed two physiotherapists. Within the NSD, 11 teams (69%) employed at least one physiotherapist, and four teams (25%) reported that they did not employ a physiotherapist. A total of seven teams amongst the three divisions did not have a fitness trainer. The majority of teams within the PSL employed at least one (n=12, 75%) or two (n=2, 13%) fitness trainers. Approximately half of the teams among the three divisions did not employ a club doctor (n=23, 48%), and more than half of these teams did not employ a biokineticist (n=32, 67%). There were significantly more full-time participants in the PSL than the other two leagues (PSL 13 vs. NFD 6 vs. NSD 6, $\chi 2 = 8.18$, $p = 0.017$).

3.5.3 Planning and Executing Recovery Methods

Across all three soccer leagues, the personnel most responsible for planning and executing post-training and post-match recovery methods were the fitness trainers (see Table 12). The fitness trainers planned the recovery methods in more than half the teams (n=25) and executed them in 65% of the teams ($\chi^2 = 21.06$, $p = 0.007$). Two teams (both within the NSD) indicated that they did not use recovery methods.

Table 12: Distribution of responsibility for planning and executing recovery methods per league

		Premier Soccer League	National First Division	National Second Division	Total
Plans Recovery	**Fitness Trainer**	8	12	5	25
	Biokineticist	2	1	1	4
	Physiotherapist	5	3	5	13
	Coach	-	-	2	2
	Doctor	-	-	1	1
	Other	1	-	-	1
Executes Recovery	**Fitness Trainer**	10	14	6	30
	Biokineticist	2	1	-	3
	Physiotherapist	4	1	5	10
	Coach	-	-	2	2
	Doctor	-	-	-	-
	Other	-	-	-	-

Staff planning (χ^2 = 10.14, p = 0.255) and *executing* (χ^2 = 11.95, p = 0.063) *recovery methods. Both are not significant as p > .05*

3.5.4 Recovery methods

a) Recovery methods used

Across the three leagues, hydration (94%), nutrition (85%) and stretching (85%) were most frequently utilised in post-exercise recovery. Active recovery and CWI were both used by all 16 PSL teams, however the percentage decreased progressively by tier. Massage was used by 81% of PSL teams, but only by 50% of NFD and 38% of NSD teams. Overall, NSD teams used significantly fewer recovery methods than PSL teams (PSL 7 ± 2 vs. NSD 5 ± 1, $p < 0.003$). A summary of the recovery methods used per league is presented in Table 13 below.

Table 13: Recovery Methods Utilised in Each League

Recovery Methods	Premier Soccer League (n=16)	National First Division (n=16)	National Second Division (n=16)	Chi Square	P-value (p<0.05)	Total
Hydration	15 (94%)	16 (100%)	14 (88%)	2.13	0.34	45 (94%)
Nutrition (Carbohydrates and Proteins)	16 (100%)	12 (75%)	13 (81%)	4.3	0.11	41 (85%)
Cold Water Immersion	16 (100%)	10 (63%)	7 (44%)	12.2	0.002	33 (69%)
Active Recovery	15 (94%)	13 (88%)	8 (56%)	10.6	0.004	36 (75%)
Sleep Protocols	1 (6%)	2 (13%)	2 (13%)	0.4	0.80	5 (10%)
Stretching	14 (88%)	14 (88%)	13 (81%)	0.5	0.76	41 (85%)
Massage	13 (81%)	8 (50%)	6 (38%)	6.6	0.03	27 (56%)
Compression garments	7 (44%)	7 (44%)	0 (0%)	9.8	0.007	14 (29%)
NSAIDS (Non-Steroidal Anti Inflammatory)	1 (6%)	1 (6%)	2 (13%)	0.54	0.76	4 (8%)
Contrast Water Therapy	4 (25%)	4 (25%)	1 (6%)	2.46	0.29	9 (19%)
Electromyostimulation	1 (6%)	0 (0%)	1 (6%)	1.04	0.59	2 (4%)

n = number of participants who answered the question in each league
% = percentage number of participants in that league who used the specific recovery method
Total = overall number of participants who used the specific recovery method in their team

b) Situational frequency of use of recovery methods

Participants were required to indicate when they made use of each of the recovery methods (options included post-match, post-training, day after exercise, during congested fixtures, when injured or only after intense exercise). Participants were able to choose more than one option if they used that recovery method more often, hence the large number of responses recorded. The majority of recovery methods utilised were implemented when the exercise was more intense: post-match (n= 152),

congested match schedule (n= 148) and after intense session or match (n= 142; χ^2 = 66.123, p value = 0.0217). However, participants also indicated that they performed a considerable amount of recovery methods the following day after exercise (n= 116) regardless of the intensity or match schedule. Table 14 details when specific recovery methods were implemented.

Table 14: Situational frequency of use of recovery methods among soccer teams

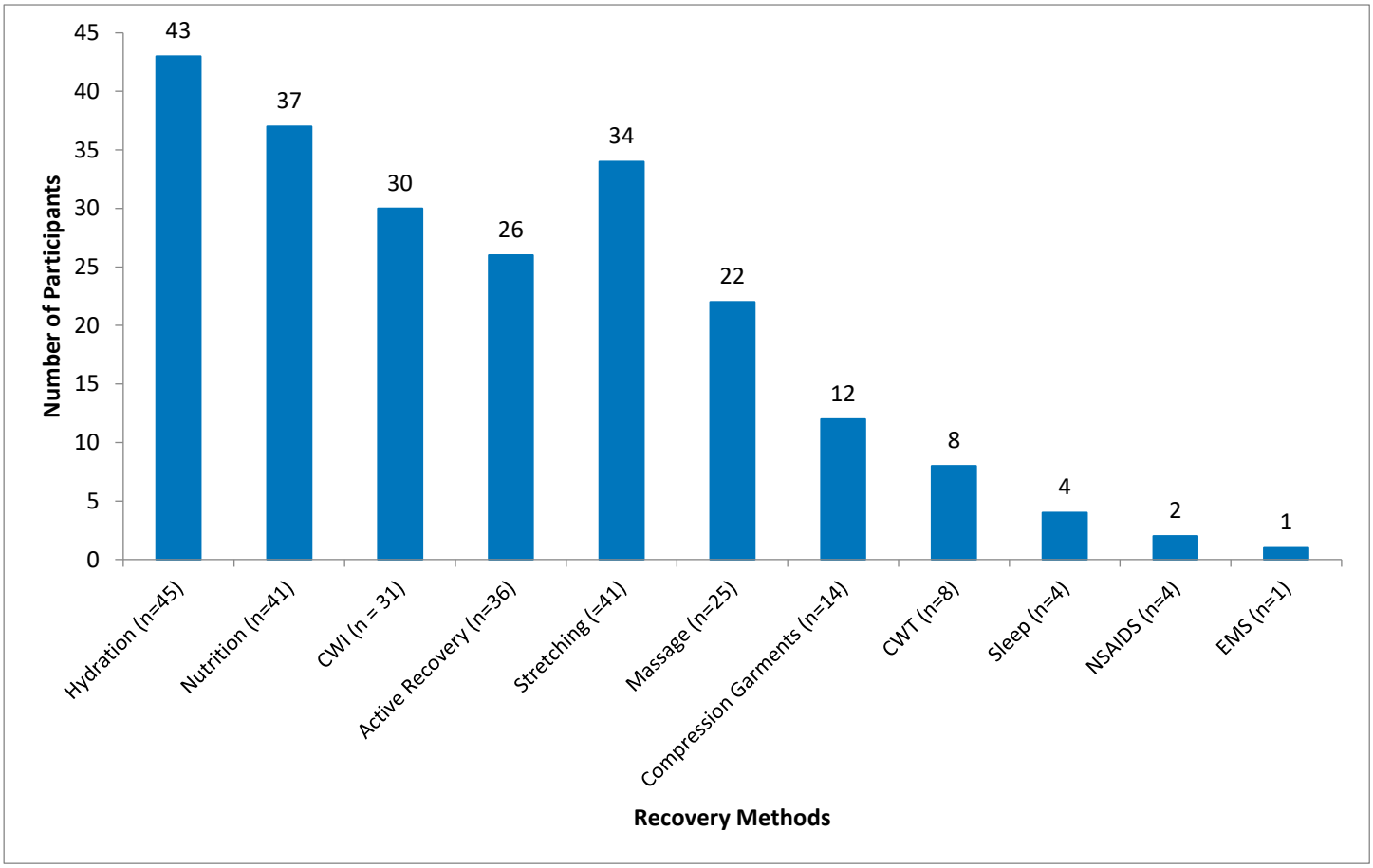
Recovery method	Post-match	Post-training	Day after exercise	Congested schedule	When injured	After intense exercise
Hydration	42 (93%)	42 (93%)	21 (46%)	32 (71%)	10 (22%)	34 (75%)
Nutrition	24 (58%)	17 (41%)	11 (24%)	15 (36%)	6 (15%)	13 (32%)
Cold water immersion (CWI)	21 (68%)	6 (19%)	8 (26%)	22 (71%)	12 (39%)	22 (71%)
Active recovery	21 (58%)	18 (50%)	27 (75%)	22 (61%)	10 (28%)	18 (58%)
Sleep protocols	2 (50%)	3 (75%)	3 (75%)	2 (50%)	3 (75%)	4 (100%)
Stretching	29 (71%)	40 (98%)	31 (76%)	34 (83%)	19 (46%)	33 (80%)
Massage	5 (20%)	3 (12%)	11 (44%)	14 (56%)	6 (24%)	9 (36%)
Compression garments (CG)	7 (50%)	2 (14%)	4 (29%)	7 (50%)	5 (38%)	8 (57%)
NSAIDS	1 (25%)	-	-	-	1 (25%)	-
Contrast water therapy (CWT)	2 (25%)	-	2 (25%)	1 (13%)	-	3 (38%)
Electromyostimluation (EMS)	-	-	-	-	1 (100%)	1 (100%)

- *Number of recovery practitioners who indicated "Always" or "Almost always" using a recovery method under particular conditions*
- *n = number of total responses selected by participants for when recovery methods are used*

c) Attitudes towards recovery methods

Seventy-nine percent of respondents either agreed, or strongly agreed that recovery methods were effective. Hydration and nutrition were thought to be the most effective. All participants who implemented the use of CWT and sleep methods considered them to be effective, although there was a low usage of these methods throughout the three leagues. Below, Figure 4 details the perceived effectiveness among each recovery method.

Figure 4: Number of participants who considered specific recovery methods as effective



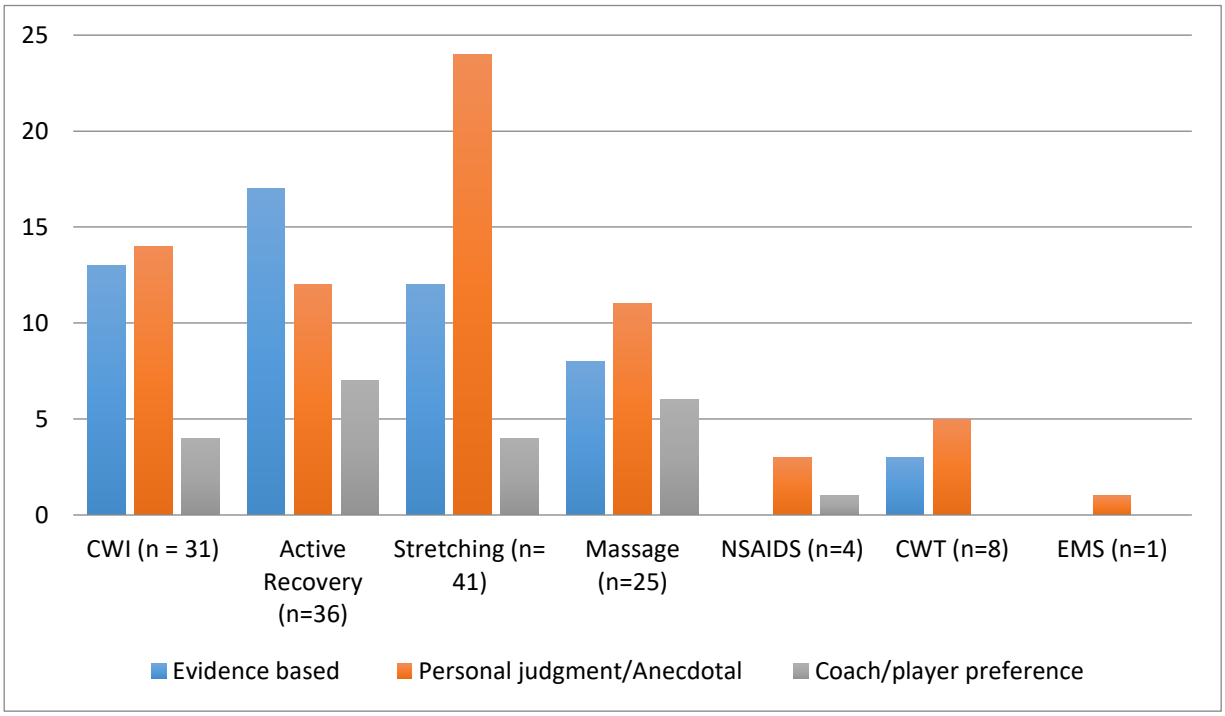
**(n) is the number of participants who answered the question, the number on top of each bar is the number of participants who thought that specific method was effective.*

CWI – Cold water immersion; CWT – Contrast water immersion; NSAIDS – Non-Steroidal Anti-Inflammatories; EMS - Electromyostimulation

d) The source of recovery method protocols

Figure 5 illustrates the distribution of where participants sourced the protocols for specific recovery methods used. Participants (>50%) were reliant on anecdotal evidence for stretching, massage and CWT protocols. Active recovery was the only method where evidence-based protocols were said to be used more often than anecdotal evidence, even though a lack of evidence supports active recovery as an effective recovery method. Appendix IV details additional information obtained from the questionnaire relating to recovery method protocols.

Figure 5: Most common sources of recovery method protocols



*(n) is the number of participants who answered the question
* not all recovery methods had a question related to protocol sources

CWI – Cold water immersion; CWT – Contrast water immersion; NSAIDS – Non-Steroidal Anti-Inflammatories; EMS - Electromyostimulation

e) Barriers for use of recovery methods

Stretching was the most commonly used recovery method with the least barriers to implementation. The greatest barrier faced by team staff was players lack of interest (n=89), followed by a lack of funds (n=79). Participants were allowed to list as many barriers to implementation they faced, therefore the responses were more than the number of participants. A specific lack of funds for nutrition (78%) and compression garments (71%) was reported as the most overwhelming barrier to implementation. The majority of participants felt that their teams' coaching staff were committed to the recovery methods they had implemented. Table 15 outlines the various barriers encountered per recovery method.

Table 15: Recovery Methods Barriers in Each League

Recovery Methods	Inadequate Funds	Lack of Staff	Inadequate Equipment	Lack of Time	Players not Interested	Coach not Interested
Hydration (n=45)	21 (47%)	9 (20%)	4 (9%)	9 (20%)	17 (38%)	3 (7%)
Nutrition (n=41)	32 (78%)	9 (22%)	6 (15%)	10 (24%)	15 (37%)	1 (2%)
CWI (n=31)	7 (23%)	9 (29%)	14 (45%)	14 (45%)	15 (48%)	4 (13%)
Active Recovery (n=36)	1 (3%)	3 (8%)	6 (17%)	2 (6%)	17 (47%)	2 (6%)
Sleeping Protocols (n=4)	-	1 (25%)	-	1 (25%)	1 (25%)	-
Stretching (n=41)	1 (2%)	2 (5%)	1 (2%)	3 (7%)	11 (27%)	2 (5%)
Massage (n=25)	5 (25%)	13 (52%)	2 (8%)	6 (24%)	4 (16%)	2 (8%)
Compression garments (CG) (n=14)	10 (71%)	-	5 (36%)	1 (7%)	6 (43%)	1 (7%)
NSAIDS (n=4)	1 (25%)	-	-	-	-	-
CWT (n=8)	1 (13%)	3 (38%)	3 (38%)	3 (38%)	3 (38%)	2 (25%)
EMS (n=1)	-	-	-	-	-	-
TOTAL	79	49	41	49	89	17

CWI – Cold water immersion; CWT – Contrast water immersion; NSAIDS – Non-Steroidal Anti-Inflammatories; EMS - Electromyostimulation

3.6 Discussion

Recovery functions to reverse the effects of fatigue and return the players' metabolic and physiological systems to homeostasis. Recovery is considered to be achieved when the player can perform activities which match or exceed pre-training/competition levels (Bishop et al., 2008, Nedelec et al., 2012). Increased match and training schedules in the modern game has led to disrupted recovery times (Ascensão et al., 2008), leading to potential injury and underperformance (Dupont et al., 2010, Ekstrand et al., 2004). Recovery methods have been developed over the years to assist athletes to maximise performance and regeneration (Barnett, 2006, Murray and Cardinale, 2015). However, a lack of evidence-based guidelines and current literature on the most effective post-exercise recovery methods have led to the implementation of varied methods with no clear protocols. There is currently no available data reporting on recovery methods in South African

soccer, therefore the purpose of the present study was to outline the use of post-exercise recovery methods currently utilised in professional soccer teams within South Africa.

Recovery methods were assessed across three professional leagues in South African soccer. The top five recovery methods used in South African football were hydration, nutrition, stretching (used by more than 85% of teams), active recovery and CWI (used by more than 65% of teams). A greater number of recovery methods were used in the PSL compared with the NFD and NSD. The biggest barrier to implementing recovery methods was a lack of player interest, followed closely by financial issues. The majority of the recovery method protocols were sourced anecdotally.

3.6.1 Recovery method use vs evidence available to justify its use

Hydration and nutritional strategies were commonly cited and supported by sound evidence (Halson, 2008, Nedelec et al., 2013). However, CWI, active recovery, massage and stretching were also commonly cited despite the lack of a substantial evidence base to substantiate these recovery strategies (Nedelec et al., 2013, Tavares et al., 2016, Van Wyk and Lambert, 2009, Venter, 2014). This is in line with previous studies in soccer both locally (Venter, 2014) and internationally (Nedelec et al., 2013). Although nutrition and hydration were the most used post-exercise recovery methods in the present study, this was most likely due to lifestyle choices, instead of an intended decision to improve recovery (Crowther et al., 2017b). Stretching was therefore the most prevalent recovery method utilised with the express purpose of aiding in recovery. The popularity of stretching as a recovery method may be due to its ease of use, lack of requirement for equipment or large spaces, as well as being self-administered and cost-effective (McAtee, 2002).

The majority of recovery methods staff used in the current study were based on anecdotal protocols rather than evidence-based protocols (see Figure 5). Interestingly, the only recovery method which was reported as evidence-based was that of active recovery. Although evidence suggests that active recovery may contribute to fatigue players further (Koizumi et al., 2011), certain studies suggest that active recovery may assist players adapt to exercise loads and taper neural and temperature changes (Barnett, 2006, Reilly and Ekblom, 2005, Reilly and Brooks, 1986). Despite the uncertain evidence base, active recovery remains a popular recovery method. In the present study, almost 50% of participants revealed that players were not interested in active recovery post-exercise, which should be a strong enough signal to either have solid evidence to justify its use, or more likely to stop using active recovery post-exercise.

After reviewing the available literature on the most commonly used recovery methods (Chapter Two), a lack of evidence (as with active recovery) was found for a host of recovery methods. This paragraph will briefly synopsize the recovery methods used without sufficient evidence (i.e. stretching, massage, CG, CWI, CWT and EMS). Studies investigating the benefits of stretching were equivocal (Herbert et al., 2011, Kinugasa and Kilding, 2009). There seemed to be no guiding evidence on correct protocols for stretching times or type, with the vast majority of soccer teams using anecdotal evidence leading to a diverse and inconsistent population of stretching protocols (Dadebo et al., 2004, Herbert et al., 2011). No defined massage protocol or evidence to elicit improved recovery in athletes have previously been established (Brummitt, 2008, Moraska, 2005). Although, most studies found CG to have no effect on performance or recovery, an improvement in perceived recovery post-CG use was reported (Duffield et al., 2010, Davies et al., 2009, Duffield et al., 2014, MacRae et al., 2011a). Effective CG protocols are yet to be established; however, it is assumed that CG is able to aid in muscle recovery post muscle damaging exercise (Davies et al., 2009, Hill et al., 2013, Hill et al., 2017). A further popular recovery method (particularly in contact sport) deemed to decrease swelling and inflammation and improve muscle recovery post damaging exercise was CWI (Ascensão et al., 2011, Cheung et al., 2003). Nevertheless, the literature revealed a large range of CWI protocols (Bailey et al., 2007), (Ingram et al., 2009, Poppendieck et al., 2013, Vaile et al., 2008) without any compelling evidence (Glasgow et al., 2014). Contrast water therapy and EMS methods, used sporadically by staff in the present study, also showed no substantial evidence in improving recovery post-exercise (Nedelec et al., 2013).

Without good clinical evidence, staff and players potentially rely on the perception of effectiveness of recovery methods (Crowther et al., 2017b). Cold-water immersion, hydration, nutrition and stretching were seen to be the most effective recovery methods in the present study, which in turn were also the most prevalent. This appeared as a trend in previous studies, where the recovery method perceived as the most effective was generally the most used (Tavares et al., 2016, Van Wyk and Lambert, 2009). For example, stretching was the most prevalent and also perceived as the most effective among staff in the present study, yet there is no evidence indicating the use of stretching as a recovery method in improving DOMS or physical recovery markers (Cheung et al., 2003, Herbert et al., 2011). Staff are therefore investing in a recovery method without demonstrable efficacy.

3.6.2 Why are staff implementing recovery methods without sound evidence?

Results of the present study indicate that staff appear to be struggling to provide clinical guidance on optimal recovery protocols (Bahnert et al., 2013) and are settling for a ‘something is better than nothing’ approach (Van Wyk and Lambert, 2009). Staff and coaches utilise recovery methods that

they consider to be effective based on anecdotal evidence (Simjanovic et al., 2009) and a placebo benefit (Bérdi et al., 2015). Despite the limited availability of resources or evidence, staff appear to be acting in the best interest of their teams. Due to the lack of current guidelines for recovery method protocols, staff are forced to rely on anecdotal protocols. A further absence of evidence-based medicine by health care providers may lead to poor recovery, subsequent poor performance, further potential injuries and limited careers of individual soccer players. Educating staff of the effects of various recovery methods, or lack thereof, can result in the implementation of some of the most effective recovery methods (i.e. hydration, nutrition and sleep interventions) instead of potentially wasting time and resources on ineffective recovery methods. Time is a precious commodity in professional sport, therefore team staff need to ensure the best use of players time by implementing targeted recovery methods specifically suited to the needs of their athletes (Henderson et al., 2016).

3.6.3 Barriers to implementation of recovery methods

The present study reported stretching and active recovery to have the least barriers to implementation (see Table 15)**.** Although hydration and nutrition were the most prevalent recovery methods, these were also cited as having the most barriers to implementation, which questions the efficacy of the protocols and whether hydration and nutrition were specifically implemented to aid in the recovery of the athlete.

a) Barriers due to lack of qualified personnel

In the present study, only one team provided their players with daily meal plans and more than 20% were not involved in any formal protocols (see Appendix IV). Venter (2014) observed that half of the players in their study had no refueling (i.e. hydration and nutrition) strategy and Nedelec et al. (2012) did not report on whether staff in French soccer teams had made use of nutrition and hydration protocols. None of the teams in the present study mentioned the involvement of a dietician or nutritionist in implementing the recovery methods. Nutritional knowledge is often sourced through media and anecdotal sources with high inter-athlete variability (Blennerhassett et al., 2018). It has been noted that a lack of nutritional knowledge from players and staff can hinder positive nutritional change (Caruana Bonnici et al., 2019). Therefore, there is a significant opportunity to involve an experienced and educated health professional (i.e. dietician/nutritionist) who is able to provide evidence-based advice on the most effective nutritional and hydration practices for soccer players in South Africa (Caruana Bonnici et al., 2019, Blennerhassett et al., 2018). Further involvement of a dietician/nutritionist can assist in planning cost-effective recovery methods aimed at nutrition, specifically in lower tiered leagues faced with the challenge of a lack of funds.

The present study found that the most common post-match drink was a combined electrolyte and CHO beverage and the most common post-training drink to be water. It has been established that water alone cannot replace sodium and electrolyte loss (Maughan and Shirreffs, 1997, Shirreffs and Maughan, 2000, Shirreffs and Sawka, 2011), while CHO drinks have been shown to assist in reversing glycogen depletion post-exercise (Krustrup et al., 2011, Mohr et al., 2003, Thorlund et al., 2009). Finances were cited as a barrier to implementation and therefore could explain the use of water instead of a more expensive CHO-based drink post-exercise. The barrier of limited finances may also affect the food options made by players, leading to a poor quality of nutrition for recovery and further justifying the inclusion of a local nutritionist on healthcare teams, who understands the background and eating habits of South African players. Further, a nutritionist may also act as a medium between players and staff members, so as to best meet the player's nutritional needs and eradicate any myths regarding performance supplementation products athletes are constantly exposed to (Dascombe et al., 2010).

b) Barriers due to lack of player buy-in

Player 'buy-in' is key to the effective implementation of any training or recovery method. Approximately 40% of players showed a 'lack of interest' to implementing nutrition and hydration as a recovery method, according to the staff interviewed. It is important to acknowledge that within South African leagues, player profiles are comprised of individuals from diverse backgrounds with different knowledge, habits, experience and willingness to engage in nutritional and hydration practices solely aimed at recovery. It is imperative to encourage player recovery 'buy-in', by providing food and beverages that are appealing and practical to consume post-exercise, further highlighting the importance of experienced nutritionist involvement. In order to meet recovery targets, staff should be aware of cultural differences between players and should attempt to consider individual preferences as best as possible to eradicate any further barriers to implementation (Ranchordas et al., 2017). However, additional information from all stakeholders (including players) is needed to get a comprehensive understanding of the situation. Therefore, a survey including all stakeholders is necessary.

Athletes are often unaware of the effects of the recovery methods performed (Crowther et al., 2017b) and their perceptions are usually based on information from team staff (Bérdi et al., 2015). Results from the present study confirmed that staff have implemented recovery methods based on anecdotal, rather than evidence-based protocols. This may explain why the greatest barrier to implementation was reported as 'lack of player interest', alluding to the fact that if staff are not

convinced of the effects of certain recovery methods, players will quickly lose interest. Players are often grouped together in team sports and treated with a 'one size fits all' philosophy. A recent consensus on recovery has emphasized the need for increased individualisation to meet the specific recovery needs of each player and involving all parties (i.e. coach, player, health professionals and researchers) in planning optimised recovery protocols to further improve athlete 'buy-in' (Kellmann et al., 2018). The ideal recovery protocol was an approach which elicited an increased perception of recovery while also addressing appropriate physiological mechanisms to improve recovery post-exercise (Cook and Beaven, 2013, Kellmann et al., 2018, Venter and Grobbelaar, 2017).

c) Barriers due to lack of coach/staff buy-in

Coaches were not considered as a barrier to the implementation of recovery methods in the present study; however, a more effective use of the coaches' influence on their players should be used to encourage the practice of effective recovery methods and attempt to change players' perceptions. Coaches 'buy-in' is imperative in order to have an influence over training and recovery programmes (Ekstrand et al., 2017). Advocating for the use of evidence based protocols in recovery will aid in best-practice and eliminate the diverse use of unsubstantiated recovery methods. Coaches should view recovery as a standard component of any training regime and encourage the use thereof (Kellmann et al., 2018). Clear and effective communication between all team stakeholders is essential and should include regular meetings which enhance player compliance.

3.6.4 Recovery methods use among the different South Africa soccer leagues

A further valuable finding of the present study saw teams in the top league (first tier) making use of a greater number of recovery methods than teams in lower divisions**.** This is somewhat consistent with findings from a previous study which explored the use of recovery methods between amateur and elite teams (Tavares et al., 2016). The increased use of massage and CWI in the top tiered leagues in South Africa were most likely due to access to the necessary therapists and equipment (i.e. teams in top tiered leagues had greater resources). While inferring that top tiered teams would have access to greater resources and potentially less barriers to the implementation of recovery methods is warranted, the quality of recovery methods should be emphasized over the quantity.

In addition to hydration and nutrition, sleep has been reported to have fairly compelling evidence as an effective recovery method (Nedelec et al., 2015b, Simpson et al., 2017). Despite this, only a minority (less than 10%) of South African teams utilised sleep interventions as a recovery method in the present study. French soccer teams perceived sleep interventions to be an effective strategy, although this recovery method was not implemented (Nedelec et al., 2013). Further, only 35% of

local rugby teams made use of sleep interventions as a recovery method (Van Wyk and Lambert, 2009). An overwhelming amount of research has confirmed the negative effects of poor sleep on recovery (Fullagar et al., 2014) and data on sleep problems among athletes illustrates increasingly high prevalence rates (Erlacher et al., 2011, Lastella et al., 2015b, Tuomilehto et al., 2017). Sleep has previously been considered as an integral form of recovery (Fullagar et al., 2014, Nedelec et al., 2015b, Simpson et al., 2017). Sleep interventions are a cost-effective method which is easily accessible to each player through a variety of mediums (Simpson et al., 2017).

Little is known about the effectiveness of sleep interventions to assist with recovery and performance within team sports; however, sleep interventions should potentially take priority over the recovery methods mentioned above that are not based on sound evidence. Sleep interventions which could potentially aid recovery and performance in athletes will be reviewed in the next chapter, in order to isolate the most effective evidence-based sleep interventions.

3.6.5 Limitations

Limitations of the present study included having to contact each team to find the most senior staff member responsible for player recovery. In future, it would be of value to interview one profession across the study as different professions can be seen to hold different beliefs and ideas. Additionally, a survey with players and coaches will assist improving the context surrounding use and understanding of recovery with key stakeholders. The present study was also subject to the limitations of similar survey/questionnaire type studies (Brookover & Fielder, 2003). Several interviews were not live (e.g. face to face, skype or telephonic), and required participants to complete an online questionnaire, which may have led to participants sourcing information for their responses from elsewhere. Open-ended questions could assist to further guide and inform practice instead of the close ended questions in the current questionnaire. With the exception of demographic information, participant characteristics were largely unavailable (Wright, 2005). Matters of confidentiality when completing online surveys are often a concern of participants (Couper, 2000) and may result in response bias, where participants feel obligated to provide socially pleasing or positive responses. The variety of healthcare practitioners provide an understanding of the numerous professions involved in soccer; however, this may also account for the wide-ranging recovery approaches reported. Future studies should review the knowledge and perceptions of the various professionals implementing recovery methods, which will allow a good baseline comparison of what the staff know versus what they think.

3.6.6 Conclusion

The findings of the present study suggest that the use of recovery methods occurs at all professional levels of South African soccer. Several teams have adopted recovery methods without sufficient evidence to justify its use (i.e. stretching, massage, active recovery and CWI). Reliable evidence has been reported in support of the use of nutrition, hydration and sleep as recovery methods. While nutrition and hydration are well utilised across South African soccer teams, the protocols for implementation should be reviewed to incorporate evidence-based practices. Teams in the top tiered league utilised significantly more recovery methods, most likely due to the amount of resources at their disposal. However, a lack of player interest was reported as one of the greatest barriers to implementation. Anecdotal protocols, poor evidence, numerous barriers to implementation and lack of education has led to the diverse use of recovery methods across South African soccer. This highlights the significance of educating both staff and players on the importance of recovery, eliciting player 'buy in' and the exclusive implementation of effective evidence-based recovery methods (Crowther et al., 2017b, Ekstrand et al., 2017).

CHAPTER 4: NON-PHARMACOLOGICAL SLEEP INTERVENTIONS TO ENHANCE RECOVERY AND PERFORMANCE IN ATHLETES - A SYSTEMATIC REVIEW

4.1 Introduction

4.1.1 Background to the review

Sleep has been shown to play a pivotal role in an individual's development, health and daily life (Gerber et al., 2010). During sleep our bodies are metabolically recovering from the effects of waking (Frank, 2006), physiologically restoring (Akerstedt and Nilsson, 2003) and in a state of learning (Walker et al., 2005). Due to an increased strain on the body with an athlete's lifestyle, it has been postulated that athletes require more sleep compared to non-athletes, in order to physiologically and psychologically recover from training (Bird, 2013).

Various studies have demonstrated that inadequate sleep or sleep deprivation negatively affects athletic performance (Reilly and Piercy, 1994b, Skein et al., 2011a), cognition (Dinges et al., 1997, Goel et al., 2009) and well-being (Cohen et al., 2009). Previous studies which have investigated the effect of sleep deprivation on the recovery and performance outcomes of athletes have generally reported that, the greater the amount of sleep loss, the greater the negative effect on performance and recovery indices (Blumert et al., 2007, Fullagar et al., 2015b, Fullagar et al., 2016a, McMurray and Brown, 1984, Reilly and Piercy, 1994b, Skein et al., 2011a). The abovementioned studies measured sleep deprivation for an exaggerated period of time not realistic to the athletic population, therefore the results are not generalisable (Fullagar et al., 2015b). Most available studies, including the abovementioned, observed acute sleep loss; however, chronic sleep loss is more likely a concern in athletes, especially over a competitive season (Gupta et al., 2017, Tuomilehto et al., 2017). Furthermore, previous research was not conducted in team sports making extrapolations to these populations problematic.

Athletes endure a diverse range of psychological and physiological stressors during training, match play and travel (Fullagar et al., 2015a, Nedelec et al., 2015a). Early training schedules, late match times, stimulant exposure, cramped travel, jet-lag or change in circadian rhythm, change in altitudes, competition factors and congested scheduling can compromise sleep quality, quantity and patterns, making it challenging to meet the standard for recommended sleep hygiene (Juliff et al., 2015b, Mah et al., 2011, Nedelec et al., 2015a, Sargent et al., 2014b). Incomplete recovery may result in potential

injury (Dupont et al., 2010) or underperformance (Nédélec et al., 2012). Recent research has demonstrated a positive link between adequate sleep and optimal performance and recovery (Simpson et al., 2017, Samuels, 2008, Skein et al., 2011b). Despite this, athletes are not acquiring sufficient sleep quantity and quality (Erlacher et al., 2011, Fullagar et al., 2016b, Knufinke et al., 2017, Lastella et al., 2014), (Venter, 2012). Therefore, addressing the factors which disrupt sleep quality and quantity are imperative to optimise performance (even by a small margin) for each athlete (Venter, 2012).

Athletes often cite sleep as one of the most important recovery strategies (Halson, 2014). Unfortunately, the relationship between sleep and athletic performance is not fully understood (Fullagar et al., 2015a) and is often considered an inferior intervention by athletic staff administering recovery methods. Interestingly, players reporting sleep disturbances in previous studies indicated having no sleeping strategy to counteract these problems (Juliff et al., 2015a).

The present study indicated that almost no soccer teams in South Africa considered using sleep protocols as a means of player recovery, while recent literature on interventions benefitting sleep in athletes are lacking. Research among sleep deprived athletes and the negative effects thereof is prevalent, therefore many recommendations hypothesise extending sleep quantity. While this may be a fair assumption, few collective reviews are available to construct these assumptions into tangible evidence. Sleep interventions are easily accessible, cheap, simple, generally healthy and the results of a previous study indicate that it was not always a primary consideration for soccer teams as a recovery method (Nedelec et al., 2013). Practitioners need clear advice and guidance regarding which sleep interventions to invest in. Therefore, the aim of the present review is to systematically assess whether studies provide beneficial evidence of non-pharmacological sleep interventions in athletes, which have positively affected sleep as a method to improve recovery and performance outcomes. A brief overview of selected non-pharmacological sleep interventions will be provided in the section below.

4.1.2 Description of non-pharmacological sleep interventions

It has been reported that non-pharmacological interventions are effective in the treatment of insomnia (Petit et al., 2003); however, it is considered less effective than pharmacological treatments in assisting with sleep onset (Hu et al., 2010, Nowell et al., 1997, Zhao et al., 2012a). Non-pharmacological sleep interventions aim to improve sleep quantity and/or quality by altering poor sleep habits, addressing stressors which may be negatively impacting sleep and challenging negative attitudes, thoughts and beliefs regarding sleep (Montgomery and Dennis, 2004). Interventions are

diverse and predominately include educational awareness, behavioural modifications and non-medication based therapies (i.e. red-light therapy, relaxation methods, brainwave entrainment, etc.; (Montgomery and Dennis, 2004, Nedelec et al., 2015b). Non-pharmacological SHS have been suggested for athletes to counterbalance the effects of sleep loss (Fullagar et al., 2015a, Halson, 2014, Hauri, 1991). Simply, SHS are aimed at avoiding behaviour which compromises sleep and encourage situations/behaviours which promotes sleep quality and quantity (Nedelec et al., 2013, Stepanski and Wyatt, 2003). Sleep Hygiene Strategies will form an umbrella term for sleep interventions aiming to improve sleep quantity and quality. The sleep interventions reviewed in the present study will be considered below.

a) Educational awareness and sleep recommendations

Education/awareness strategies have provided recommendations based on behavioural and environmental aspects of athletes' lifestyles that affect sleep (De Sousa et al., 2007). These sessions aimed to create awareness of the importance and benefits of good sleep to maximize athlete sleep quality (Lastella et al., 2015b). Various studies have demonstrated improved sleep after educational sessions in a non-athlete population (De Sousa et al., 2007, Kakinuma et al., 2010). Studies using an athlete population are limited, however a recent study found that education sessions improved sleep quantity in elite female athletes without looking at recovery or performance outcomes (O'Donnell and Driller, 2017).

b) Sleep extension

Acute and chronic sleep deprivation has been confirmed to cause sleepiness and reduced cognitive functioning (Goel et al., 2009). Increasing sleep duration was proposed to combat the effects of sleep loss and potentially increase performance and recovery (Mah et al., 2011, Schwartz and Simon, 2015). Several studies have also shown the benefits of sleep extension on motor and mood faculties (Arnal et al., 2015, Juliff et al., 2017, Kamdar et al., 2004), however the amount of time needed to extend sleep (Juliff et al., 2015b), or the results of additional sleep in improving recovery and performance outcomes remain equivocal.

c) Napping

Napping is a behavioural action that can be used to decrease sleep debt and is considered a sleep extension strategy (Petit et al., 2014). Naps have been previously shown to decrease sleepiness, improve cognition and assist with memory tasks (Postolache et al., 2005), as well as the benefits shown with sleep extension (Mah et al., 2011). Conversely, naps taken at the wrong time may lead to sleep inertia (Naitoh et al., 1993) or effect later sleep cycles (Owens et al., 2010). Current

recommendations specify that naps should be taken eight hours after waking for approximately 20 minutes (Venter, 2012).

d) Removal of devices

The use of electronic devices to stay connected and occupied has significantly increased in today's society (Romyn et al., 2016). An increase in the use of electronic devices late at night during an athlete's sleep window decreases sleep duration and may potentially affect sleep quality (King et al., 2014, Shochat, 2012). A further issue arising from the use of electronic devices prior to bedtime is the light emission from the device, which may potentially interfere with ordinary circadian sleep rhythms (Chang et al., 2015). It has been hypothesised that if the tasks performed on the electronic device are stressful and increase alertness, sleep quality may further be negatively affected (Jones et al., 2017). Recently, the type of light wavelength or spectral distribution (i.e. short wavelengths and blue in colour) have been negatively associated with disrupting circadian rhythm and decreasing melatonin secretion (Dijk et al., 2012). Therefore, by removing access to electronic devices before sleep, it is hypothesised that sleep quantity and quality will improve (Dunican et al., 2017).

e) Red light therapy

The previous section illustrated how specific light waves can disrupt sleep, namely short, blue wavelengths (Dijk et al., 2012). Red-light therapy has been hypothesised to oppose the negative effects of blue light and increase melatonin secretion, thereby promoting sleep onset (Yeager et al., 2007) and improving sleep quality (Zhao, 2012).

f) Brainwave entrainment

Sleep quality can be measured by the volume and amplitude of brainwaves (i.e. alpha, theta and delta) of between one and nine hertz (Hz) during sleep (Guilleminault and Kreutzer, 2003, Rodenbeck et al., 2006). These frequencies are repeated in cycles approximately five to seven times according to the sleep stages (Iber et al., 2007). Brainwave entrainment is therefore understood as stimulating the brain during sleep with frequencies between one and nine hertz, replicating a healthy sleep cycle (Abeln et al., 2014). Using an auditory stimulus of the various frequencies creates a non-invasive, time-efficient method to assist sleep (Rhodes, 1993). The brain is able to detect these frequencies from an external stimulus, even though the exact process is not clearly understood (Pratt et al., 2009). A positive effect on psychomotor performance and mood (Wahbeh et al., 2007) has been observed post intervention. It has been hypothesised that brainwave entrainment will improve sleep quality, decrease sleep onset latency and improve mood post sleep (Rhodes, 1993, Abeln et al., 2014).

g) Pharmacological interventions

Pharmacological interventions have shown various negative side effects including residual sedation and daytime tiredness (Kales and N. Vgontzas, 1995), dizziness and cognitive impairments (Holbrook et al., 2000), risk of dependency (Proctor and Bianchi, 2012), and change in sleep patterns (decreased slow-wave sleep); all of which may lead to decreased athletic performance in soccer. Addiction to sleep medication is a recent problem affecting many athletes (Tuomilehto et al., 2017). Soccer players should consider non-pharmacological sleep interventions unless advised otherwise by medical personnel, to avert the negative side-effects associated with pharmacological treatments (Taylor et al., 2016).

4.1.3 Review question

The following systematic review aims to answer the following question: What are the effects of non-pharmacological sleep interventions on recovery and performance in athletes? Due to the lack of studies focusing on the sleep interventions used by soccer players to improve recovery and performance, athletes in general will be reviewed.

4.1.4 Objectives

The specific objectives of the present systematic review are listed below:

1. To establish the evidence base concerning non-pharmacologic sleep interventions, which aim to benefit athlete recovery and/or performance indices, in isolation. This will be established through a systematic review of peer-reviewed journals and abstracts in this field.
2. To establish how these interventions, affect recovery and performance indices primarily and sleep indices secondarily.
3. To identify underlying causes negatively affecting athlete sleep quality and quantity and how we can address these issues to improve sleep indices.

4.2 Methods

A systematic review was performed on all studies relating to sleep interventions in athletes and considered interventions focused on improving sleep indices to enhance recovery and performance. The present study made reference to the PRISMA-P guidelines (Shamseer et al., 2015b) to structure the systematic review. The comprehensive protocol developed is included in Appendix VII and includes all the relevant criteria for the systematic review. Each study included in the review was methodologically assessed for quality and bias using the Critical Appraisal Skills Programme (CASP)

tool. This systematic review has been registered on the PROSPERO database (Ref: CRD42017068294). The PRISMA-P checklist and CASP tool can be found in Appendix VI and Appendix IX respectively. Ethical and confidential considerations were not required for the present review as the data used was collected from articles that are either publicly available or approved for publication.

4.2.1 Search Strategy

The present systematic review considered articles that had been published or previously approved for publication. All study designs that met the inclusion and exclusion criteria (outlined below) and applied a sleep intervention with favourable intentions towards recovery and performance outcomes were considered in the review. Studies qualifying for inclusion in the present systematic review comprised of Randomised Control Trials (RCTs), cross-over and cohort studies. Articles were searched for using the following databases: Academic Search Complete, MEDLINE, CINAHL, SportDiscus, Biomedical Reference collection, AMED, PsycINFO and PsycARTICLES. Articles and databases were searched up to and including October 2017. The search was stopped to allow for analysis and write up before submission. Each search term included the term 'sleep' in combination with a variety of sport and athlete terms, as well as investigation and experimental designs. The final search term included were: ((sleep[Title/Abstract]) AND (athlet*[Title/Abstract] OR football*[Title/Abstract] OR sport*[Title/Abstract] OR soccer[Title/Abstract])) AND (baseline OR random* OR control* OR research OR experiment or investigat*).

The inclusion criteria for the present systematic review comprised of:

- Articles which reviewed non-pharmacological interventions to enhance sleep in athletes, which had outcome measures of recovery and/or performance indices;
- Studies employing an intervention with a control condition for comparison.
- Studies published in English, regardless of the county of origin. It must be noted that this may have led to a language bias;
- Studies conducted on human participants;
- Original or review articles with titles and abstracts relevant to the research questions; and
- All studies up to and including October 2017.

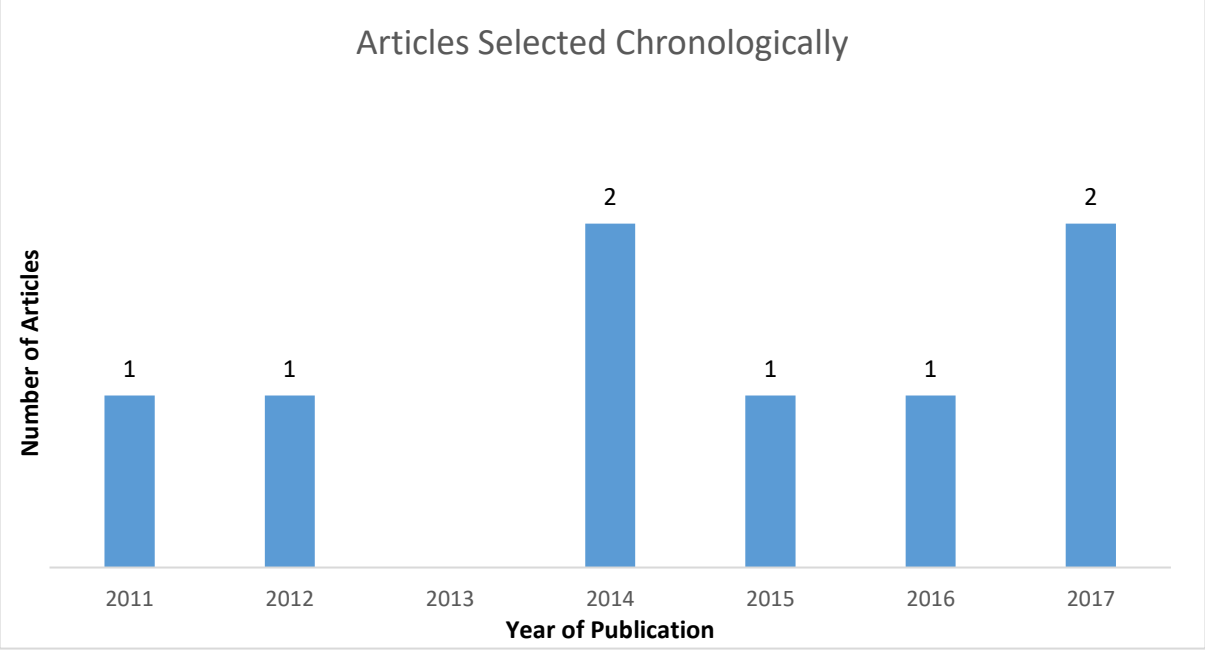
Articles meeting the following exclusion criteria were not used in the review:

- Articles not written in English;
- Articles not conducted with human sporting participants (athletes);
- Studies involving complete or partial sleep deprivation;

- Studies involving any pharmacological intervention;
- Studies combining multiple interventions;
- Studies with altitude changes;
- Studies using nutrition as an intervention, as the benefits of nutrition on sleep has already been established in previous reviews {Halson, 2014, Nedelec, 2015);
- Studies undertaking a significant change in exercise intensities, as acute increases in exercise has an effect on sleep indices (Uchida et al., 2012);
- Studies where participants had previously been diagnosed with a sleep disorder, concussion or flag in a pre-test evaluation;
- Articles without an abstract;
- Studies not employing an intervention (i.e. observational studies); or
- Studies not using a recovery or performance measurement as an outcome measure.

The researcher examined each title and abstract and selected appropriate full-text articles to further investigate their appropriateness for inclusion in the review. All articles were assessed for eligibility in terms of the pre-determined inclusion and exclusion criteria outlined above. Any ambiguous studies were referred to the supervisor for consensus on inclusion or exclusion. Duplicates were then removed to isolate the final number of studies for review. Eight articles emerged, published between 2011 – 2017 (see Figure 6). Figure 7 details the systematic search and study selection process.

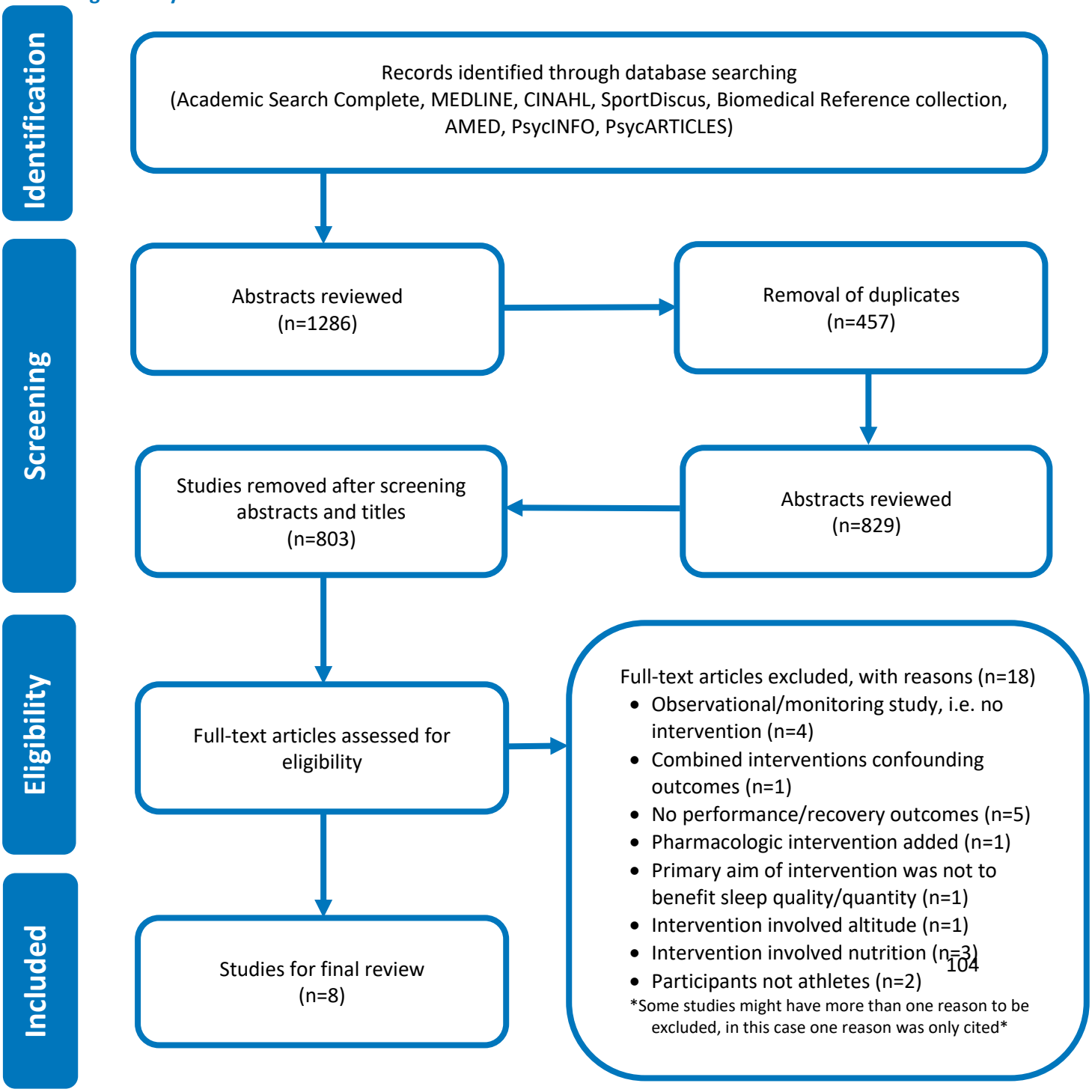
Figure 6: Articles reviewed chronologically by year



4.2.2 Methodological quality

Each study included in the review was assessed for methodological quality; this included ensuring that the studies addressed a clearly focused issue, recruited cases appropriately, accurately measured outcomes, assessed "blindness" of participants and personnel, treated intervention and control groups equally, ensured sufficient follow-up of cases, reported results precisely, and reported statistics and generalisable results clearly (see Appendix VII). A CASP checklist (see Appendix IX) was used to evaluate each study in accordance with the above-mentioned criteria. The CASP checklist awarded a tick (✓) if the study met the criteria listed and an (✗) if the criteria was not met. A score was then tallied out of the ten criteria checked (see Table 17). A mean score of 6.63 out of 10 was calculated for the eight included studies.

Figure 7: Systematic review search flowchart



4.3 Results

4.3.1 Study selection

Eight databases were searched to obtain all the literature available according to our specific search strategy. The initial search revealed 1286 articles, however after removing duplications only 829 remained. The titles and abstracts were reviewed by the researcher, who found 26 articles which were of possible use and the full-text was retrieved for further evaluation. Of these articles, 18 were excluded for various reasons (see Figure 7). The eight remaining articles were used for this systematic review (see Table 16).

a) Excluded studies

Several full-texts were retrieved for further investigation for potential use in this systematic review; either a portion of the study or the entire study could be included. Appendix VIII provides a detailed account of the excluded studies and provides details and commentary on the outcome measurements used in these studies and their results.

b) Included studies

Table 16 provides details of the studies which met all inclusion criteria and were included in the review. Data was extracted from each article into the table below.

Table 16: List of included studies in the review

Study 1: Brainwave entrainment for better sleep and post-sleep state of young elite soccer players - a pilot study (Abeln et al., 2014)		
Participants	**Intervention Group:** Elite male soccer (n=15)**;** Age = 16.28 ± 1.02 years **Control Group:** Sport students 10 male/11 female (n=21); Age 22 ± 3.12 years	
Design	Cohort study	
Sleep protocol/ intervention and comparator	Stimulated for eight weeks during sleep with binaural beats (INFRASONICS Gmbh) around 2-8 Hz vs Control group not stimulated with beats. Both slept on same pillow	
Measure(s) of sleep	Sleep diary (once a week) using a scale of 1 (very bad) to 10 (very good) for subjective sleep quality SSA once a week	
Recovery/Performance outcome measures	Validated mood, motivational and perceived physical state questionnaire for athletes was administered online once a week	
Results (text summary in CASP table)	**Intervention Group (**mean ± SD) Subjective sleep quality Pre 6.33 ± 1.19 Post 7.95 ± 1.29** Sleep duration (min) Pre 509.37 Post 508.40 SSA Total score Pre 56 Post 62 ** Mood questionnaire (motivation) Pre 3.08 ± 0.58 Post 3.62 ± 0.86 ** Sleepiness Pre 2.46 ± 0.66 Post 1.30 ± 1.12 **	**Control Group (**mean ± SD) Subjective sleep quality Pre 6.69 ± 1.53 Post 7.06 ± 1.55 Sleep duration (min) Pre 436.33 Post 448.52 SSA Total score Pre 38 Post 36 Mood questionnaire (motivation) Pre 2.70 ± 0.79 Post 2.94 ± 0.79 Sleepiness Pre 2.60 ± 1.07 Post 2.39 ± 0.88 **

Study 2: The Effects of the Removal of Electronic Devices for 48 hours on Sleep in Elite Judo Athletes (Dunican et al., 2017)		
Participants	**Intervention Group:** Elite male judo (n=9)**;** Age (mean ± SD) 17.2 ± 5.1 years **Control Group:** Elite judo (n=9)**;** 8 females + 1 male**;** Age (mean ± SD) 18.9 ± 2.9 years	
Design	Observational /intervention Design	
Sleep protocol/ intervention and comparator	Over 6 days and nights Control group allowed to use electronic devices throughout study. Intervention group had all electronic devices removed for 48 hours (days 3 & 4) and forbidden to use/access	
Measure(s) of sleep	Actigraphy (Readiband) measured sleep duration, SOL, SO, wake after sleep onset, SE and WT Sleep diary for sleep related questions regarding Insomnia (ISS), daytime sleepiness (ESS) and obstructive sleep apnea (Berlin questionnaire), caffeine and electronic device use	
Recovery/Performance outcome measures	Rate of perceived exertion during training periods. Cognitive performance (Cogstate research tool) and physical performance (SL-THT)	
Results (text summary in CASP table)	**Intervention Group (**mean ± SD) <u>SL-THT (m)</u> Pre 4.8 ± 3.0 Post 5.8 ± 1.6 <u>Cognition speed (s)</u> Pre 2.40 ± 0.05 Post 2.36 ± 0.05 <u>Sleep duration (Actigraphy) (min)</u> Pre 386 ± 44 Post 378 ± 90 <u>Sleep duration (Sleep diary) (min)</u> Pre 437 ± 70 Post 540 ± 56 RPE was 7 ± 1 for both groups for all training sessions	**Control Group (**mean ± SD) <u>SL-THT (m)</u> Pre 7.9 ± 1.2 Post 6.2 ± 3.6 <u>Cognition speed (s)</u> Pre 2.38 ± 0.26 Post 2.38 ± 0.27 <u>Sleep duration (Actigraphy) (min)</u> Pre 433 ± 47 Post 434 ± 50 <u>Sleep duration (Sleep diary) (min)</u> Pre 465 ± 46 Post 471 ± 48

Study 3: The effect of an acute sleep hygiene strategy following a late-night soccer match on recovery of players (Fullagar et al., 2016)	
Participants	Twenty well trained amateur football players in the German league (no age specifics given)
Design	Randomised cross-over design
Sleep protocol/ intervention and comparator	Lights dimmed, ear plugs and eye-masks in cool temperature rooms (17°C) No technological or light stimulation was allowed for 15–30 min prior to bedtime (electronic devices taken away) Finally, lights were turned off at 00:00. In control condition, players remained awake until they were allowed to go to bed at 02:00. Alcohol and caffeine were not allowed during testing
Measure(s) of sleep	Actigraphy (Sensewear) measured sleep parameters (sleep duration, TIB, SOL, SE, wake episodes) Sleep diary measured subjective responses on perceived sleep restfulness, general recovery state upon waking Sleep Chronotype questionnaire (MEQ)
Recovery/Performance outcome measures	CMJ (height, force production), YoYo Intermittent Recovery test (distance, maximum HR, lactate), HIMS, venous blood (creatine kinase, urea and c-reactive protein) and the Acute Recovery and Stress Questionnaire for perceived fatigue and recovery Training load - GPS data, HR and RPE)
Results (text summary in CASP table)	**Intervention Group (**mean ± SD) <u>Sleep duration (Actigraphy) (min)</u> Baseline 414 ± 66 Match night 369 ± 43 * <u>CMJ height (cm) and Force (N)</u> 12h post night match: 36 / 1700 **Control Group (**mean ± SD) <u>Sleep duration (Actigraphy) (min)</u> Baseline 398 ± 61 Match night 270 SD ± 27 * <u>CMJ height (cm) and Force (N)</u> 12h post night match: 35 / 1800 No other significant differences were observed for any other physical, sleep, blood or perceptual measurements taken.

Study 4: The Effects of Sleep Extension on the Athletic Performance of Collegiate Basketball Players (Mah et al., 2011)		
Participants	11 university basketball players aged (mean ± SD) = 19.4 ± 1.4 years	
Design	Prospective Cohort	
Sleep protocol/ intervention and comparator	Sleep extension for at least 10h a night for 5-7 weeks. A baseline of 2-4 weeks was used as a control group in which athletes slept as "normal"	
Measure(s) of sleep	Actigraphy measured sleep-wake schedules Sleep Diary (Sleep duration, napping, TIB, WT, minutes awake during night) ESS (daytime sleepiness)	
Recovery/Performance outcome measures	Timed sprint (282m and shooting accuracy (free-throws and 3-point shooting). Reaction time via PVT, Mood, vigour and fatigue (POMS)	
Results (text summary in CASP table)	Objective sleep duration (mean ± SD) (Actigraphy)(min) Pre 400.7 ± 61.8 Post 507.6 ± 78.6 ** Subjective sleep duration (diary)(min) Pre 470.0 ± 65.9 Post 624.2 ± 68.4 ** PVT Performance (Mean reaction time) (ms) Pre 310.84 ± 77.13 Post 274.51. ± 42.01 * 282m Feet Sprint (s) Pre 16.2 ± 0.61 Post 15.5 ± 0.54 ** Free-throws (out of 10) Pre 7.9 ± 0.99 Post 8.8 ± 0.97 **	Three-point field goals (out of 15) Pre 10.2 ± 2.14 Post 11.6 ± 1.50 ** Subjective self-rating at games (1-10) Pre 7.8 ± 1.07 Post 8.8 ± 1.19 ** ESS Questionnaire Pre 9.64 ± 3.80 Post 3.36 ± 1.69 ** POMS Total Mood Disturbance Pre 13.76 ± 17.17 Post 10.36 ± 9.62 **

Study 5: A 20 min nap in athletes changes subsequent sleep architecture but does not alter physical performances after normal sleep or 5-h phase-advance conditions (Petit et al., 2014)		
Participants	16 male athletes aged (mean ± SD) 22.2 ± 1.7 years	
Design	Counter-balanced randomised control trial	
Sleep protocol/ intervention and comparator	20 min nap or no nap (control) post-lunch in normal sleep and in 5-h phase advanced sleep *Only included normal sleep results in this review, as excluded travel*	
Measure(s) of sleep	PSG and EEG measured sleep/wake times and data (TST, SE, number of waking's, SOL, sleep time in different sleep stages) A camera and technician monitored participants in case of napping (control group)	
Recovery/Performance outcome measures	Wingate anaerobic test administered twice following each pre-trial night (Monark 814 E cycle ergometer). Blood lactate from the ear-lobe post Wingate test (after 5 min). Core body temperature measured (YSI 400, Rectal Temperature Probe, Smiths Medical ASD)	
Results (text summary in CASP table)	**Intervention Group (**mean ± SD) <u>Sleep duration (PSG) (min)</u> Post-trial night 433.94 ± 18.61 <u>SOL (min)</u> Post-trial night 24.27 ± 11.77* <u>Wingate cycle test (Mean Power) (Watts)</u> First trial 713.36 ± 110.5 Second trial 720.19 ± 103.9	**Control Group (**mean ± SD) <u>Sleep duration (PSG) (min)</u> Post-trial night 443.38 ± 16.81 <u>SOL (min)</u> Post-trial night 13.28 ± 5.52* <u>Wingate cycle test (Mean Power)(Watts)</u> First trial 708.86 ± 93.2 Second trial 711.5 ± 100.6

Study 6: Sleep extension improves serving accuracy: A study with college varsity tennis players (Schwartz & Simon, 2015)		
Participants	Twelve (seven females and five males) students on a college varsity tennis team (mean age of 20.2 years)	
Design	Prospective cohort	
Sleep protocol/ intervention and comparator	Sleep at least 9h including naps for one-week vs baseline (normal sleep routine, approximately 7h)	
Measure(s) of sleep	ESS and the Stanford Sleepiness Scale (daytime sleepiness)	
Recovery/Performance outcome measures	Tennis serving accuracy	
Results (text summary in CASP table)	<u>ESS score</u> (mean ± SD) Pre 12.15 ± 4.20 Post 5.67 ± 2.46 * <u>Stanford Sleepiness Scale score</u> Pre 3.56 ± 0.77 Post 2.67 ± 0.64 *	<u>Sleep duration (subjective)(h)</u> Pre 7.14 ± 0.87 Post 8.85 ± 0.60 * <u>Serving accuracy (out of 50)</u> Pre 17.83 ± 7.84 Post 20.92 ± 6.80 *

Study 7: A novel sleep optimization programme to improve athletes' well-being and performance (Van Ryswyk et al., 2017)		
Participants	25 male AFL senior level players aged (mean ± SD) = 23.7 ± 2.0	
Design	Prospective Cohort	
Sleep protocol/ intervention and comparator	Sleep optimization programme over six weeks including: 2 x 1 h education sessions, from specialist in sleep hygiene, recommendations for sleep hygiene and individual sleep targets, feedback and specific consultations to improve sleep throughout	
Measure(s) of sleep	Daily sleep diaries (caffeine intake, time in bed, naps, time at which lights were turned off for sleep, alcohol intake) Actigraphy (sleep duration, SE, SOL and WT) ESS questionnaire PSQI questionnaire MEQ questionnaire	
Recovery/Performance outcome measures	POMS questionnaire (mood state, fatigue and vigour) Perceived Stress Scale and Training Distress Scale (general and training stress) Reaction time via PVT	
Results (text summary in CASP table)	<u>Sleep duration (Actigraphy) (min)</u> **(**mean ± SD) Pre 426.6 ± 55.3 Post 436.3 ± 64.0 <u>Sleep duration (Sleep diaries) (min)</u> Pre 498.8 ± 53.8 Post 518.7 ± 34.3 * <u>POMS - Vigour</u> Pre 11.6 ± 6.4 Post 15.9 ± 4.9 ** No noticeable changes in Perceived Stress Scale and Training Distress Scale scores, ESS or PSQI	<u>POMS - Fatigue</u> Pre 6.2 ± 3.5 Post 4.1 ± 3.8 * <u>PVT Mean reaction time (ms)</u> Pre 254.02 ± 25.06 Post 267.37 ± 44.29

Study 8: Red light and the sleep quality and endurance performance of Chinese female basketball players (Zhao et al., 2012)		
Participants	**Intervention Group:** Female basketball players (n=9)**:** Age (mean ± SD) 19.30 ± 4.30 years **Control Group:** Female basketball players (n=9)**:** Age (mean ± SD) 17.90 ± 2.81 years	
Design	Randomised parallel cohort study (pretest-posttest design)	
Sleep protocol/ Intervention comparator	Thirty minutes of irradiation from a red-light therapy instrument every night for 14 days. The placebo group did not receive light illumination (however went through the same testing procedures as intervention group). Both groups were blinded to treatment	
Measure(s) of sleep	PSQI – Chinese version Serum Melatonin (pg/ml)	
Recovery/Performance outcome measures	Cooper 12-Minute Run test	
Results (text summary in CASP table)	**Intervention Group** <u>PSQI index sub scores: (mean/SD)</u> -higher scores reflect worse sleep quality- <u>Sleep duration (min)</u> Pre 0.30 ± 0.48 Post 0.30 ± 0.48 <u>Sleep quality</u> Pre 1.80 ± 0.92 Post 1.30 ± 0.48* <u>SOL</u> Pre 1.80 ± 1.03 Post 0.30 ± 0.48* <u>Serum Melatonin (pg/mL)</u> Pre 22.2 ± 7.2 Post 38.8 ± 6.7* No significant difference between groups for distance run (Cooper 12-minute run)	**Control Group** <u>PSQI index sub scores: (mean/SD)</u> -higher scores reflect worse sleep quality- <u>Sleep duration (min)</u> Pre 0.70 ± 0.48 Post 0.90 ± 0.57 <u>Sleep quality</u> Pre 1.90 ± 0.74 Post 2.20 ± 0.63 <u>SOL</u> Pre 0.70 ± 0.48 Post 0.80 ± 0.42 <u>Serum Melatonin (pg/mL)</u> Pre 21.7 ± 6.8 Post 23.8 ± 7.3

Abbreviations: Hz – Hertz; SSA - Self-Assessment questionnaire of Sleep and Awakening quality; SD – Standard Deviation; CASP – Critical Appraisal Skills Programme; SOL – Sleep Onset Latency; TIB- Time in Bed; SE – Sleep Efficiency; SO – Time of Sleep Onset; TST – Total Sleep Time; ESS - Epworth Sleepiness Scale; SL-THT - Single Leg-Triple Hop Test; m – metre; s – seconds; min – minute; °C – Degrees Celsius; MEQ - Morningness Eveningness Questionnaire; CMJ - Countermovement jump; HIMS - Heart Rate Interval Monitoring System; ISS - Insomnia Severity Index; POMS – Profile Of Mood States; GPS - Global positioning systems; RPE – rate of perceived exertion; HR – heart rate; cm – centimeter; h – hour; N – Newtons (force); PVT - Psychomotor Vigilance Test; PSQI –Pittsburgh Sleep Quality Index; ms – milliseconds; AFL – Australian Football League; pg/ml – pictogram per millilitre; WT – Time at Wake; Gmbh: Gesellschaft mit beschränkter Haftung (German for 'company with limited liability')

- $P < 0.05$ = *; $P < 0.001$ = **

4.3.2 Assessment of methodological quality

A few common sources of low methodological quality were found in a number of the included studies. Table 17 below shows how the studies were critically analysed using the CASP checklist and Appendix IX further breaks down how these scores were evaluated. Notably high dropout rates (>20%) were reported in three of the studies (Abeln et al., 2014, Fullagar et al., 2016a). Only one of the eight included studies, used the gold standard measurement (PSG) for sleep indices (Petit, 2014). Generally, confounding variables were not adequately managed across three of the studies (Abeln et al., 2014, Mah et al., 2011, Schwartz and Simon, 2015). Most of the included studies used poor control group selections or designs (see Table 17 and Appendix IX). Three of the studies (Mah et al., 2011, Schwartz and Simon, 2015, Van Ryswyk et al., 2017) did not include a control group at all and relied on baseline measurements. Abeln et al. (2014) used a control group of non-athletes; Dunican et al. (2017) used a control group of predominatly females while the intervention group only included males; and the control group in the study conducted by Fullagar et al. (2016a) were required to maintain a later bed-time, thereby questioning the natural control of this group.

Finally, the exact standardisation of the intervention protocols in three of the studies are debatable (Mah et al., 2011, Schwartz and Simon, 2015, Van Ryswyk et al., 2017). Van Ryswyk et al. (2017) allowed each participant a different number of education sessions depending on their sleep needs; and in both sleep extension studies (Mah et al., 2011, Schwartz and Simon, 2015), the intervention duration differed between athletes, and no strict protocols were in place to ensure the effectiveness of the intervention. These two studies also had the smallest sample sizes of n=11 (Mah et al., 2011) and n=12 (Schwartz and Simon, 2015). The majority of studies had flaws in their methodology, and all should be viewed with caution (see Table 16, Table 17 and Appendix IX).

Table 17: Critical Appraisal Skills Programme (CASP) criteria scores awarded

Study	Focused Issue	Appropriate Recruitment of cases	Outcome and Exposure accurately measured	Appropriate recruitment of controls	Control of confounding factors	Complete follow up	Statistics clearly reported	Results believable	Generalisa-bility of results	Results correlate with other evidence	CASP score
Abeln et al., 2014	✓	✓	✓	×	×	×	✓	×	✓	×	5
Dunican et al., 2017	✓	✓	✓	×	✓	×	✓	×	✓	×	6
Fullagar et al., 2016	✓	✓	✓	✓	×	×	✓	×	✓	✓	7
Mah et al., 2011	✓	✓	✓	×	×	✓	✓	×	✓	✓	7
Petit et al., 2014	✓	×	✓	✓	✓	✓	✓	✓	×	×	7
Schwartz & Simon, 2015	✓	×	×	×	×	✓	✓	×	✓	✓	5
Van Ryswyk et al., 2017	✓	✓	✓	×	✓	✓	✓	×	✓	✓	8
Zhao et al., 2012	✓	✓	✓	✓	✓	✓	✓	✓	×	×	8

4.3.3 Description of the studies

a) Eligibility criteria

More than half of the investigators screened and excluded participants in their studies if they were previously diagnosed with a sleep disorder or a history of sleep problems (Abeln et al., 2014, Fullagar et al., 2016a, Dunican et al., 2017, Petit et al., 2014). No exclusion criteria was noted in the other studies (Schwartz and Simon, 2015), (Van Ryswyk et al., 2017), (Zhao et al., 2012b), with one study remunerating individuals for their participation (Schwartz and Simon, 2015).

b) Participant characteristics

The mean age of participants in the included studies ranged from 16 to 23 years, with only one study failing to mention participants' age (Fullagar et al., 2016a). More than 70% of participants across all the included studies were male, with only one study including exclusively females (Zhao et al., 2012b). The studies included participants from a variety of sports, including basketball (Zhao et al., 2012b, Mah et al., 2011), football (Fullagar et al., 2016a, Abeln et al., 2014, Van Ryswyk et al., 2017), tennis (Schwartz and Simon, 2015) and judo (Dunican et al., 2017). One study did not mention the name of the sport that the athletes participated in and referred to them only as 'healthy athletes' (Petit et al., 2014).

c) Study characteristics

All studies, except the study conducted by (Zhao et al., 2012b) developed a familiarisation process for participants prior to the investigation, including either: a habituation sleep in the lab or at home. with or without a device, education on processes, or obtaining baseline measurements prior to the intervention.

More than half of these studies reported zero or minimal dropout from the original participant cohort (Mah et al., 2011, Petit et al., 2014, Schwartz and Simon, 2015, Van Ryswyk et al., 2017, Zhao et al., 2012a), whereas the remaining studies reported at least a 20% drop out rate (Abeln et al., 2014, Dunican et al., 2017, Fullagar et al., 2016a). All studies had varying intervention lengths, with the shortest being one night (Petit et al., 2014, Fullagar et al., 2016a) and the longest eight weeks in duration (Abeln et al., 2014). Two studies implemented an approximate timeline of one week (Dunican et al., 2017, Schwartz and Simon, 2015) and a further two studies were approximately six weeks in duration (Mah et al., 2011, Van Ryswyk et al., 2017). The red-light therapy intervention had a duration of two weeks and included outcome measurements pre- and post-intervention (Zhao et al., 2012b). Outcome measurements for sleep, performance and recovery indices are listed in Table 18 below.

Table 18: Changes in sleep, recovery and performance outcomes measured

Study	Sport	Intervention	Sleep Duration	Sleep Quality	Daytime Sleepiness	Recovery	Performance	CASP score
(Abeln et al., 2014)	Football	Brainwave entrainment (8 week)	↔	↑	↑	↑	NR	5
(Dunican et al., 2017)	Judo	Device restriction (2 days)	↔	↔	↔	↔	↔	6
(Fullagar et al., 2016a)	Football	Sleep hygiene protocol (1 night)	↑	↔	↔	↔	↔	7
(Mah et al., 2011)	Basketball	Sleep extension (5-7 weeks)	↑	NR	↑	↑	↑	7
(Petit et al., 2014)	Not mentioned	Post-prandial naps (1 day)	↔	↓	NR	↔	↔	7
(Schwartz and Simon, 2015)	Tennis	Sleep extension (5-7 days)	↑	NR	↑	NR	↑	5
(Van Ryswyk et al., 2017)	AFL	Sleep education (6 weeks)	↔ (objective) ↑ (subjective)	↔	↔	↑	NR	8
(Zhao et al., 2012a)	Basketball	Red-light therapy (2 weeks)	↔	↑	↑	NR	↔	8

Abbreviations: AFL: Australian Football League, NR: not reported; ↓ Significant deterioration; ↑ significant improvement; ↔ No significant change;

CASP: Critical Appraisal Skills Programme

d) Sleep measurements

Four studies utilised actigraphy and sleep diaries (Fullagar et al., 2016a), Mah et al., 2011, (Van Ryswyk et al., 2017, Mah et al., 2011) to measure sleep indices. The study conducted by (Zhao et al., 2012b) only considered sleep quality through the use of a sleep questionnaire; whereas (Abeln et al., 2014) utilised sleep questionnaires and a sleep diary, and (Schwartz and Simon, 2015) only utilised a sleep diary. The method of only utilising a sleep diary as the intervention when measuring sleep extension (Schwartz and Simon, 2015) seemed out of the ordinary, especially considering previous poor correlations of accurate sleep times comparing subjective and objective measures (Girschik et al., 2012). Although PSG is considered the most accurate measure of sleep indices, it was only utilised by one study (Petit et al., 2014). Generally, it was difficult to compare the effectiveness of several sleep interventions, each using different measurement tools.

The majority of sleep outcome measurements observed sleep duration, sleep quality, sleep onset latency (SOL), sleep efficiency (SE), time in bed, wakings and naps, as well as a variety of questionnaires including the Pittsburgh Sleep Quality Index (PSQI), Self-Assessment of Sleep and Awakening Quality Scale (SSA), Epworth Sleepiness Scale (ESS), Stanford Sleep Scale, sleep diaries and occasionally certain screening tools for insomnia or sleep disorders. These measurements were fairly consistent throughout each of the studies, with only one study measured serum melatonin (Zhao et al., 2012b).

e) Performance outcome measurements

Performance measurements were often related to the sport of the athlete, including tennis serving accuracy (Schwartz & Simon, 2015) and basketball shooting (Mah et al., 2011), general strength (i.e. CMJ height/force; (Fullagar et al., 2016a) and single-leg triple hop tests (Dunican et al., 2017), or fitness (i.e. Cooper 12-Minute Run test; (Zhao et al., 2012b), 282m timed sprint; (Mah et al., 2011) and Wingate anaerobic cycle test (Petit et al., 2014). Two studies tested reaction time with a psychomotor vigilance test (Mah et al., 2011, Van Ryswyk et al., 2017) and one study tested cognitive performance using reaction time measurements (Cogstate research tool; (Dunican et al., 2017).

f) Recovery outcomes measured

Recovery outcomes measurements included: indices returning to baseline, fatigue, stress and mood, blood markers, muscle soreness or the ability to repeat a maximum effort. Half of the studies included recovery outcome measurements (Abeln et al., 2014, Fullagar et al., 2016a, Petit et al., 2014, Van Ryswyk et al., 2017). The Profile of Mood States (POMS) questionnaire was utilised in two studies (Mah et al., 2011, Van Ryswyk et al., 2017), while various mood/wellness questionnaires

were used throughout the remaining six studies. Only two studies noted the rate of perceived exertion (RPE; (Dunican et al., 2017); (Fullagar et al., 2016a) and a further two noted blood markers (i.e. blood lactate; (Fullagar et al., 2016a), (Petit et al., 2014). Fullagar et al. (2016a) also administered a battery of other recovery tests and blood markers including CMJs (also a performance measure), YoYo Intermittent Recovery test (YYIRT; i.e. distance, maximum HR and lactate), heart rate interval monitoring system (HIMS) and venous blood markers (i.e. creatine kinase, urea and c-reactive protein).

4.3.5 Effect of interventions

a) Effect on sleep

An overview of the effects on sleep indices for each study can be seen in Table 18 above. In general, interventions that continued over an extended period had more of a beneficial effect on sleep indices than interventions of a shorter duration.

i) Sleep duration

In general, interventions aimed at extending sleep duration were effective (Fullagar et al., 2016a, Mah et al., 2011, Schwartz and Simon, 2015, Van Ryswyk et al., 2017). No significant change in sleep duration was noted in interventions aiming to increase sleep quality (Abeln et al., 2014, Zhao et al., 2012a). A study investigating the use of restricting devices of judo athletes to aid in improved sleep indices also found no statistical significance in sleep duration (Dunican et al., 2017). The increase in sleep duration post intervention reported in this study can be attributed to the methodological approach, which allowed athletes to wake up later (i.e. no early training time) post intervention, thereby affording a sleep extension opportunity. Participants overestimated sleep by almost one hour extra in sleep diaries compared to the actigraphy ($p = 0.001$; (Dunican et al., 2017), concurring with similar overestimation results in the studies conducted by both (Mah et al., 2011) and (Van Ryswyk et al., 2017), therefore highlighting the importance of objective measures.

ii) Sleep quality

Sleep quality was significantly improved using brainwave entrainment according to sleep diaries and the SSA questionnaire (Abeln et al., 2014), as well as with red-light therapy using the PSQI questionnaire (Zhao et al., 2012a). In contrast, three studies reported no significant improvement in either PSQI nor SE scores (Dunican et al., 2017, Fullagar et al., 2016a, Van Ryswyk et al., 2017), therefore no measurable effects on sleep quality could be concluded. Petit et al. (2014) found post-prandial naps to be detrimental to sleep indices. The two studies implementing sleep extension protocols assessed daytime sleepiness and sleep duration, rather than sleep quality variables (Mah et al., 2011), (Schwartz and Simon, 2015).

iii) Daytime sleepiness

Both studies using the sleep extension protocol saw significant improvements in daytime sleepiness. Mah et al. (2011) found large improvements ($p < 0.001$) in ESS scores, however the participants baseline ESS scores were very low, indicating possible sleep debt. Schwartz and Simon (2015) also reported improved ESS scores ($p < 0.01$) post intervention and, in addition, noted significantly improved scores ($p < 0.05$) on the Stanford Sleepiness Scale. Examination of the POMS in participants undergoing brainwave entrainment showed significant improvements ($p < 0.001$) in the sleepiness criteria compared to the control group post intervention. In agreement, Zhao et al. (2012) found daytime dysfunction to improve post red light therapy.

b) Effect on performance

In reference to the seven out of eight studies that evaluated sleep and performance, one study restricted the use of electronic devices (Dunican et al., 2017), one utilised a SHS protocol (Fullagar et al., 2016a), two studies used a sleep extension protocol (Mah et al., 2011, Schwartz and Simon, 2015), one evaluated naps (Petit et al., 2014), a further study used sleep education sessions (Van Ryswyk et al., 2017) and the final study used red-light irradiation (Zhao et al., 2012b). An overview of the performance outcomes is described in Table 18 above. Both studies investigating sleep extension found a statistically significant improvement in sport specific performance post intervention (tennis serving, $p < 0.05$, and basketball shooting accuracy, $p < 0.001$; (Mah et al., 2011, Schwartz and Simon, 2015). Post intervention general performance outcomes (timed sprint, $p < 0.001$, and reaction time, $p < 0.05$) also significantly improved in basketball players (Mah et al., 2011). Napping, which can potentially be included into a sleep extension category, did not yield any vast improvements in performance post intervention (Petit et al., 2014). The single study reviewing the beneficial effects of a nap on physical performance in athletes found no differences in peak power, mean power or fatigue indices when comparing the control (no napping) and intervention (±20 min napping) groups for a time trial on the Wingate cycle ergometer (Petit et al., 2014).

Reaction times did not significantly improve after a six week sleep optimisation programme (Van Ryswyk et al., 2017). A further study also showed no improvement in any reaction times or performance measurements when the use electronic devices were restricted in elite judo athletes (Dunican et al., 2017). The difference noted in the performance measurement was likely attributed to an all-male control group and an intervention group comprised of 90% female participants (the selection bias was noted in this study; (Dunican et al., 2017). No noticeable changes were seen in CMJ height and force production post sleep recommendations (Fullagar et al., 2016a) or in the

Cooper 12-Minute Run test post red-light (Zhao et al., 2012b). Overall, only sleep extension demonstrated a clear performance improvement effect. All other interventions were inconclusive.

c) Effect on recovery

Six studies out of eight evaluated sleep and recovery; one used brainwave entrainment (Abeln et al., 2014), another used practically enforced sleep recommendations (Fullagar et al., 2016a) and a further study used sleep education sessions (Van Ryswyk et al., 2017). Two studies employed sleep extension protocols (Mah et al., 2011, Schwartz and Simon, 2015), and the final study made use of nap evaluations (Petit et al., 2014), although including recovery outcomes, had a predominately performance focus. An overview of effects on recovery for each study can be seen in Table 18 above.

The two studies which made use of the POMS questionnaire to assess mood and motivation in their outcomes both found significant improvements post-intervention (Mah et al., 2011, Van Ryswyk et al., 2017). Van Ryswyk et al. (2017) reported that the POMS highlighted significant improvements in vigour ($p < 0.001$) and fatigue ($p < 0.05$) in 25 Australian Football League (AFL) players following a six week sleep optimisation programme (Van Ryswyk et al., 2017). In contrast, (Mah et al., 2011) found statistically significant results in POMS total mood disturbance scores ($p < 0.001$) and subjective self-rating at games ($p < 0.001$) following a sleep extension intervention. A further study, using brainwave entrainment as a sleep intervention, reported significant improvements in the motivational state ($p < 0.01$) of football players post intervention (Abeln et al., 2014).

Both studies investigating the effects of RPE found no difference in perception of effort during a standardized task before and after the intervention (Dunican et al., 2017, Fullagar et al., 2016a). No significant between-condition differences were observed for YYIRT distance, however both the SHS ($p = 0.01$) and control groups ($p = 0.04$) showed significant reductions in distance compared with baseline measurements at 12 hours post-match (Dunican et al., 2017, Fullagar et al., 2016a). No other significant differences were observed for any other physical, sleep, blood or perceptual measurements taken in their study (Fullagar et al., 2016a). Sleep interventions had a greater effect on the perception of recovery (i.e. questionnaires, mood scales, etc.) than on objective recovery measures.

4.4 Discussion

The studies included in this review broadly support a conclusion that interventions improving sleep indices generally improved recovery or performance outcomes. Furthermore, interventions that had a longer implementation length seem to have a more beneficial effect on sleep indices and, in turn, recovery and performance compared to interventions with shorter implementations. This may be justified as the intervention required additional time to take effect or that athletes may not be as sensitive to acute changes in sleep, and chronic patterns are more important. However, it is suggested that the longer the intervention, the increase in understanding and awareness of the players' own sleep variables and its effect on recovery and performance post-exercise. This is also indicated by the benefits of sleep education sessions described in the literature (O'Donnell and Driller, 2017, Van Ryswyk et al., 2017). However, due to the heterogeneous array of interventions, outcomes and results in the current review and the poor quality of most of the reviewed studies, a conclusive summary cannot be provided in reference to the present topic; therefore, results should be viewed with caution. Instead of isolating the most effective sleep intervention, it seems as if a combination of these interventions should be used to target the individual needs of each athlete, thereby functioning holistically. Addressing the factors negatively affecting an athlete's sleep quantity and quality will also assist in promoting healthy sleep (Nedelec et al., 2015b).

4.4.1 Sleep extension

From this review, sleep extension studies exhibited the most significant effect on improving recovery and performance outcomes (Mah et al., 2011, Schwartz and Simon, 2015). Both studies (Mah et al., 2011, Schwartz and Simon, 2015) showed sport-specific improvements post sleep extension in their respective sports. In partial agreement, Edwards and Waterhouse (2009) reported decrements in dart throwing performance when players were sleep deprived by 4 hours. As sleep debt detrimentally affects cognition, athlete learning and skill development (Frank and Benington, 2006, Owens et al., 2010, Spiegel et al., 1999, Owens and Group, 2014, Simpson et al., 2017); the impact on sport specific skills will be greater than the impact on recovery and performance indices (Fullagar et al., 2015b). Recent studies championing sleep extension found increased sleep duration to be directly correlated with higher finishing positions for teams participating in a netball tournament (Juliff et al., 2017), as well as in runners utilising a sleep extension protocol before a race (Poussel et al., 2015). However, both of these studies monitored athlete performance instead of implementing a specific intervention and were therefore excluded from this review.

Basketball players reported improved physical and mental well-being, fatigue and vigour ratings post intervention (Mah et al., 2011). Increased sleep duration improved RPE scores, which resulted in an increased time to exhaustion in healthy individuals (Arnal et al., 2016) and improved mood, daytime sleepiness and reaction time in healthy adults (Kamdar et al., 2004). Mood and energy improvements were also noted when participants increased sleep up to 14 hours a day for 4 weeks (Barbato et al., 1994). While these long sleep durations are most likely not practical for busy athletes, it does provide some insight into the potential benefits of sleep extension and advocates further research for this type of intervention.

Although the exact amount of extended sleep needed to improve recovery and performance is not known, increased sleep duration has led to increased sleep quality ratings (Juliff et al., 2017). However, forcing athletes to increase sleep duration and spend more time in bed could create anxiety regarding falling asleep within a given timeframe and cause detrimental effects, specifically among athletes with insomnia or sleep disorders (Simpson et al., 2017). Previous studies exploring sleep duration and time in bed has shown varying results between objective and subjective sleep data (Baker et al., 1999, Lauderdale et al., 2008, Mah et al., 2011, Van Ryswyk et al., 2017). The reviewed studies that used sleep diaries and actigraphy all showed significant differences between objective compared to subjective sleep measurements (Dunican et al., 2017, Mah et al., 2011, Van Ryswyk et al., 2017). The significant difference reported between objective and subjective measurements suggests that athletes may not be competent in self-reporting sleep. Individuals may be unable to recognize their own levels of sleep impairment (Van Dongen et al., 2003), emphasizing the importance of sleep monitoring and awareness.

The studies focusing on sleep extension did not include any control groups, therefore a practice effect on performance differences cannot be ruled out. In both sleep extension studies (Schwartz and Simon, 2015) the intervention duration differed between athletes, and no strict protocols were employed to ensure the efficacy of the interventions. These studies also had the smallest sample sizes of the included studies. Multiple confounding variables littered both studies and while the study conducted by Mah et al. (2011) obtained a CASP score of seven, their results should be interpreted with caution. Insufficient data was described by Schwartz and Simon (2015), hence a lower CASP of five was calculated. In conclusion, a more rigorous investigation is required to improve the credibility of these results.

Napping may be beneficial in increasing sleep duration in an athlete with a sleep debt (Nedelec et al., 2015b). However, naps showed no beneficial effects on performance or recovery measurements in the study conducted by (Petit et al., 2014). Conversely, naps exhibited a negative effect on SOL the following night, which the authors surmised may be due to either the unfamiliar environment or the nap itself (Petit et al., 2014). In addition, it was noted that participants showed greater daytime sleepiness following a nap, which may possibly be explained by sleep inertia (McDevitt et al., 2012, Naitoh et al., 1993). Naps taken later during the day have previously been noted to potentially negatively affect nighttime sleep architecture (Simpson et al., 2017). While this study's results are in contrast to previous studies on naps (Waterhouse et al., 2007), the authors employed a sound methodology, used athletes as participants and importantly measured sleep accurately (with PSG; (Petit et al., 2014). The study's CASP total was seven, primarily as a result of the ungeneralisable results towards the athlete population and the unpractical use of the lab in field studies. However, this may be considered one of the more reliable studies exploring the effects of naps to date. The effects of naps on physical performance and recovery are mixed and further research focusing on nap time of day, individual variance and the duration of the nap is required (Milner and Cote, 2009, Simpson et al., 2017). Currently, no benefits on recovery or performance as a result of naps have been reported.

4.4.2 Education programmes and sleep behavioural changes

Van Ryswyk et al. (2017), who focused on athlete education and sleep awareness over a six-week period reported improvements in fatigue and vigour on the POMS questionnaire, which correlated with results from the study conducted by Mah et al. (2011). No performance outcomes were measured and further, no other significant effects were noted bar self-reported increases in sleep duration and sleep quality (Van Ryswyk et al., 2017). The authors attributed adjusted feelings of fatigue and vigour to the increased self-reported sleep duration (Van Ryswyk et al., 2017). Two recent studies in elite female athletes (O'Donnell and Driller, 2017) and ice-hockey players (Tuomilehto et al., 2017) also reported the beneficial effects on sleep duration and sleep quality following sleep-hygiene education and awareness sessions. It should be noted that Van Ryswyk et al. (2017) did not include a control group or a standardised quantity of education per participant. However, the study employed a sound methodology and obtained a CASP score of eight, above the average score of the reviewed studies. This study was completed pre-season to increase participation, however future studies should consider in season interventions so as to be more replicable.

In contrast, Fullagar et al. (2016a), who enforced a sleep hygiene protocol for one night found no improvements in any of their performance or recovery outcomes. It should be noted that none of the previous studies investigating sleep education interventions in athletes used any performance measurements (O'Donnell and Driller, 2017, Tuomilehto et al., 2017, Van Ryswyk et al., 2017). In partial agreement with the abovementioned studies Fullagar et al. (2016a) was able to obtain a SHS that improved sleep duration. Whereas a previous study utilising SHS reported improved sleep quality and SOL in adolescents (Stepanski and Wyatt, 2003), Fullagar et al. (2016a) reported poorer sleep quality and SOL following SHS. This was possibly attributed to the enforcement of early bedtimes in the SHS group and unfamiliar sleeping environments (Fullagar et al., 2016a). Poor sleep indices have previously been seen in athletes who experienced changing sleep environments (Pitchford et al., 2017) and forced wake times (Sargent et al., 2014a). Comparison with the control group is questionable as participants in the control group were forced to stay awake, thereby initiating sleep restriction which decreases sleep, recovery and performance indices (Fullagar et al., 2016a). Although there was a high dropout rate which also leaves the implementation and follow-up in question, the study employed a sound methodology and research question. The intervention was far too short to have any significant impact, and although a CASP score of seven was obtained, these results should be interpreted with caution. Athlete recovery and performance is likely to be fairly resilient to acute changes in sleep patterns and, as a result, longer term interventions may be necessary to demonstrate efficacy.

4.4.3 Red-light therapy

Athletes' sleep quality significantly improved after eight weeks of red-light therapy, however no clear effect on performance was noted (Zhao et al., 2012a). A previous study reported similar improvements in muscle torque fatigue after red-light diode treatment in healthy adults (Baroni et al., 2010). Whereas, a recent study reported that red-light therapy had a normalising effect on objective and subjective vocal fatigue among healthy adults (Kagan and Heaton, 2017). It is hypothesised that red-light therapy increases arteriolar vasodilation and peripheral microcirculation to aid in recovery and performance (Baroni et al., 2010, Zhao et al., 2012a). The above findings support the biological plausibility of red-light therapy as an intervention to improve sleep indices, recovery and performance. However, the lack of generalisability remains an issue due to the lack of available, convincing evidence and buy-in from staff. Further, the study did not include any objective sleep measures, which as seen above, can be very different from subjective measures. Nevertheless, the study obtained a CASP score of eight, one of the highest reviewed, presenting a thorough methodology, participant selection and follow up sections.

4.4.4 Brainwave entrainment

Brainwave entrainment yielded positive effects on sleep quality, daytime sleepiness and perceived recovery (Abeln et al., 2014). Previous research has shown brainwave entrainment to enhance sleep indices and act as a relaxation strategy (Zhuang, 2009). Although brainwave entrainment is comfortable to use, non-invasive and relatively inexpensive (Abeln et al., 2014), a lack of clinical evidence is available to confirm the benefits for athletes to improve recovery or performance outcomes. The results of this study (Abeln et al., 2014) cannot be generalised to the greater athletic population due to the poor quality of the study, which included a low CASP score (5) and specifically: the use of a mixed gender non-athletic control group, holiday interference with data collection times, poor control of confounding variables and no control of sleep environment, high dropout rates and poor outcome measures for recovery and performance. Brainwave entrainment, which can be considered as a form of relaxation (Abeln et al., 2014, Zhuang, 2009), further emphasised the benefits of relaxation strategies for athletes. Recent reviews have suggested that relaxation strategies are an important component of sleep protocols to reduce psychological strain, which can negatively impact sleep indices (Knufinke et al., 2017, Tuomilehto et al., 2017). Further research on the implications of relaxation and meditative techniques for recovery can be a cost-effective strategy for athletes.

4.4.5 Removal of electronic devices

No differences in any performance, recovery or sleep measurements were noted when electrical devices were restricted (Dunican et al., 2017). A recent study investigating the effect of different types of tasks with or without an electronic device prior to bed, found no significant differences in sleep quality, quantity or next day athletic performance (Jones et al., 2017). Circadian physiology, sleep indices or SOL were also found to have no changes when participants used devices with bright lights compared to dim or filtered lights (Heath et al., 2014). This study in this review (Dunican, 2017) was of poor quality (obtaining a CASP score of six). The intervention was too short, the groups were self-selected which brought on skewed results, and a fairly high drop-out rate was reported.

Previous studies reported that blue-light emitted from screens increased alertness and negatively impacted cognitive performance and circadian physiology (Cajochen et al., 2011, Chang et al., 2015). It is hypothesised that the negative effect of the blue (shortwave) light on SOL is outweighed by the relaxing, arousal-reducing nature of social media or a movie (Knufinke et al., 2017). Relaxing strategies as a part of sleep protocols are potentially becoming a viable solution for many of the underlying causes of sleep problems. Athletes are exposed to an increased level of artificial light through devices, airport travelling and stadium lights (Fullagar et al., 2016c, Knufinke et al., 2017,

Nedelec et al., 2015a). Blue-light blockers have been shown to suppress bright light and prevent the negative effects from bright light on circadian physiology and subjective alertness (van der Lely et al., 2015). Therefore, blue-light blockers may be a more pragmatic solution than completely restricting device usage in today's society. As research investigating the negative effect of blue lights on performance and recovery and the positive effects of red light is currently limited, additional research is required before sleep protocols adopt light therapy.

There remains a void of scientific literature to conclusively bridge the gap between sleep and recovery performance outcomes. The inconsistency and lack of consensus pertaining to the most effective appropriate sleep and recovery performance outcomes was highlighted in this review. The finding may be due to a large variation in methodologies, outcome measures and findings which limits the ability to pool data to draw conclusive recommendations. Despite the limitations and clinical heterogeneity of the included studies, the review indicated that sleep interventions and protocols appeared to be beneficial interventions for optimizing recovery and performance. Sleep extension is cost-effective and easy to implement; however, it requires the buy-in of coaches to adapt training schedules, and players to commit to reasonable sleep times. An education programme is imperative to reinforce the importance of good sleep, and despite late training times, encourage early bed-times. Education will hopefully diminish the taboo of sleeping early, especially among younger team athletes (Venter, 2014).

Two recent reviews have clearly revealed that athletes are facing sleep disorders and problems, hindering their potential (Gupta et al., 2017, Tuomilehto et al., 2017). A host of other studies outline issues affecting athletes sleep throughout the season (Fullagar et al., 2014, Leeder et al., 2012b, Nedelec et al., 2015a). Recommendations to assist players and staff to incorporate effective sleep interventions are outlined as follows:

- Sleep monitoring and screening should be adopted via simple sleep and recovery questionnaires. A recent ASSQ has been outlined as a reliable and effective measure to screen sleep (Samuels et al., 2015). In addition the RESTQ has been shown to be valid in monitoring athlete recovery.
- Wristwatch actigraphy can be used to constantly monitor changes to an athlete's sleep, while providing feedback via sleep data (Leeder et al., 2012b). Due to a lack of finances in South African soccer teams, purchasing watches may not be possible, therefore vigilant

monitoring of daily questionnaire responses will be required to detect any recovery or sleep issues (Knufinke et al., 2017, Tuomilehto et al., 2017).

- Staff should make use of PSG and sleep consultants when sleep disorders are suspected (Meltzer et al., 2015, Tuomilehto et al., 2017).
- Sleep education for staff and players in group and individual contexts should be prioritised (Van Ryswyk et al., 2017). Coaches should understand that better sleep will result in improved training and performance, therefore scheduling sleep and training sessions accordingly (i.e. avoid early training times; Ekstrand, 2017, Sargent, 2014).

Simple techniques should be adopted for sleep efficiency. These techniques include, but are not limited to:

- Avoiding stressful situations before sleep and utilising relaxation techniques during the evening (i.e. meditation, music, brainwave entrainment, red-light therapy; (Abeln et al., 2014, Knufinke et al., 2017).
- Maintaining a cool (18-20 degrees), dark, comfortable and quiet environment (Bird, 2013).
- Avoiding stimulants late in the day (Drake et al., 2013), unless required for match-play.
- Utilising sleep extension protocols by gradually increasing nightly sleep times (Mah et al., 2011, Simpson et al., 2017).
- Avoiding early morning activities (e.g. training sessions, team breakfast or travel) after late soccer matches (Lastella et al., 2015b, Sargent et al., 2014a).
- Using blue-light blocking glasses in the evening or during post-game travel (van der Lely et al., 2015).

4.6 Limitations

Whilst there was no formal use of a second reviewer to replicate the search, a second reviewer assessed the keywords and eligibility of the studies. This should not negate from the variability; as the review was registered, appropriate search strategy used and eligibility criteria was documented. Studies were limited to only English language, which might have decreased the scope of research. There was sporadic literature using sleep interventions in combination with other recovery methods which was excluded because of the difficulty to isolate the effects of the specific recovery method. Although this review excluded sleep deprived participants to the best of its knowledge, future studies could review sleep interventions in sleep deprived athletes if each participant had a similar sleep debt baseline. To broaden the scope of research, non-athletes could be included, however

caution will need to be applied when pooling the results with athletes. Lastly this review only included studies using recovery or performance outcomes, which limited available research using sleep interventions and only looking at sleep indices (i.e. (O'Donnell and Driller, 2017). Furthermore, grey literature could have been more thoroughly reviewed, i.e. Open Grey. The limitations found in the reviewed literature which affected the quality of the systematic review outcomes will be discussed below.

A primary criticism of research investigating sleep interventions is the lack of PSG measurements. Polysomnography is recognized as the "gold standard" for measuring sleep quality and quantity (Halson, 2008, Halson, 2014), however only one study in the present review made use of these measurements (Petit et al., 2014). Equivocal measurements may be due to the variation of measurement instruments such as questionnaires, sleep diaries and actigraphy used across the reviewed studies. Furthermore, without access to PSG data, the researchers have limited ability to interpret clinical sleep data.

It has recently been reported that athletes experience decreased sleep quality and quantity before competition or match-play (Erlacher et al., 2011, Juliff et al., 2014, Juliff et al., 2015b, Lastella et al., 2014). Only two studies in the present review were conducted within a competitive season (Mah et al., 2011) or training phase (Zhao et al., 2012a). A further study, although tested during a competitive season (Abeln et al., 2014) used a control group of non-athletes, leading to difficulty in generalising results to an athletic population. The remaining studies took place during friendly matches (Fullagar et al., 2016a), pre-season periods (Van Ryswyk et al., 2017), training camps (Dunican et al., 2017) or during random trials (Petit et al., 2014, Schwartz and Simon, 2015). Consequently, the results reported in these interventions indicate challenges in translating the results into competitive scenarios and match situations. Additionally, the wide scope of sporting codes with varying training times, travelling needs, skill requirements and stressors, combined with individual sleep-wake cycles and internal stressors renders generalisability of results to the athlete population problematic.

The studies included in the present review generally had poor representative control groups (Abeln et al., 2014, Fullagar et al., 2016a, Dunican et al., 2017), no control group at all, or involved inadequate sample sizes (Mah et al., 2011, Schwartz and Simon, 2015, Van Ryswyk et al., 2017). In addition, the predominance of male participants results in difficulty when translating to female athletes. Finally, high drop-out rates (Abeln et al., 2014, Fullagar et al., 2016a, Dunican et al., 2017) and poor longitudinal follow ups further limited the quality and generalisability of the results. By

addressing these limitations, future research can uncover more reliable and meaningful results for player and staff development.

4.7 Conclusion

Results of the current review highlight the role of sleep extension as a strategy for improved athlete recovery and performance. There was a dose response effect for these interventions, where a longer implementation length had a more beneficial effect than interventions with shorter implementations on sleep indices and, in turn, recovery and performance. Nevertheless, the overall methodological quality of the studies presented in the review also highlights the increased need for high quality research before practical, evidence-based interventions benefitting sleep, recovery and performance outcomes can be fully recommended.

Existing sleep protocol recommendations (Fullagar et al., 2014, Fullagar et al., 2015b, Simpson et al., 2017, Nedelec et al., 2015b) have outlined a useful summary whereby sleep disorders are identified, underlying internal or external stressors are corrected, and additional sleep interventions are applied where necessary. Additional recommendations regarding the role of nutritional interventions for aiding sleep for recovery and performance can be reviewed in the work presented by (Halson, 2008, Halson, 2014), while interventions aimed at combating sleep and air travel can be reviewed in the study published by (Fowler et al., 2015b). Further comment on these factors is beyond the scope of the present review.

The clinical implications of sleep protocols first requires future studies to implement appropriately designed observation and longitudinal studies investigating athlete sleep indices, using both subjective and objective measures (Fullagar et al., 2014, Fullagar et al., 2015a, Simpson et al., 2017). Furthermore, there remains a need to develop a consensus regarding how to effectively and efficiently measure sleep, as the use of PSG is not practical and the diverse range of subjective measures available is unhelpful. Once these factors have been addressed, and the sleep issues and dysfunctions are isolated and identified, athletes' sleep foundations can be improved (Gupta et al., 2017, Tuomilehto et al., 2017), which can then be investigated to assess the effects on recovery and performance margins (Mah et al., 2011, Schwartz and Simon, 2015, Venter, 2014).

CHAPTER 5: PRACTICAL APPLICATIONS OF REVIEW FINDINGS AND LITERATURE:

Based on the findings of the review and the literature, a summary of situations potentially affecting the sleep quality and quantity of soccer players (see Figure 8) and suggested practical implications that may potentially be used for sporting organisations and staff to tackle these issues was designed (see Figure 9).

5.1 Situations negatively affecting sleep quantity and quality

5.1.1 Training & match schedule

Early morning training times and erratic schedules have been shown to affect an individual's circadian rhythm, which may negatively affect performance and decrease sleep duration (see Figure 8; (Sargent et al., 2014b, Venter, 2012). Data obtained from swimmers who trained in the early mornings showed a decreased sleep quantity (Sargent et al., 2014a), which may lead to decreased mood, poor motivation (Reilly and Piercy, 1994b) and lower immune functioning (Rae et al., 2017). On the other hand, late night matches result in late bed-times and a further disruption of normal sleep/wake schedules, resulting in decreased sleep quantity and quality (see Figure 8; (Fullagar et al., 2015a, Juliff et al., 2015b, Meyer et al., 2014). Late match times have a snowball effect on sleep, as it potentially increases caffeine usage, night meals and light exposure. Many soccer players in South Africa are required to wake-up early for recovery sessions, team breakfasts or post-match travel. Obtaining management 'buy-in' to delay schedules, specifically after late-night matches, to allow for sleep extension, may prove beneficial for player recovery (both physiologically and psychologically).

Travelling for long hauls has a combination of effects which negatively affect sleeping patterns, quantity and quality (see Figure 8; (Fowler et al., 2015a). Jet-lag fatigue (travelling across time-zones; Samuels, 2012) is different from travel fatigue (fatigue over the season, considering distance and frequency of travel; Fullagar et al., 2015). South African soccer leagues compete within the same time zone; therefore, the effects of jet-lag are not a concern. However, due to the vast geography of South Africa and the poor financial situation of many teams, lengthy bus trips are the standard mode of travel. Road and air travel include cramped spaces, temperature fluctuations, noisy environments, long periods of inactivity, dehydration, lighting fluctuations, travel anxiety, poor nutrition and athlete mood changes (see Figure 8; Reilly and Edwards, 2007, Venter, 2012). Difficulty initiating sleep at the final destination, mood fluctuations and poor sleep during the journey increases travel fatigue (see Figure 8; Samuels, 2012).

5.1.2 Light exposure

Late night matches expose players to bright stadium lights and potential further light exposure (i.e. airport, bus, plane and hotel) when travelling post-match (see Figure 8; (Nedelec et al., 2015b). Exposure to bright light inhibits the secretion of melatonin (Stiller and Postolache, 2005, Waterhouse et al., 2007), which assists in decreasing body temperature and slows down metabolic functions to prepare for sleep, causing increased alertness and decreased sleepiness (Cajochen, 2007). Light from televisions, computers or cellphone screens can also cause a disruption to sleep, as well as being a distraction from sleep (Nedelec et al., 2015b). Soccer players' increased use of social media applications has increased time spent using these devices and therefore the exposure to bright light (van der Lely et al., 2015). Instead of restricting the use of devices, which may not be practical among young athletes, it is suggested that these devices offer built-in 'night-modes' or filters to minimise exposure to blue-light (Gringras et al., 2015). Alternatively, players should wear blue-light blocking glasses at night (see Figure 8; (van der Lely et al., 2015).

5.1.3 Napping

Napping, although postulated as a beneficial aid to extend sleep, can have the reverse effect of disrupting sleep the following night (Petit et al., 2014, Venter, 2012) and cause less efficient sleep (Owens et al., 2010). It is hypothesised that napping, at any time and of any amount, out of a specific window may lead to later sleep difficulties (Venter, 2012). This window is postulated to be approximately eight hours after waking from initial sleep, for between 10-20 minutes (Postolache et al., 2005, Venter, 2012). Naps taken at the wrong time or for an increased duration may lead to extended sleep inertia (Naitoha et al., 2010), which can negatively affect performance and daytime dysfunction (see Figure 8). In South African soccer, it is common to train twice per day, therefore it should be encouraged to take a short nap at the club after lunch. Clubs should provide sleeping facilities which potentially could create an optimal sleeping environment; alternatively, players should be allowed to return home to their own sleeping spaces. Naps should be monitored using wristwatch actigraphy and players should set alarms to allow for a maximum of 20 minutes sleep time.

5.1.4 Influence of caffeine intake

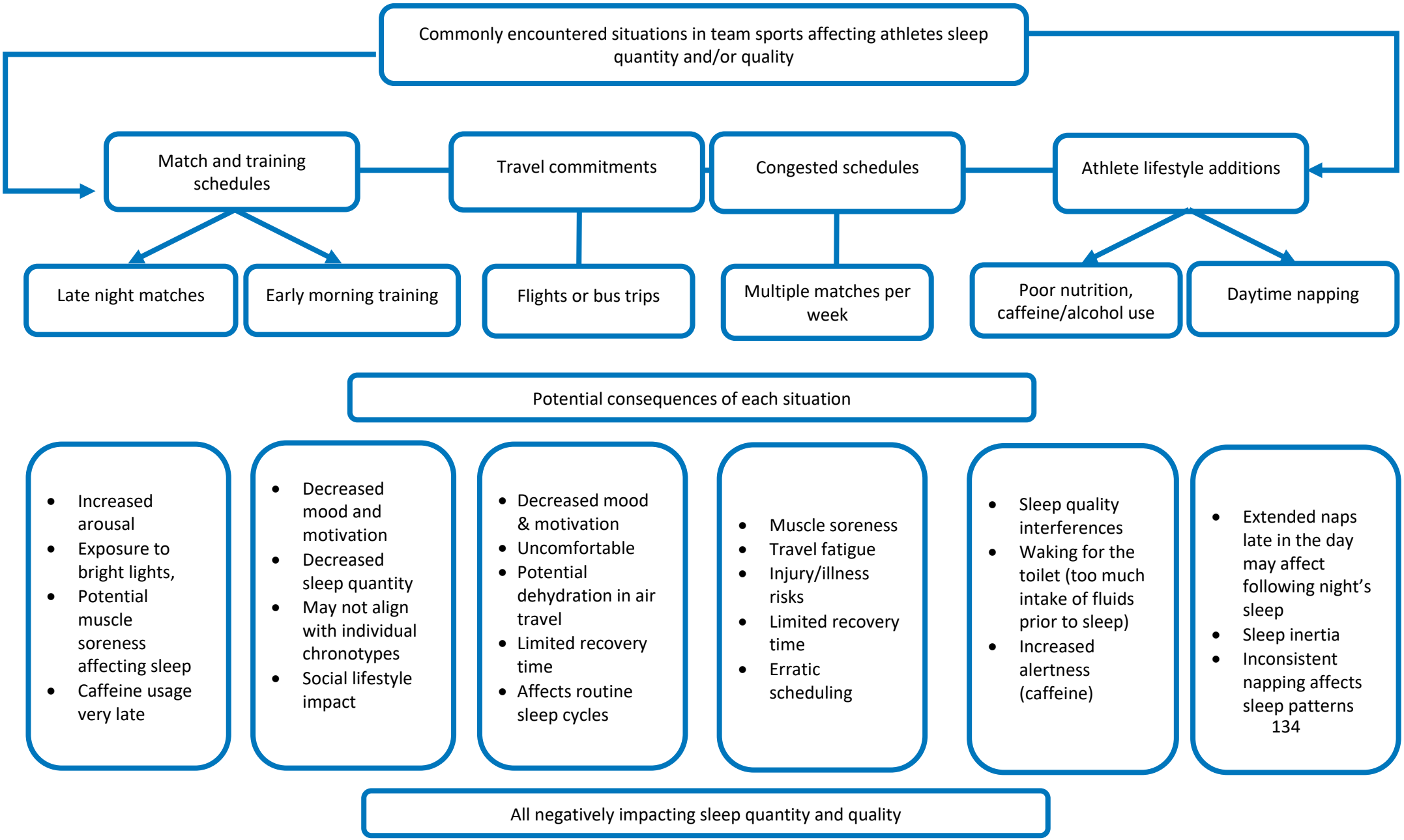
A recent systematic review, reported caffeine to have a negative effect on sleep quality and consequent daytime functioning (Clark and Landolt, 2017). It was reported that consuming approximately 200mg of caffeine after two weeks of abstinence increased SOL, reduced short-wave sleep and the neurophysiological markers of sleep intensity (Clark and Landolt, 2017, Landolt et al.,

2012). A previous study reported that the consumption of caffeine several hours before bed time did not significantly affect sleep quality. However, upon further analysis, the authors found that the participants who had consumed caffeine had a lesser quality of sleep than the control group (Pontifex et al., 2010). This concurred with a further study that reported caffeine consumption up to six hours before sleep resulted in sleep disturbances (Drake et al., 2013). Additionally, caffeine has been linked to inhibiting melatonin secretion (Shilo et al., 2002), therefore we can assume that caffeine has more negative than positive effects on sleep, especially when consumed close to bedtime (see Figure 8). Soccer players consume caffeine-based beverages, chewing-gum and medication to increase alertness and potentially improve performance for matches (Foskett et al., 2009, Ranchordas et al., 2017), however caution should be exercised when consuming caffeine before and after late-night matches.

5.1.5 Individual Characteristics

Finally, individual variation between each athlete needs to be considered, as different stressors such as family, work, sponsors, social, training, etc., will have a unique effect on each athlete's sleep (Venter, 2014). Individual athletes will also develop distinct sleep protocols which work best for them (Leeder et al., 2012b) and corresponds to their chronotypes (Barclay et al., 2014). Soccer players experience stress trying to sleep in conjunction with training, match and social factors outside of sport (Nedelec et al., 2015a). Increased stress may also lead to fluctuating emotions resulting in a disruption in sleep quality (Silva et al., 2012). Stress management tools, relaxation techniques and psychological interventions can assist soccer players in managing their sleep more effectively (Knufinke et al., 2017).

Figure 8: Situations potentially affecting athlete sleep quality and quantity



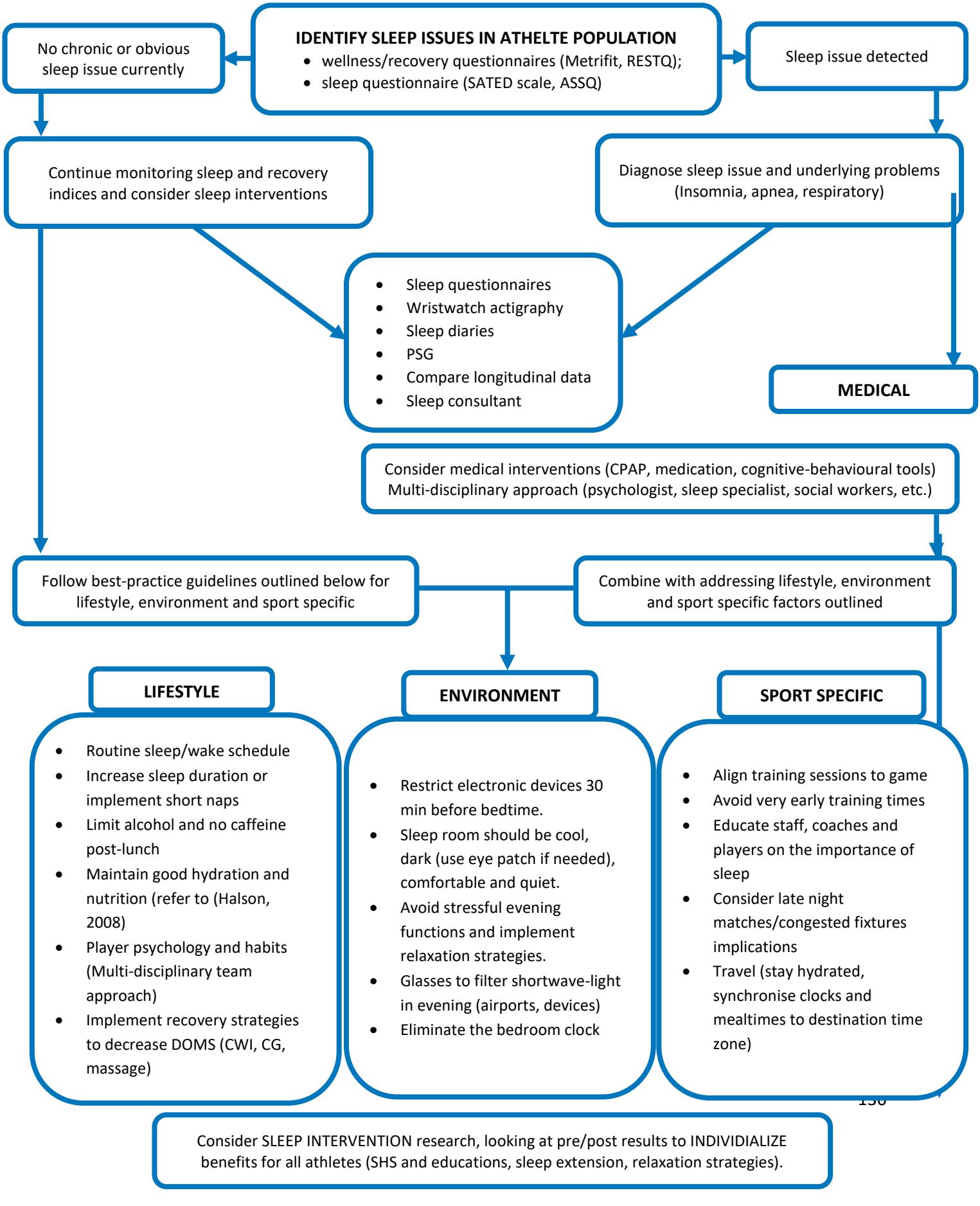
5.2 Strategies to address sleep disturbances

An integrated model to address sleep disturbances in athletes is presented in Figure 9 below. This integrated model is based on relevant literature and the systematic review findings, as discussed in Chapter Two and Chapter Four respectively. The first step of the integrated model for sleep disturbances in athletes is screening the athlete consistent with standard athlete care for wellness/recovery, which includes the Metrifit, Recovery-stress questionnaire (RESTQ) the Athlete Sleep Screening Questionnaire (ASSQ; (Samuels et al., 2015) or Satisfaction, Alertness, Timing, Efficiency and Duration of sleep (SATED) scale questionnaires (Benitez et al., 2017). These short questionnaires provide staff with a broad understanding of recovery and sleep of each athlete. If no obvious sleep or recovery issues are detected, the players should be monitored throughout the season to flag any potential issues, while aiming to improve athlete recovery and sleep with evidence based recovery methods.

Should either of these basic screening methods identify a problem, a further evaluation/analysis of sleep using validated tools such as actigraphy, PSG, sleep specialists and sleep questionnaires should be carried out throughout the season as required. Obtaining a multifaceted understanding of sleep through subjective and objective measures will assist in identifying and isolating concerns that may be addressed using evidence-based interventions. Medical, environmental, lifestyle and sport-specific situations should to be addressed before additional sleep interventions are incorporated, thereby forming a solid foundation to improve recovery and/or performance (Juliff et al., 2015b, Nedelec et al., 2015a, Nedelec et al., 2015b, Knufinke et al., 2017, Tuomilehto et al., 2017). These will be discussed in detail below.

Figure 9: Integrated model for addressing sleep disturbances in athletes

RESTQ – Recovery Stress Questionnaire; ASSQ – Athlete Sleep Screening Questionnaire; SATED –Satisfaction, Alertness, Timing, Efficiency, Duration of sleep; PSG – polysomnography; CPAP – Continuous passive airway pressure; DOMS – delayed onset muscle syndrome; CWI – cold water immersion; CG – compression garments; SHS – sleep hygiene strategies



5.2.1 Addressing medical factors

Any players who signal the possibility of sleep disorders during the basic screening, or present with symptoms of excessive daytime fatigue or sleep difficulties should be referred to a sleep specialist or sleep clinic for evaluation (Simpson et al., 2017). Disrupted sleep is also a common symptom of overtraining syndrome (McKinnon, 2000), therefore monitoring load with coaching management should also be considered. Common sleep disorders such as insomnia can be treated by specialists or online methods (cognitive behavioural therapy). Other common disorders to consider are obstructive sleep apnea, circadian malalignment, snoring and narcolepsy. While many athletes are medicating to fall asleep (Tuomilehto et al., 2017), addiction to medications can cause a host of potential side-effects affecting recovery and performance (Grobler et al., 2000, Tuomilehto et al., 2017).

Sleep disorders should be treated using a multi-disciplinary approach, as mental health issues also present with a pattern of disrupted sleep. Therefore, referral to a psychiatrist or other professional may be necessary to assist players. Psychological interventions assisting with emotional de-stressing is especially important in the demanding and stressful environments of professional soccer (Nedelec et al., 2015a). A recent survey conducted by the International Federation of Professional Footballers (FIFPRO) examined the employment and life situation of soccer players globally, including South Africa. Results indicated that, on average, African players had poor wages, contract difficulties, and an increase in physical abuse (by fans or club staff) more than anywhere else in the world. South African players were three times more likely than the global average to be involved in violent attacks by other players (BBC, 2016, FIFPRO, 2017).

5.2.2 Addressing lifestyle factors

Education is imperative to encourage changes in lifestyle habits and to promote positive sleep behaviour. Previous studies have outlined the positive effects of athlete education on sleep (O'Donnell and Driller, 2017, Tuomilehto et al., 2017, Van Ryswyk et al., 2017). Routine sleep/wake schedules, even on off days, have previously been suggested to align circadian rhythms and promote optimal sleep propensity (Stepanski and Wyatt, 2003). However, increased time in bed may lead to disrupted sleep (Spielman et al., 1987). As a result, requiring athletes to adhere to specific schedules which include late night matches is unrealistic. South African soccer teams travel long distances between each game and often play late matches as a result of television schedules. Therefore, an optimal sleep schedule with opportunities for extended sleep should be managed. Nighttime sleep should ideally be more than

seven hours in duration (Hirshkowitz et al., 2015), with an opportunity for players to utilise sleep extension strategies which have showed some promising results in improving recovery and performance (Mah et al., 2011, Schwartz and Simon, 2015). Napping, as mentioned above, should be considered with caution.

Limiting alcohol use (Feige et al., 2006) and ceasing caffeine consumption post-lunch (Drake et al., 2013) are guidelines that athletes and staff should consider. Team management should consider managing sleep schedules if matches are later in evening, as caffeine is often used as a performance enhancer. Maintaining good hydration and nutrition (refer to (Halson, 2014, Nedelec et al., 2015b) can assist sleep quality. Each player's social situation should be considered by management to assist with family, financial and lifestyle integration (Venter, 2014).

5.2.3 Addressing environmental factors

The sleeping environment constantly changes with travel, therefore basic principles to encourage better sleep should be managed. Coaches endorsement is imperative to allow for smooth environmental transitions for optimised recovery (Ekstrand et al., 2017). A bilateral understanding between players and coaching staff regarding the reasoning behind improved recovery through environmental/behaviour adaption is necessary. External staff, such as sports psychologists, should be used to implement this cohesion (Venter, 2014). Removing electronic devices from athletes did not effect sleep and recovery outcomes (Dunican et al., 2017, Jones et al., 2017), however the increased exposure to bright-light has been linked with increasing alertness and decreasing melatonin secretion, thereby increasing SOL (Cajochen et al., 2011). Therefore, blue-light blockers (van der Lely et al., 2015) or 'night mode' applications on devices are suggested to filter bright light (Gringras et al., 2015). Blue-light blockers can be used for any artificial light exposure at inopportune times (i.e. airports, bus, plane, hotel) to aid in optimal melatonin levels in accordance with sleep times (van der Lely et al., 2015).

The ideal sleeping environment should be cool, dark (using an eye mask if needed), comfortable and quiet (Simpson et al., 2017). Ideally, the room should be consistent with sleep-only behaviour to accustom the body and environment with sleep. The player should avoid stressful evening functions and implement relaxation strategies prior to bedtime. Relaxation strategies can include listening to ambient music and/or watching television (it has been suggested that the relaxing state of watching television can outweigh the negative effects of the emitting devices' light) (Knufinke et al., 2017). Meditation and

prayer are often used as relaxation techniques (Venter, 2014), whereas brainwave entrainment and red-light therapy, although lesser used, are beneficial relaxation strategies (Abeln et al., 2014, Zhao et al., 2012a). Accessory recovery strategies should be implemented to potentially decrease DOMS post-match and aid in sleep onset are namely CWI (Glasgow et al., 2014), massage (Dupuy, 2018) and CG (Hill et al., 2017).

5.2.4 Addressing sports specific factors

Team staff should attempt to align training sessions and game times to adjust circadian rhythms and avoid unnecessary early sessions (i.e. training, breakfasts and travel where possible). Due to the vast amounts of travel required in South African soccer, players and staff should remain abreast of the optimum strategies to maintain regular sleep and recovery during the fluctuating schedules. Although travel in South African soccer occurs in the same time-zone (so jet-lag is not a concern), air travel can result in dehydration, erratic meal times and poor environmental conditions (cramped, noisy, artificial light; (Fowler et al., 2015a, Samuels, 2012). Where possible, players should incorporate increased fluid intake, earplugs, eye masks, sporadic stretching breaks and meal synchronisation (Simpson et al., 2017). While travelling across the country, South African soccer players are affected by changes in altitude. Unfortunately, a lack of research is available to provide advice as to the best protocol to assist with the effects of altitude changes on sleep (Lundby et al., 2012).

CHAPTER 6: SUMMARY AND CONCLUSIONS

The primary aim of this dissertation was to determine the prevalence and scope of recovery methods in professional South African soccer. Firstly, a thorough review of the existing literature relating to post-exercise recovery and the effects of recovery methods in athletic populations was performed. The literature review revealed that participating in athletic endeavors such as soccer stressed immune, musculoskeletal, nervous and metabolic systems (Reilly and Ekblom, 2005), which consequently resulted in post-exercise fatigue (i.e. dehydration, glycogen depletion, muscle damage and mental fatigue; (Nédélec et al., 2012). Recovery functions to reverse the effects of post-exercise fatigue, is aimed at restoration of metabolic, psychological and physiological systems to homeostasis, and is achieved when a player can perform activities which match or exceed pre-training/competition levels (Bishop et al., 2008, Nédélec et al., 2012).

Adequate evidence is presented in support of nutrition and hydration in enhancing post-exercise recovery by addressing dehydration and glycogen depletion (Nedelec et al., 2013, Shirreffs and Sawka, 2011). In contrast, evidence supporting the benefits of other popular recovery methods (i.e. CWI, CWT, massage, stretching, CG and active recovery) on recovery indices was inconclusive (Glasgow et al., 2014, Nedelec et al., 2013). The importance of sleep in athlete health and recovery (Bird, 2013, Simpson et al., 2017) and the negative effects of poor sleep on recovery has been previously established (Fullagar et al., 2014). However, the lack of sleep interventions using athletes in clinical trials made it difficult to make definitive conclusions or recommendations with regards to sleep interventions as an effective recovery method.

The first study in this dissertation utilised a survey based approach to investigate the current practices regarding post-exercise recovery methods by medical professionals involved in professional soccer teams in South Africa (Chapter Three). Following the evidence reported in the literature review (Chapter Two), the study objectives as described in Section 1.3.2 above, may be addressed as follows:

6.1 Recovery methods in South African professional soccer; what is currently being used?

Forty-eight professional soccer teams across three divisions in South Africa participated in a survey to ascertain the current recovery strategies being utilised. Results of the survey highlighted the variety of recovery methods used (between five and seven) by each team. Cold-water immersion, hydration, nutrition and stretching were seen to be the most effective and prevalent recovery methods by respondents. Despite sleep being identified as an important recovery method in athlete recovery, less than 10% of staff used SHS. Most recovery methods implemented by staff were based on anecdotal or personal preference rather than evidence-based protocols.

Teams in the top tier of the South African soccer league (PSL) utilise more recovery methods than teams in the lower divisions (NFD and NSD). A similar trend was identified across previous studies which reported that elite teams used more recovery methods than less elite or lower division teams (Crowther et al., 2017b, Tavares et al., 2016). This is most likely due to the fact that teams in higher divisions generally have access to more resources (i.e. funds, equipment and staff) to assist with implementing recovery methods (i.e. hydrotherapy facilities for CWI or CWT, therapists for massage or to instruct/monitor recovery classes). Additionally, teams in higher divisions generally have access to more funds to invest in better player nutrition and hydration for recovery. As was reported in the present study, teams in lower tiers generally only rehydrated with water post-exercise instead of with a CHO based option. While it is reasonable to infer that top tiered teams would have more resources and potentially less barriers to the implementation of recovery methods, it should be emphasised that the quantity of recovery method protocols should not be prioritised over quality evidence-based methods.

6.2 Barriers to implementing post-exercise recovery methods in soccer

The greatest barrier to implementing recovery methods identified by staff was a ‘lack of player interest’, with around 40% of staff reporting that players interest in implementing recovery methods was an obstacle. Player ‘buy-in’ is key to implementing any training or recovery method effectively. The issue of compliance or player ‘buy in’ may be further complicated due to the large variability in player backgrounds with associated perceptions, beliefs and experiences. Unfortunately, players are often grouped together in team sports and treated with a ‘one size fits all’ philosophy, which may affect

overall player compliance to the use of recommended recovery strategies. It is likely that staff implement recovery methods based on the available capacity within their working environments.

A recent consensus on recovery has emphasised the need for greater individuality to meet the specific needs of the individual player to best improve athlete 'buy-in' and recovery (Kellmann et al., 2018). The survey carried out in Study One could be construed as bias as it only asked staff and coaches to identify barriers for recovery implementation, therefore it is easy for them to identify the players 'buy-in' as a barrier. However, there is an onus on staff and coaches to educate players appropriately and utilise an evidence based approach towards recovery, which appears to be lacking. In this regard, coaches are able to assist, as they exert a strong influence on player 'buy-in' (Bérdi et al., 2015, Ekstrand et al., 2017) and were also not seen as a barrier to recovery implementation in South African soccer.

Lack of finances were also cited as a barrier to implementation, specifically for nutrition, hydration and CG. Compression garments can be expensive and no compelling evidence for recovery improvements post soccer matches is currently reported in the literature. This is a logical barrier for implementation and teams should rather allocate their finances towards beneficial evidence-based recovery options. Lack of finances was reported to affect quality nutrition and hydration practices across South African soccer teams, more so for teams in lower leagues. These teams, who receive less sponsorships and financial assistance from the leagues, use water for rehydration instead of the recommended CHO option post-training. An opportunity exists to involve health professionals in nutrition planning to streamline the hydration and nutrition recovery protocols in the most cost-effective way possible to suite each team's resources and needs.

Sleep interventions typically require very little cost or resources and could easily be adopted by most of the clubs concerned. This is important considering the fundamental role sleep plays in athlete recovery, however knowledge of its use and implementation in soccer athletes is lacking. Consequently, a systematic review (carried out in Study Two) of the literature was performed to investigate the effects of sleep interventions on recovery and performance in athletic populations.

6.3 Sleep interventions in athlete recovery – what does the evidence tell us?

The systematic review observed that interventions aimed at improving sleep outcomes in athletes generally resulted in improved sleep indices and enhanced recovery or performance outcomes. The efficacy of interventions to benefit sleep indices such as sleep extension, education and behaviour changes and relaxation strategies seem to improve recovery (Simpson et al., 2017). Furthermore, a dose response was evident, with interventions implemented for a greater duration seeming to have a more beneficial effect on sleep indices and, in turn, recovery and performance.

Specifically, sleep extension interventions had the most promising results and appeared as the most practical strategy for improving recovery/performance. As sleep extension has been isolated as a cheap, simple, easily accessible and generally healthy intervention with beneficial effects, it should be implemented across all leagues in South African soccer. Improved quality RCTs with larger samples sizes, increased athletic populations, improved in depth sleep measurements and effective control groups in match-based scenarios to replicate real world situations and psychology should also be considered.

As outlined in Chapter Three, sleep as a recovery strategy was rarely implemented in South African soccer despite a growing body of research highlighting the beneficial effects of sleep and sleep interventions in athlete health, recovery and performance (Gerber et al., 2010, Mah et al., 2011, Nedelec et al., 2015a, Samuels, 2008). Consequently, supplementary sleep recovery methods are vital to ensure optimal athlete sleep quality and quantity. Sleep is a complex process involving a myriad of inter relating biological, psychological and environmental (Davenne, 2009, Samuels, 2008, Reilly and Waterhouse, 2009). These factors range from light disturbances (Charles and Emery, 1999), jetlag and travel fatigue (Samuels, 2012), nutritional (Halson, 2008), individual traits, genetic disposition or sleep disorders (Nedelec et al., 2015a, Sehgal and Mignot, 2011) individual social stressors or anxiety (Demarzo and Stein, 2012, Fietze et al., 2009) and environmental stressors (Nedelec et al., 2015a). Therefore, the feasibility of health care practitioners intervening in each of these areas would not be realistic. Despite the complex and multifactorial nature of sleep and sleep recovery, two previous reviews (Nedelec et al., 2015a, Fullagar et al., 2015a) have outlined common situations among team sport athletes which negatively impact sleep quality and/or quantity and recovery, where health care practitioners may be able to intervene to improve athletes performance outcomes (see Figure 9).

Sleep as an intervention for recovery cannot be considered in isolation and the overall context of an individual or athlete's lifestyle should also be considered and included. Sleep habits and routines interact with a variety of internal (i.e. mood, psychology, stress, sociological, physiological; (Nedelec et al., 2015a) and external metrics (i.e. diet, training load, competition anxiety or stress, match result, weather, environmental factors, supplement consumption; (Nedelec et al., 2015a), all of which are independent variables. Therefore, it is fundamental that any intervention aimed at improving any one variable considers the impact of the above outlined internal and external metrics. By only improving, say sleep extension, without considering a holistic view of the athlete and the underlying issues potentially causing poor sleep, long term success is unlikely. Recovery efficiency should improve with a combination of recovery methods (Bieuzen et al., 2013, Duffield et al., 2014), placing emphasis on addressing evidence-based nutrition, hydration and sleep intervention recovery protocols. Due to the relatively poor methodological quality of most of the reviewed studies, a conclusive summary cannot be provided in reference to this topic. It is unlikely that improving sleep will be harmful to an athlete's performance or recovery, and although evidence reporting positive effects is inconclusive, there is also no evidence suggesting a decline in performance or recovery.

This is the first study, to the researcher's knowledge, that sought to systematically investigate recovery practices and methods in South African soccer through the use of a survey based approach. The research outcomes of the present study and systematic review have contributed to the current void of data on the prevalence of recovery methods in South African soccer. Additionally, this research project has increased the growing body of knowledge that exists on sleep in athletes. Staff are now in a better position to acknowledge the importance of sleep in athletes and the monitoring thereof. Certain sleep interventions were explored with potential benefits for recovery and performance, however further research is required. Staff in South African soccer should emphasise recovery interventions focusing on improving nutrition, hydration and sleep and utilise resources aimed at benefiting recovery through evidence based protocols.

6.4 Dissemination Strategy

The findings of this dissertation will be disseminated via South African soccer clubs, in the form of a short presentation and an informative leaflet. The recovery method survey and systematic review will be prepared as two separate papers and submitted to journals for publication consideration. Visual aids

and infographics will be created for use on social media platforms and shared with South African soccer connections, athletes and researchers involved in recovery both locally and globally.

6.5 Conclusion

Based on the findings of the present study, it is recommended that SAFA and health professionals working within the Health Professionals Council of South Africa collaborate to review current recovery method protocols employed in South African soccer. The results of the present study indicate that recovery methods are implemented without a full understanding of the beneficial physiological and psychological effects on recovery and performance indices. Given the fundamental role of recovery in professional sport, this highlights the need for further research by focusing on evidence-based recovery methods and the mechanistic effects of interventions to improve recovery.

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APPENDIX I: Information sheet and Informed Consent

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Information Sheet

"The Use of Recovery
Methods by South African Soccer Teams"

Dear Colleague,

Thank you for the opportunity of asking you to participate in this study. I am a UCT student, currently completing a Master's degree in Physiotherapy. I have previously completed my undergraduate degree in physiotherapy and am working with an elite soccer team in the PSL. This study aims at finding out what recovery methods are being used throughout South African soccer teams post-exercise. In addition, it will assess the knowledge and attitudes of the staff involved with recovery methods of these teams. This study has been given ethics approval by the University of Cape Town, Faculty of Health Sciences Human Research Ethics Committee.

Soccer teams in South Africa are using recovery strategies based on anecdotal evidence, past experiences or personal preferences rather than readily available scientific evidence. In addition, different members of the health care team or coaching staff take on the responsibility of recovery methods for different teams in South Africa, leaving a varied form of recovery throughout the sport. The study will be in the form of a structured questionnaire, interviewed personally by the investigator. The questionnaire should take approximately 45 minutes of your time. Once the study has finalized all the data, experts in the field of recovery will be consulted to form a consensus on recovery post-exercise. After this a best-practice guidelines document will be disseminated to all the soccer teams' staff involved with recovery, including you. The guidelines will be based upon the questionnaire

from the participants, the expert consensus and current literature. The participant can expect to receive feedback throughout the study process.

If you agree to participate in this study, please complete the informed consent form. Once the form has been signed, you are agreeing to take part in the questionnaire with the investigator. If you do not sign the informed consent you will not be able to take part in this study.

At all times, confidentiality will be maintained, and you will not be identifiable on the questionnaire or any other document. No information will be able to be accessed by any governing body, i.e. SAFA or any sporting team. Only the investigator will have access to the data. Data will be analyzed and reported on collectively in the form of presentations, dissertations and possibly publications. The study will only work if each participant answers all the questions as honestly and accurately as possible, so please take your time to think about your answers carefully.

Informed Consent:

Title of the study:

"The use of recovery methods by South African soccer teams"

Dear Colleague,
The main aim of this study is to determine the use, knowledge and attitudes of support staff working for professional soccer teams in South Africa, who are involved with recovery methods post-exercise. These issues will be explored in a questionnaire-based survey designed on previous and current literature and validated by professionals in the recovery field. Experts in the field of recovery will, at a later stage, add input and consensus into the study to help develop best-practice guidelines for recovery post-exercise in soccer.

I (full name)_____ hereby confirm that:

1. I have read the attached "Subject Information Sheet" and have familiarized myself with the study information.
2. I will be requested to complete a previously validated questionnaire in connection with the studies title "The *Use of Recovery Methods by South African Soccer Teams*".
3. The questionnaire will take approximately 45 minutes to complete.
4. My participation in this study is completely voluntary and I am free to withdraw at any time.
5. Privacy and confidentiality will be maintained, and my name will not be asked of or used in any documents or analyses.
6. The questionnaire and study records will be kept in a safe locked environment.
7. Data collected from the study may be used or presented in a research paper, presentations or a dissertation.
8. By signing below, I understand all of the information above including any benefits or risks involved in the study.

Questions or Concerns:

If at any time you have any questions about the study, please feel free to contact any of the individuals listed below. You are assured that all enquiries will remain strictly confidential.

Investigator: Dustin Maree dustinmaree@gmail.com (Cell: 0824505536)

Supervisor: Dr. Theresa Burgess theresa.burgess@uct.ac.za

Supervisor: Professor Mike Lambert mike.lambert@uct.ac.za

Ethics Committee: Professor Marc Blockman (Chairperson, Human Research Ethics Committee)

marc.blockman@uct.ac.za (Tel: 021 406 6492)

Signed:

Participant: _____ Date: ____/_____/2013

Investigator: _____ Date: ____/_____/2013

Thank you very much for your consideration in participation of this study. All information will help successfully guide improvements in South African soccer.

Kind Regards,

Dustin Maree

APPENDIX II: Questionnaire

QUESTIONNAIRE:

The Use of Recovery Methods by Elite South African Soccer Teams.

1. Demographic and background information

1.1 What is your current age? _____ years?

1.2 What is your profession? (✓)

Doctor	Physiotherapist	Fitness Coach	Biokineticist	Other

1.3 How long have you been qualified in your profession

_____ years?

1.4 How long have you been working with your current soccer team?

_____ years?

1.5 Are you working full-time or part-time? _____?

1.6 Which league is your soccer team currently playing in? (✓)

PSL	NFD	SAFA Second Division	None

1.7 Who plans the recovery methods in your team post-training?(✓)

Myself	Other staff	Multidisciplinary	Do not use

If other staff, please specify _____?

1.8 Who executes the recovery methods in your team post-training? (✓)

Myself	Other staff	Multidisciplinary	Do not use

If other staff, please specify _____?

1.9 Who plans the recovery methods in your team post-match?(✓)

Myself	Other staff	Multidisciplinary	Do not use

If other staff, please specify _____?

1.10 Who executes the recovery methods in your team post-match? (✓)

Myself	Other staff	Multidisciplinary	Do not use

If other staff, please specify _____?

2. Post-match fatigue and recovery

2.1 On average, what is the distance covered by elite outfield soccer players during a 90 minute match? (Mohr, Krustrup et al. 2005, Bradley, Sheldon et al. 2009, Andersson, Raastad et al. 2008)

a. Between 9-11kilometers *

b. Between 6-8 kilometers

c. I do not know

d. Less than 6 kilometers

e. More than 12 kilometers

2.2 Approximately what percentage of an elite player's body mass is lost during a 90 minute soccer game in thermo-neutral conditions. (Mohr, Mujika et al. 2010, Reilly 1997, Edwards, Noakes 2009)

a. 10%

b. 7%

c. Less than 1%

d. Approximately 4-5 %

e. I do not know

f. Approximately 2%*

2.3 After how much time on average do you think that the body recovers to pre-match levels of performance, after a 90-minute soccer game? (Dupont, Nedelec et al. 2010, Ispirlidis, Fatouros et al. 2008)

a. 12-24 hours

b. 72-96 hours*

c. 24-48 hours

d. Two weeks

e. One month

2.4 What is currently considered the main cause of fatigue after repeated high intensity exercise? (Nédélec, McCall et al. 2012)

a. Increase in muscle and blood lactate

b. Impaired muscle function due to down regulation of the central nervous system*

c. An increase in muscle pain

d. Creatine Kinase and inflammation in the muscle is increased

e. The increase in swelling in the muscle causes a decrease in function therefore causing fatigue

2.5 What do you think the injury rate difference would be for players playing a 90-minute soccer game twice a week compared to players playing only once a week? (Dupont, Nedelec et al. 2010)

a. 15 % higher injury rate

b. 10% lower injury rate

c. No difference

d. 6% higher injury rate*

e. 35% higher injury rate

2.6 What are some of the markers, if any, do you use to assess muscle damage? (Nédélec, McCall et al. 2012)(✓)

Maximal voluntary contraction	
Blood markers – CK and myoglobin concentration	
Muscle pain scales	
We do not use muscle damage markers	
Range of Motion testing	
Swelling measurement of muscle	
Fatigue questionnaires	
Do not use any	
I am not sure	
Other	

If Other, please specify…….

2.7 What is your opinion on: mental fatigue playing a major role in in post-match fatigue?(Jeffreys 2005)

a. Strongly agree

b. Moderately agree

c. Undecided

d. Moderately disagree

e. Strongly disagree

2.8 Do you use any tools to monitor the soccer player's recovery or training loads? If so, what do you use? (Brink, Nederhof et al. 2010, Nédélec, McCall et al. 2012, Nédélec, McCall et al. 2013) (✓)

Weight scales	
Fatigue scales	
Muscle soreness scales	
Heart Rate monitoring	
Changes in Hormones	
Fluid intake	

Other…….

2.9 Fatigue following a soccer match is dependent only on the fitness of the player. (Nédélec, McCall et al. 2013)

a. Strongly agree

b. Moderately agree

c. Undecided

d. Moderately disagree

e. Strongly disagree

* Fatigue following a soccer match is multifactorial and related to dehydration, glycogen depletion, muscle damage and mental fatigue. Consider extrinsic and intrinsic variables and match contextual factors.

2.10 Soccer teams who use more recovery methods than other soccer teams will have a better chance of performing and getting results?

a. Strongly agree

b. Moderately agree

c. Undecided

d. Moderately disagree

e. Strongly disagree

2.11 What recovery methods are you currently using to improve the psychological and physical wellbeing of the player's post-exercise (training or match). You may tick as many boxes that indicate that you use the method in some form or another. (✓)

Nutrition: Hydration	
Nutrition: Carbohydrates	
Nutrition: Proteins	
Cold-water immersion	
Contrast water therapy	
Compression Garments	
Massage	
Stretching	
Sleeping Protocols	
NSAIDS (Non-Steroidal Anti-Inflammatory Drugs)	
EMS (Electro-Myo Stimulation)	
Alcohol Avoidance	
Hyperbaric Oxygen Therapy	
Other…….	

Recovery Methods

Recovery methods are being utilized, by many professional soccer teams around the world. Each recovery method aims to reverse the symptoms of fatigue and accelerate the time to fully recover post-exercise (Nédélec, McCall et al. 2013). More money is being made available for teams to implement methods, but a lack of research has led to no defining guidelines. This leads to different teams using varying approaches according to the staff member involved in recovery, rather than defining protocols. The following sections on recovery methods will be asked: Hydration; Nutrition: Carbohydrates and Proteins; Cold-water immersion; Active recovery; Sleeping protocols; Stretching; Massage and Compression garments.

3. Hydration

3.1 After a match what fluid/s do most of the player's drink? (Nédélec, McCall et al. 2013, Shirreffs, Taylor et al. 1996)

a. Water
b. Energade/Powerade*
c. Energy drink (Redbull)
d. Not sure - whatever is available
e. Nothing
f. High Sodium drink*
g. Protein drink
h. Other ……

3.2 After training what fluid/s do most of the player's drink? (Nédélec, McCall et al. 2013, Shirreffs, Taylor et al. 1996)

a. Water
b. Energade/Powerade
c. Energy drink (Redbull)
d. Not sure - whatever is available
e. Nothing
f. High Sodium drink
g. Protein drink
h. Other ……

3.3 How much are the players encouraged to drink after exercise? (Nédélec, McCall et al. 2013, Shirreffs, Taylor et al. 1996)

a. No one monitors

b. 500 milliliters (ml) (One bottle)

c. Re-hydrating is discouraged

d. Continue drinking fluids until they fall asleep

e. Depending on how much fluid has been lost *

3.4 On a scale of 1-5 list how effective you think that rehydrating is post-exercise on:

1= Very effective; 2= Moderately effective; 3= No effect; 4= Moderately ineffective; 5 = Very ineffective.

Reducing muscle pain:	
Promoting glycogen synthesis:	
Increasing blood lactate removal:	
Decreasing Mental Fatigue:	
Overall as a recovery method post-exercise	

3.5 Does the team practice any alcohol avoidance techniques? (✓)

YES	NO

3.6 What effects, if any do you think alcohol has on recovery post-exercise? (Feige, Gann et al. 2006, Barnes, Mündel et al. 2010)

a. Increases recovery time

b. Has no effect on recovery

c. Decreases recovery time

d. Does not matter, especially if they win

e. I am not sure

3.7 Do you experience any limitations from implementing rehydration as a recovery method post-exercise? (✓)

YES	NO

If YES, what limitations do you experience?

4. Nutrition: Carbohydrates and Proteins

4.1 What carbohydrate consumption is considered ideal post-exercise? (Nédélec, McCall et al. 2013, Jentjens, Jeukendrup 2003)

a. 0.5g carbohydrates kg/h straight after the game

b. Two Power-aid bottles

c. Low carbohydrate meal the following morning

d. Hi-carbohydrate meal the following morning

e. 1.2g carbohydrates kg/h for as soon as possible, continuing for 5 hours *

f. No foods, only water

g. I don't know

4.2 If a lower amount of carbohydrate is consumed, what can be co-ingested to help with glycogen synthesis and improve recovery? (Nédélec, McCall et al. 2013, Jentjens, Jeukendrup 2003)

a. Omega-3 Fatty acids

b. Water

c. Nothing else is needed

d. Proteins*

e. Anti-inflammatories or foods with anti-inflammatory properties

f. I don't know

4.3 Do the players get any other nutritional supplement post-training? (✓)

YES		NO	

If YES, What?

4.4 Do the players get any other nutritional supplement post-match? (✓)

YES		NO	

If YES, what?

4.5 On a scale of 1-5 list how effective you think that nutrition: additional carbohydrates and protein is post-exercise on:

Reducing muscle pain:	
Promoting glycogen synthesis:	
Increasing blood lactate removal:	
Decreasing Mental Fatigue:	
Overall as a recovery method post-exercise	

1= Very effective; 2= Moderately effective; 3= No effect; 4= Moderately ineffective; 5 = Very ineffective

4.6 Is the habitual diet of the players monitored?

a. Only when they eat at the club

b. Not at all

c. Players receive daily diet plans and nutritional advice.

d. Players get information on nutrition once a season

e. I do not know.

4.7 Do you experience any limitations implementing nutrition as a recovery method post-exercise? (✓)

YES	NO

If YES, what?

5. Cold-Water Immersion

5.1 Do you ever use Cold-water immersion? (✓)

YES	NO

If you answered YES, when do you use it? You may (✓) more than one box, where necessary.

After every match	
After every training session	
The following day after a match	
Only when a hard training session has been completed	
Congestive match fixtures	
Only when the player is injured	
Only if a player requests it	
Never use this method for recovery	

5.5 Does anyone measure the water temperature? (✓)

YES	NO

If yes, what is the average water temperature?

5.6 How deep are the players immersed into the cold water when using this recovery method?

a. Chest

b. Umbilical line

c. Up to the kneecap

d. Up to the hip – below the genitals

e. Full body

5.7 What do you make use of as the container for the cold-water immersion?

a. Jacuzzi

b. Portable bath

c. Swimming pool

d. Shower

e. Plastic drum

f. Other _____

5.8 Do some of the players not make use of the immersion? ✓ (Tick where necessary)

YES	NO

If YES, why not?

They are injured	
They do not like ice/cold water	
They have their own beliefs about recovery	
I do not know	
Other	

If Other, please specify…….

5.9 Where are your protocols for cold-water immersion from?

a. My own judgment and experience

b. Current literature

c. Research papers and field experiments

d. Anecdotal evidence

e. Coaching staff perceptions

5.10 What are some of the physiological responses, as the water gets colder (water temperature decreases), when our body is immersed in cold water? (Wilcock, Cronin et al. 2006)

a. Heart rate reduces a metabolism increases

b. Heart rate increases and blood pressure decreases

c. The body maintains no physiological changes

d. Oxygen consumption is decreased to maintain core temperature

e. I do not know

5.11 On a scale of 1-5 list how effective do you think that cold-water immersion is post-exercise on:

1= Very effective; 2= Moderately effective; 3= No effect; 4= Moderately ineffective; 5 = Very ineffective

	MATCH	TRAINING
Reducing muscle pain:		
Promoting glycogen synthesis:		
Decreasing blood flow:		
Decreasing Mental Fatigue/improving psychological state:		
Overall as a recovery method post-exercise		

5.12 Do you use any other forms of hydrotherapy?

5.13 Do you experience any limitations from implementing CWI as a recovery method post-exercise? (✓)

YES	NO

If YES, what?

6. Active Recovery

Do you use active recovery? (✓)

YES	NO

6.1 If you use Active Recovery, when do you use it? (You may ✓ more than one box, where necessary).

After every match	
After every training session	
The following day after a match	
Only when a hard training session has been completed	
Congestive match fixtures	
Only when the player is injured	
Only if a player requests it	
Never use this method for recovery	

6.2 Where are your protocols for active recovery from?

a. My own judgment and experience

b. Current literature

c. Research papers and field experiments

d. Anecdotal evidence

e. Coaching staff perceptions

6.3 What is your preferred exercise for active recovery?

a. Cycling

b. Pool running

c. Field running (cool down)

d. Gym routine

e. Rest

f. Other……

6.4 What is the suggested intensity that active recovery exercise should be performed at to accelerate pH recovery and enhance lactate removal? (Fairchild, Armstrong et al. 2003, Sairyo, Iwanaga et al. 2003)

a. I am not sure

b. 30-60%

c. 70%

d. 80%

e. Less than 35%

6.5 What is the duration of the active recovery protocol?

a. 0-10 minutes

b. 30 minutes

c. 45 minutes to 1 hour

d. I do not keep time

e. When the player feels sufficient time has passed

6.6 On a scale of 1-5 list how effective you think that active recovery is post-exercise on:

1= Very effective; 2= Moderately effective; 3= No effect; 4= Moderately ineffective; 5= Very ineffective

Reducing muscle pain:	
Promoting glycogen synthesis:	
Increasing blood lactate removal:	
Decreasing Mental Fatigue:	
Overall as a recovery method post-exercise	

6.7 Do you experience any limitations from implementing active recovery as a recovery method post-exercise? (✓)

YES	NO

If YES, what?

7. Sleep interventions

7.1 Do you implement any sleeping interventions or advice as a part of recovery methods? (✓)

YES	NO

7.2 During slow wave sleep, metabolic activity is at its lowest and growth hormone is secreted, which allows for maximal muscle growth and repair. (✓)

TRUE	FALSE

7.3 How many hours of sleep is recommended for athletes a night? (Calder 2004)

a. 6 hours

b. 7-9 hours*

c. 5-7 hours

d. Less than 6 hours to remain sharp

e. More than 10 hours to help heal muscles

f. Does not matter

7.4 What is your opinion of the following statement relating to players sleeping during the day – "power naps"? "Power naps" or sleeping during the day makes players tired, aggressive and moody; potentially negatively affecting their performance. (Lagarde, Batejat 1995, Waterhouse, Atkinson et al. 2007)

a. Strongly agree

b. Moderately agree

c. Undecided

d. Moderately disagree

e. Strongly disagree

7.5 On a scale of 1-5 list your perceptions on the effects of a lack of sleep on: 1= Very effective; 2= Moderately effective; 3= No effect; 4= Moderately ineffective; 5 = Very ineffective

	MATCH	TRAINING
Reducing muscle pain:		
Promoting glycogen synthesis:		
Decreasing stiffness:		
Decreasing Mental Fatigue		
Overall as a recovery method post-exercise		

7.6 Do you experience any limitations from implementing sleep interventions as a recovery method post-exercise? (✓)

YES	NO

If YES, what?

8. Stretching

8.1 Do you use stretching as a recovery method? (✓)

YES		NO	

If Yes, when do you use stretching? (You may ✓ more than one box, where necessary).

After every match	
After every training session	
The following day after a match	
Only when a hard training session has been completed	
Congestive match fixtures	
Only when the player is injured	
Only if a player requests it	
Never use this method for recovery	

8.2 Where are your protocols for stretching from?

a. My own judgment and experience

b. Current literature

c. Research papers and field experiments

d. Anecdotal evidence

e. Coaching staff perceptions

8.3 What is the average time duration of your stretching protocol?

a. 0-5 minutes

b. 10-20 minutes

c. 30 minutes

d.1 hour

e. Let the players stretch until they feel sufficient time has passed

8.4 Static stretching is a bouncing rhythmic movement that uses the momentum of the swinging body to lengthen the muscle whilst ballistic stretching is a slow, controlled stretch of a relaxed muscle. (✓). (Mahieu, Mcnair et al. 2007)

TRUE	FALSE

8.5 Stretching exercises immediately post-exercise have been shown to be effective in decreasing symptoms of muscle damage. (Cheung, Hume et al. 2003, Connolly, SAYERS et al. 2003, Gulick, Kimura et al. 1996, Mika, Mika et al. 2007)

a. Strongly agree

b. Moderately agree

c. Undecided

d. Moderately disagree

e. Strongly disagree

8.6 On a scale of 1-5 list how effective you think that sleeping protocols are post-exercise on: 1= Very effective; 2= Moderately effective; 3= No effect; 4= Moderately ineffective;5= Very ineffective

	MATCH	TRAINING
Reducing muscle pain:		
Promoting glycogen synthesis:		
Decreasing Mental Fatigue/improving psychological state:		
Overall as a recovery method post-exercise		

8.7 Stretching after exercise which causes muscle damage, may lead to further damage of muscle tissue? (Lund, Vestergaard‐Poulsen et al. 1998)

a. Strongly agree

b. Moderately agree

c. Undecided

d. Moderately disagree

e. Strongly disagree

8.8 Do you experience any limitations from implementing stretching as a recovery method post-exercise? (✓)

YES	NO

If YES, what?

9. Massage

9.1 Do you use massage as a recovery method? (✓)

YES	NO

If Yes, when do you use massage? (You may ✓more than one box, where necessary).(Tiidus, Shoemaker 1995)

After every match	
After every training session	
The following day after a match	
Only when a hard training session has been completed	
Congestive match fixtures	
Only when the player is injured	
Only if a player requests it	
Never use this method for recovery	

9.2 Who gives the massage treatments post-exercise?

a. External massage therapists

b. Interns or students

c. Physiotherapist

d. No One

e. Whoever is available

f. I am not sure

g. Player uses foam rollers and self-massage techniques.

9.3 Where are your protocols for massage from?

a. My own judgment and experience

b. Current literature

c. Research papers and field experiments

d. Anecdotal evidence

e. Coaching staff perceptions

9.4 What is the duration of a massage treatment for recovery?

a. 0-10 minutes

b. 20 minutes

c. 45 minutes – 1 hour

d. Never time the sessions

e. Each time is different

9.5 On a scale of 1-5 list how effective you think that massage is post-exercise on:

1= Very effective; 2= Moderately effective; 3= No effect; 4= Moderately ineffective; 5= Very ineffective(Tiidus, Shoemaker 1995)

	MATCH	TRAINING
Reducing muscle pain:		
Decreasing blood flow:		
Decreasing Mental Fatigue/improving psychological state:		
Overall as a recovery method post-exercise		

10.1 Do the players in your soccer team use compression garments as a recovery method? (✓)

YES	NO

If Yes, when do the players use compression garments? (You may ✓more than one box, where necessary).

After every match	
After every training session	
The following day after a match	
Only when a hard training session has been completed	
Congestive match fixtures	
Only when the player is injured	
Only if a player requests it	
Never use this method for recovery	
When travelling	

10.2 Where are your compression garments from?

10.3 How do compression garments in the lower limbs function? (Sigel, Edelstein et al. 1975)

a. Evenly spread pressure through the lower leg

b. Increased pressure on the ankle and decreased on the mid-thigh*

c. Increased pressure on the mid-thigh and decreased on the ankle.

d. Only increased pressure in the mid-thigh

e. I do not think there are any pressure changes by wearing the garment

10.4 Do you know how much pressure is applied through the compression garments the players are using? (✓)(Hill, Howatson et al. 2013)

YES	NO

10.5 What is the minimum pressure that should be applied when using the compression garments?

a. 10mmHg at the ankle and 3mmHg at the level of the mid-thigh

b. 9mmHg at the ankle and 13mmHg at the level of the mid-thigh

c. 18mmHg at the ankle and 8mmHg at the level of the mid-thigh*

d. 30mmHg at the ankle and 30mmHg at the level of the mid-thigh

e. 8mmHg at the ankle and 20mmHg at the level of the mid-thigh

10.6 On a scale of 1-5 list how effective you think that compression garments are post-exercise on:

1= Very effective; 2= Moderately effective; 3= No effect; 4= Moderately ineffective; 5 = Very ineffective

	MATCH	TRAINING
Reducing muscle pain:		
Promoting glycogen synthesis:		
Decreasing stiffness:		
Decreasing Mental Fatigue		
Overall as a recovery method post-exercise		

10.7 Do you experience any limitations from using compression garments as a recovery method?

YES	NO

If YES, What?

UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Human Research Ethics Committee

Room E52-24 Old Main Building
Groote Schuur Hospital
Observatory 7925
Telephone [021] 406 6338 • **Facsimile** [021] 406 6411
Email: shuretta.thomas@uct.ac.za
Website: www.health.uct.ac.za/research/humanethics/forms

21 January 2014

HREC REF: 044/2014

Dr T Burgess
Physiotherapy
Health & Rehab
F45, OMB

Dear Dr Burgess

PROJECT TITLE: THE USE OF RECOVERY METHODS BY PROFESSIONAL SOUTH AFRICAN SOCCER TEAMS

Thank you for submitting your study to the Faculty of Health Sciences Human Research Ethics Committee for review.

It is a pleasure to inform you that the HREC has **formally approved** the above-mentioned study.

Approval is granted for one year until the 30th January 2015

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.
(Forms can be found on our website: www.health.uct.ac.za/research/humanethics/forms)

We acknowledge that the student Dustin Maree is also involved in this study.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please quote the HREC reference no in all your correspondence.

Yours sincerely

Signature Removed

PROFESSOR M BLOCKMAN
CHAIRPERSON, FHS HUMAN ETHICS
Federal Wide Assurance Number: FWA00001637.
Institutional Review Board (IRB) number: IRB00001938
This serves to confirm that the University of Cape Town Human Research Ethics Committee complies to the Ethics Standards for Clinical Research with a new drug in patients, based on the Medical Research Council (MRC-SA), Food and Drug Administration (FDA-USA), International Convention on Harmonisation Good Clinical Practice (ICH GCP) and Declaration of Helsinki guidelines.

HREC Ref 044/2014

*HREC Approval was subsequently renewed in align with the stipulated approval conditions

UNIVERSITY OF CAPE TOWN

FACULTY OF HEALTH SCIENCES
Human Research Ethics Committee

FHS016: Annual Progress Report / Renewal

HREC office use only (FWA00001637; IRB00001938) This serves as notification of annual approval, including any documentation described below.			
☐ Approved	Annual progress report	Approved until/next renewal date	30/1/2020
☐ Not approved	See attached comments		
Signature Chairperson of the HREC		Date Signed	7/2/2019

Signature Removed

Comments to PI from the HREC

Principal Investigator to complete the following:

1. Protocol information

Date (when submitting this form)	07/02/2019		
HREC REF Number	044/2014	Current Ethics Approval was granted until	30/01/2018
Protocol title	THE USE OF RECOVERY METHODS BY PROFESSIONAL SOUTH AFRICAN SOCCER TEAMS		
Protocol number (if applicable)			
Are there any sub-studies linked to this study?	☐ Yes ☑ No		
If yes, could you please provide the HREC Ref's for all sub-studies? Note: A separate FHS016 must be submitted for each sub-study.			
Principal Investigator	Theresa Burgess		
Department / Office Internal Mail Address	Division of Physiotherapy, F45, GSH OMB		

(Note: Please complete the Closure form (FHS010) if the study is completed within the approval period)

APPENDIX IV: Summary of protocols outlined by staff for recovery methods used

Recovery Method	Protocol Employed
Hydration	The most common drink post-match was a combined electrolyte and carbohydrate beverage, whereas the most common drink post-training was water.
Nutrition	The diet and habitual monitoring of player's nutrition is scarce at best and only seems to be considered when players are eating at the club (n=18, 44%). Only one team provides daily input regarding their players' nutrition, while 11 clubs reported to provide educational sessions on nutrition once a season. A further 11 teams do not involve their medical team with nutritional protocols or advice.
Cold Water Immersion	Of the 31 participants using CWI, only 11 (35%) teams measure the water temperature. These teams each reported different temperatures used for CWI, ranging from 5-12° C. Most participants measured the water line up to the umbilical line (n=19, 61%) or to the hip, below the genitals (n=10, 32%). Of the methods used to implement CWI, plastic baths was the most common (n= 26, 84%).
Active Recovery	Running (n=15, 42%), cycling (n=14, 39%) and pool exercise (n=13, 36%) were the most common exercises used for ACT. The ACT session lasted between 30-45 min= (n=14, 39%) and 45 – 60 min (n=14, 39%).
Stretching	The average stretching time was either between 5-10 min (n=22, 55%) or 20-30 min (n=17, 42%).
Massage	The average treatment time was approximately 30 min (n=14, 56%) which was administered mainly by physiotherapists (n= 14, 56%).
Compression garments	An average time of 4-6 hours was used as wear time.
Cold Water Therapy	Ice baths and cold showers were the most used method of cold application, whilst hot showers and Jacuzzis were the only choices for heat application. On average, the participants used CWT protocols for duration of between 10 to 20 minutes. However the duration of heat and cold exposure was different amongst each participant.

APPENDIX V: PROSPERO Registration for Systematic Review

National Institute for Health Research

University of York Centre for Reviews and Dissemination

PROSPERO International prospective register of systematic reviews

Review title and timescale

1 Review title

Give the working title of the review. This must be in English. Ideally it should state succinctly the interventions or exposures being reviewed and the associated health or social problem being addressed in the review.

Non-pharmacological sleep interventions to enhance recovery and performance in athletes: a systematic review

2 Original language title

For reviews in languages other than English, this field should be used to enter the title in the language of the review. This will be displayed together with the English language title.

3 Anticipated or actual start date

Give the date when the systematic review commenced, or is expected to commence.

07/06/2017

4 Anticipated completion date

Give the date by which the review is expected to be completed.

07/10/2017

5 Stage of review at time of this submission

Indicate the stage of progress of the review by ticking the relevant boxes. Reviews that have progressed beyond the point of completing data extraction at the time of initial registration are not eligible for inclusion in PROSPERO. This field should be updated when any amendments are made to a published record.

The review has not yet started ×

Review stage Started Completed

Preliminary searches Yes

Piloting of the study selection process Yes

Formal screening of search results against eligibility criteria No

Data extraction No

Risk of bias (quality) assessment No

Data analysis No

Provide any other relevant information about the stage of the review here.

Review team details

6 Named contact

The named contact acts as the guarantor for the accuracy of the information presented in the register record.

Dustin Maree

7 Named contact email

Enter the electronic mail address of the named contact.

dustinmaree@gmail.com

8 Named contact address

Enter the full postal address for the named contact.

ASPETAR Orthopaedic and Sports Medicine Hospital, Sports City Street, 29222 Doha, Qatar

9 Named contact phone number

Enter the telephone number for the named contact, including international dialing code.

+97455191146

10 Organisational affiliation of the review

Full title of the organisational affiliations for this review, and website address if available. This field may be completed as 'None' if the review is not affiliated to any organisation.

University of Cape Town

Website address:

www.uct.ac.za

11 Review team members and their organisational affiliations

Give the title, first name and last name of all members of the team working directly on the review. Give the organisational affiliations of each member of the review team.

Title First name Last name Affiliation

Mr Dustin Maree, University of Cape Town

Dr Theresa Burgess, University of Cape Town

Professor Mike Lambert, University of Cape Town

Dr Jason Tee, University of Leeds

Dr Kieran O'Sullivan, ASPETAR

Dr Sean Mc Auliffe, ASPETAR

12 Funding sources/sponsors

Give details of the individuals, organizations, groups or other legal entities who take responsibility for initiating, managing, sponsoring and/or financing the review. Any unique identification numbers assigned to the review by the individuals or bodies listed should be included.

None

13 Conflicts of interest

List any conditions that could lead to actual or perceived undue influence on judgements concerning the main topic investigated in the review.

Are there any actual or potential conflicts of interest?

None known

14 Collaborators

Give the name, affiliation and role of any individuals or organisations who are working on the review but who are not listed as review team members.

Title First name Last name Organisation details

Review methods

15 Review question(s)

State the question(s) to be addressed / review objectives. Please complete a separate box for each question.

The effects of non-pharmacological sleep interventions on recovery and performance in athletes

16 Searches

Give details of the sources to be searched, and any restrictions (e.g. language or publication period). The full search strategy is not required, but may be supplied as a link or attachment.

Databases: Academic Search Complete, MEDLINE, CINAHL, SportDiscus, Biomedical Reference collection, AMED, PsycINFO, PsycARTICLES. Limits to be used: limited to studies using human participants and published in English.

17 URL to search strategy

If you have one, give the link to your search strategy here. Alternatively, you can e-mail this to PROSPERO and we will store and link to it.

I give permission for this file to be made publicly available

Yes

18 Condition or domain being studied

Give a short description of the disease, condition or healthcare domain being studied. This could include health and wellbeing outcomes.

Recovery (e.g. blood markers, fatigue, muscle soreness, ability to repeat maximal effort) or performance (e.g. ability to serve in tennis, sprint, CMJ) in athletes after a non-pharmacological intervention to enhance sleep.

19 Participants/population

Give summary criteria for the participants or populations being studied by the review. The preferred format includes details of both inclusion and exclusion criteria.

Any subjects defined as adult athletes who participate in regular sporting competition. If participants are not athletes (more than recreationally active), studies will be excluded. Studies of athletes with concussion or sleep disorders will be excluded.

20 Intervention(s), exposure(s)

Give full and clear descriptions of the nature of the interventions or the exposures to be reviewed

Non-pharmacological interventions which aim to enhance sleep, with a view to improving recovery or performance. Studies of complete or partial sleep deprivation will be excluded. Studies involving any pharmacological interventions will be excluded. Any study measuring sleep interventions which are confounded by other factors (e.g. traveling between different time zones, training at different altitudes, undertaking significant changes in training intensity, nutritional changes) will be excluded.

21 Comparator(s)/control

Where relevant, give details of the alternatives against which the main subject/topic of the review will be compared (e.g. another intervention or a non-exposed control group).

The effects of the interventions on recovery and performance metrics will be compared to the effects of no intervention or a sham interventions (i) in a control group, or to the same group (ii) at a different time point or (iii) using a crossover trial design.

22 Types of study to be included

Give details of the study designs to be included in the review. If there are no restrictions on the types of study design eligible for inclusion, this should be stated.

Any study investigating the effect of non-pharamcological sleep interventions on recovery and performance in athletes.

23 Context

Give summary details of the setting and other relevant characteristics which help define the inclusion or exclusion criteria.

24 Primary outcome(s)

Give the most important outcomes.

Recovery or performance. Studies which do not have performance or recovery outcome measures will be excluded.

Give information on timing and effect measures, as appropriate.

25 Secondary outcomes

List any additional outcomes that will be addressed. If there are no secondary outcomes enter None.

Sleep quality and/or quantity.

Give information on timing and effect measures, as appropriate.

26 Data extraction (selection and coding)

Give the procedure for selecting studies for the review and extracting data, including the number of researchers involved and how discrepancies will be resolved. List the data to be extracted.

Data, including study population, study design, athlete demographics, comparison intervention if applicable, and the effect of sleep interventions on recovery and/or performance factors will be extracted.

27 Risk of bias (quality) assessment

State whether and how risk of bias will be assessed, how the quality of individual studies will be assessed, and whether and how this will influence the planned synthesis.

Risk of bias will be assessed using the critical appraisal skills program (CASP) for the relevant study design (e.g. randomised clinical trial, crossover).

28 Strategy for data synthesis

Give the planned general approach to be used, for example whether the data to be used will be aggregate or at the level of individual participants, and whether a quantitative or narrative (descriptive) synthesis is planned. Where appropriate a brief outline of analytic approach should be given.

The evidence for the effectiveness of each intervention will be determined by reporting the number of articles evaluating each intervention, the methodological quality of the study, and the strength of the evidence. If possible, intervention effects will be combined in a meta-analysis.

29 Analysis of subgroups or subsets

Give any planned exploration of subgroups or subsets within the review. 'None planned' is a valid response if no subgroup analyses are planned.

In the event that there is sufficient data, data for specific athletic populations, as well as specific performance or recovery metrics, may be analysed separately.

Review general information

30 Type and method of review

Select the type of review and the review method from the drop down list.

Systematic review

Rehabilitation

31 Language

Select the language(s) in which the review is being written and will be made available, from the drop down list. Use the control key to select more than one language.

English

Will a summary/abstract be made available in English?

Yes

32 Country

Select the country in which the review is being carried out from the drop down list. For multi-national collaborations select all the countries involved. Use the control key to select more than one country.

South Africa

33 Other registration details

Give the name of any organisation where the systematic review title or protocol is registered together with any unique identification number assigned. If extracted data will be stored and made available through a repository such as the Systematic Review Data Repository (SRDR), details and a link should be included here.

34 Reference and/or URL for published protocol

Give the citation for the published protocol, if there is one.

Give the link to the published protocol, if there is one. This may be to an external site or to a protocol deposited with CRD in pdf format.

I give permission for this file to be made publicly available

Yes

35 Dissemination plans

Give brief details of plans for communicating essential messages from the review to the appropriate audiences.

This study will be submitted as part of a MSc thesis. Additionally, it is anticipated that results of the review will be submitted for publication in peer-reviewed journals and presented at scientific conferences.

Do you intend to publish the review on completion?

Yes

36 Keywords

Give words or phrases that best describe the review. (One word per box, create a new box for each term)

37 Details of any existing review of the same topic by the same authors

Give details of earlier versions of the systematic review if an update of an existing review is being registered, including full bibliographic reference if possible.

38 Current review status

Review status should be updated when the review is completed and when it is published.

Ongoing

39 Any additional information

Provide any further information the review team consider relevant to the registration of the review.

40 Details of final report/publication(s)

This field should be left empty until details of the completed review are available.

Give the full citation for the final report or publication of the systematic review.

Give the URL where available.

APPENDIX VI: PRISMA-P Checklist 2015

PRISMA-P (Preferred Reporting Items for Systematic review and Meta-Analysis Protocols) 2015 checklist: recommended items to address in a systematic review protocol*

Section and topic	Item No	Checklist item
ADMINISTRATIVE INFORMATION		
Title:		
Identification	1a	Identify the report as a protocol of a systematic review
Update	1b	If the protocol is for an update of a previous systematic review, identify as such
Registration	2	If registered, provide the name of the registry (such as PROSPERO) and registration number
Authors:		
Contact	3a	Provide name, institutional affiliation, e-mail address of all protocol authors; provide physical mailing address of corresponding author
Contributions	3b	Describe contributions of protocol authors and identify the guarantor of the review
Amendments	4	If the protocol represents an amendment of a previously completed or published protocol, identify as such and list changes; otherwise, state plan for documenting important protocol amendments
Support:		
Sources	5a	Indicate sources of financial or other support for the review
Sponsor	5b	Provide name for the review funder and/or sponsor
Role of sponsor or funder	5c	Describe roles of funder(s), sponsor(s), and/or institution(s), if any, in developing the protocol
INTRODUCTION		
Rationale	6	Describe the rationale for the review in the context of what is already known
Objectives	7	Provide an explicit statement of the question(s) the review will address with reference to participants, interventions, comparators, and outcomes (PICO)
METHODS		
Eligibility criteria	8	Specify the study characteristics (such as PICO, study design, setting, time frame) and report characteristics (such as years considered, language, publication status) to be used as criteria for eligibility for the review

Information sources	9	Describe all intended information sources (such as electronic databases, contact with study authors or trial registers) with planned dates of coverage
Search strategy	10	Present draft of search strategy to be used for at least one electronic database, including planned limits, such that it could be repeated
Study records:		
Data management	11a	Describe the mechanism(s) that will be used to manage records and data throughout the review
Selection process	11b	State the process that will be used for selecting studies (such as two independent reviewers) through each phase of the review (that is, screening, eligibility and inclusion in meta-analysis)
Data collection process	11c	Describe planned method of extracting data from reports (such as piloting forms, done independently, in duplicate), any processes for obtaining and confirming data from investigators
Data items	12	List and define all variables for which data will be sought (such as PICO items, funding sources), any pre-planned data assumptions and simplifications
Outcomes and prioritization	13	List and define all outcomes for which data will be sought, including prioritization of main and additional outcomes, with rationale
Risk of bias in individual studies	14	Describe anticipated methods for assessing risk of bias of individual studies, including whether this will be done at the outcome or study level, or both; state how this information will be used in data synthesis
Data synthesis	15a	Describe criteria under which study data will be quantitatively synthesised
	15b	If data are appropriate for quantitative synthesis, describe planned summary measures, methods of handling data and methods of combining data from studies, including any planned exploration of consistency (such as I^2, Kendall's τ)
	15c	Describe any proposed additional analyses (such as sensitivity or subgroup analyses, meta-regression)
	15d	If quantitative synthesis is not appropriate, describe the type of summary planned
Meta-bias(es)	16	Specify any planned assessment of meta-bias(es) (such as publication bias across studies, selective reporting within studies)
Confidence in cumulative evidence	17	Describe how the strength of the body of evidence will be assessed (such as GRADE)

*** It is strongly recommended that this checklist be read in conjunction with the PRISMA-P Explanation and Elaboration (cite when available) for important clarification on the items. Amendments to a review**

protocol should be tracked and dated. The copyright for PRISMA-P (including checklist) is held by the PRISMA-P Group and is distributed under a Creative Commons Attribution Licence 4.0.

From: Shamseer L, Moher D, Clarke M, Ghersi D, Liberati A, Petticrew M, Shekelle P, Stewart L, PRISMA-P Group. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. BMJ. 2015 Jan 2;349(jan02 1):g7647.

APPENDIX VII: Systematic Review Protocol

Introduction

Sleep has been observed to play a pivotal role in an individual's development, health and daily life (Gerber et al., 2010). During sleep our bodies are metabolically recovering from the effects of waking (Frank, 2006), physiologically restoring (Akerstedt and Nilsson, 2003) and in a state of learning (Walker et al., 2005). Due to an increased strain on the body as a result of an athlete's lifestyle, it has been postulated that athletes require more sleep compared to non-athletes, to physiologically and psychologically recover from training (Bird, 2013). Various studies have reported that inadequate sleep or sleep deprivation negatively affects athletic performance (Skein et al., 2011b, Reilly and Piercy, 1994a), cognition (Dinges et al., 1997,(Goel et al., 2009, Dinges et al., 1997) and well-being (Cohen et al., 2009). A recent review reported that although sleep deprivation (i.e. extreme cases of sleep loss) resulting in negative effects on athletic performance, sleep restriction (i.e. less sleep then normal) showed equivocal results (Fullagar et al., 2015b). Furthermore, previous research was not conducted in team sports making extrapolations to these populations difficult. Recent research has reported a positive link between adequate sleep and optimal performance (Simpson et al., 2017, Samuels, 2008, Skein et al., 2011b). However, despite recent studies, athletes continue to experience sub-optimal sleep (Nedelec et al., 2015a, Simpson et al., 2017) and sleep restriction is a more prevalent issue than sleep deprivation (Fullagar et al., 2015b). While decreased sleep quality and quantity has been likened to overtraining syndrome (Hausswirth et al., 2014), further research is required to isolate the effects of sleep loss on athletic performance (Fullagar et al., 2015b).

A recent study which aimed to provide insight into self-reported sleep quantity and quality of approximately 100 athletes observed a strong association between poor sleep hygiene and poor sleep quality, and approximately 40% of athletes were poor sleepers (Knufinke et al., 2017). In another recent review, it was reported that a high prevalence of athletes display insomnia symptoms as a result of decreased sleep quality and quantity (Gupta et al., 2017). These results concurred with numerous studies that reported athletes displaying inadequate sleep (Venter, 2012, Lastella et al., 2015b, Fullagar et al., 2015a), potentially preventing these athletes from reaching their full potential (Knufinke et al., 2017). Therefore, addressing the factors which disrupt sleep quality and quantity are imperative to optimise performance, even by a small margin, for individual athletes (Venter, 2012). Professional team sports such as soccer often have congested match schedules throughout a season, not allowing for players to experience complete physiological and psychological recovery between matches (Nedelec et al., 2013). Incomplete recovery may lead to potential injury (Dupont et al.,

2010) or underperformance (Nédélec et al., 2012). During congested schedules, recovery strategies are implemented to accelerate recovery, decrease potential injury and regain performance measurements (Nédélec et al., 2012). Strategies including sleep, nutrition and hydration have reported the most beneficial evidence in addressing the consequences of post-match fatigue (i.e. glycogen depletion, dehydration, muscle damage and mental fatigue; (Nedelec et al., 2013). Therefore, as sleep is an integral part of the recovery process, providing a variety of physiological and psychological functions; sub-optimal sleep is a common cause of impaired recovery in athletes (Nedelec et al., 2015a).

The present study observed that almost no football teams in South Africa considered utilising sleep protocols as a means of recovery, while current literature on interventions benefitting sleep in athletes are lacking. A variety of recommendations and narrative reviews are available; however, the quality measures used in these studies are lacking and a many of the recommendations are anecdotal. Research among sleep deprived athletes is prevalent as well as the negative effects thereof, therefore many recommendations hypothesise to extend sleep quantity or quality. While this can be considered a fair assumption, poor collective reviews are currently available to construct these assumptions into concrete evidence. Therefore, the aim of the present review is to systematically assess whether any studies provide beneficial evidence for interventions in athletes, which have positively affected sleep to improve recovery and performance outcomes.

Description of non-pharmacological interventions

Non-pharmacological sleep interventions aim to improve sleep quantity and/or quality by improving poor sleep habits, addressing stressors which may be negatively impacting sleep and challenging negative attitudes, thoughts and beliefs regarding sleep (Montgomery and Dennis, 2004). Interventions are diverse and predominately include educational awareness, behavioural modifications and non-medication based therapies (i.e. red-light therapy, relaxation methods, brainwave entrainment, etc.; (Montgomery and Dennis, 2004).

It has been observed that non-pharmacological interventions are effective in the treatment of insomnia (Petit et al., 2003); however, it is considered less effective than pharmacological treatments in assisting with sleep onset (Hu et al., 2010, Zhao et al., 2012a, Nowell et al., 1997). Pharmacological interventions have observed various negative side effects including residual sedation and daytime tiredness (Kales and N. Vgontzas, 1995), dizziness and cognitive impairments (Holbrook et al., 2000), risk of dependency (Proctor and Bianchi, 2012) and changes in sleep patterns (i.e. decreased slow-

wave sleep; (Roehrs and Roth, 2010). Addiction to sleep medication is a recent problem affecting many athletes (Tuomilehto et al., 2017). Athletes should consider non-pharmacological interventions unless medically advised otherwise, to avert the negative side-effects associated with pharmacological treatments.

Importance of the present review

At present, a lack of evidence exists for intervention studies exploring the benefit of sleep in athletes. The majority of previous studies investigated sleep deprived athletes (Skein et al., 2011a, Souissi et al., 2003, Reilly and Edwards, 2007). Two recent reviews outlined the implications and recommendations for sleep optimisation in athletes (Nedelec et al., 2015b, Simpson et al., 2017), however a thorough systematic review has not been performed considering the benefits of improving sleep quality and quantity to improve athletic performance or recovery. It is important to allow the best evidence to be presented and tested, so a consensus of the most appropriate treatment guidelines can be reached. The history of recovery method usage is erratic and diverse, with massage, Cold-Water Immersion (CWI), Active recovery, compression garments (CG) and stretching all previously utilised without sufficient clinical evidence to justify sufficient benefit to the athlete (Nedelec et al., 2013). These modalities have been relying on anecdotal evidence from sporting coaches, players and staff. In today's competitive and stressful industry of professional team sport, recovery and performance are key to success, highlighting the importance of evidence-based sleep protocols. The present review will attempt to provide current evidence for athletes via a systematic process.

A systematic review includes a critical appraisal which assists with assessing the methodological quality of each study and aims to identify, evaluate and summarise all relevant literature on a given topic (Gopalakrishnan and Ganeshkumar, 2013). The present review will utilise a CASP tool to assess the quality of each article. Due to logistical reasons concerning athletes, RCTs were limited; therefore, to ensure all available evidence was included, the present study broadened their search strategy to include as many study designs as necessary, albeit maintaining strict inclusion/exclusion criterion. The present review aims to explore intervention studies used to assist sleep to improve athlete recovery or performance.

Review question

What are the effects of non-pharmacological sleep interventions on recovery and performance in athletes?

Objectives

The objectives of the present review were:

- To establish an evidence base concerning non-pharmacologic sleep interventions, which aim to benefit athlete recovery and/or performance indices in isolation. This will be established through a systematic review of peer-reviewed journals and abstracts in this field. All study designs will be considered.
- To establish how these interventions affect recovery and performance indices and sleep indices respectively.
- To consider pragmatic sleep protocol approaches for athletes and soccer players and to educate athletic staff on sleep protocol recommendations.

Methods

Approach to the review

The present review was conducted in accordance with a systematic review of quantitative research. A systematic review is a summary of previous studies that use specific and reproducible methods to systematically search, appraise and deduce information (Cook et al., 1997). Systematic reviews are able to identify where knowledge is lacking in a specific field, limit publication bias by searching for published and unpublished literature, as well as enhance methodological rigor and guide future research (Gopalakrishnan and Ganeshkumar, 2013).The Cochrane Collaboration has developed a set of guidelines for conducting a systematic review to assist both the researcher and reader to consolidate the literature in a clear, coherent manner (Green and Higgins, 2008).

Six primary factors should to be addressed when completing a systematic review or meta-analysis; these include, defining the questions, reviewing the literature, narrowing the studies down to the relevant research question, methodologically checking the quality of the studies, combining outcome measures and interpreting results (Green and Higgins, 2008). The three primary stages of the review include the planning phase, conducting the review and analysis of the results with summarisation (Green and Higgins, 2008).

During the planning phase, the researcher scans the literature to assess whether conducting the systematic review will be feasible. Once this has been decided, the systematic review will be undertaken within the constraints of a recognised protocol. The protocol will outline the research question to be addressed, how it will be addressed, the existing limits, and the exclusion and inclusion criteria that will be followed (Green and Higgins, 2008). The present study references the Preferred Reporting Items of Systematic Reviews and Meta-Analyses Protocol (PRISMA-P) guidelines (Shamseer et al., 2015a) and the protocol developed by (Limakatso et al., 2016))to structure the systematic review. This systematic review has been registered on the PROSPERO database (see Appendix V; Ref: CRD42017068294). The PRISMA-P checklist is included as Appendix VI.
The second phase will follow the guidelines included in the protocol, specifically in regard to the search strategy of articles with specific key words, methodological quality checking and data extraction (Green and Higgins, 2008, Evans and Pearson, 2001b). The final stage will attempt to combine the results into a meta-analyses or comprehensible summary. Due to the varied study interventions and outcome measures in the present review, there is a likelihood of a heterogeneous mix, therefore preventing a meta-analysis. Ethical and confidentiality considerations were not required for the present review as the data used was collected from publicly available articles or those already accepted for publication.

Criteria for eligibility

Types of studies

The present systematic review will consider published and approved for publication studies. All study designs were considered if they met the inclusion criteria and applied an intervention for sleep with beneficial intentions towards recovery and performance outcomes. Studies in the present systematic review included RCTs, cross-over studies and cohorts.

Type of participants

Any subjects defined as athletes who participated in regular sporting competition were selected. Where participants were not considered athletes (i.e. more than recreationally active), the studies were excluded. Studies where participants had been diagnosed with sleep disorders via standardised measures (i.e. sleep diaries, actigraphy, PSG, and by specialist therapist) were excluded from the review. Studies that included participants who were screened for potential confounding factors such as depression and other sleep disorders, and studies where participants had been sleep deprived (i.e. a greater deprivation than their standard sleep) or suffered recent concussion were also excluded.

Type of outcome measures

Primary outcomes

The primary outcomes will include both recovery and performance outcomes in an athletic context. Studies that did not include any recovery or performance measurements will be excluded. Performance outcomes will be measured for a specific task in the related sporting domain (i.e. tennis serving accuracy). Standardised tests previously validated will be preferred, however all performance variables will be considered. Recovery outcomes will use biomarkers to measure parameters post-exercise/intervention and the degree to which return towards baseline values (Lee et al., 2017). Recovery measurements also serve as adequate measurement of athlete health, mood and readiness to play sport (Fullagar et al., 2015a).

Secondary outcomes

Sleep quality and quantity will also be assessed. Outcome measures of interest for sleep indices will include sleep duration (including napping), Sleep Onset Latency (SOL), Sleep Efficiency (SE), daytime sleepiness, time in bed, mood after waking and sleep time in different stages. PSG was considered the benchmark sleep measurement; however, due to its impractical field nature, cost and environment, it was not always utilised (Sargent et al., 2016). Actigraphy watches allow for sleep testing without laboratory settings and although it is not as reliable, was considered approximately 93% as reliable as PSG (Driller et al., 2016). Subjective measures will also be considered, such as sleep diaries and questionnaires evaluating different aspects of sleep. The questionnaires included are the Pittsburgh Sleep Quality Index (PSQI), Self-Assessment of Sleep and Awakening Quality scale (SSA), and Epsworth Sleepiness Scale (ESS).

Type of interventions

Non-pharmacological interventions which aimed to enhance sleep in order to improve recovery or performance metrics will be included. The effects of the interventions on recovery and performance metrics will be compared to the effects of no intervention or a mock interventions: (i) in a control group, or to the same group, (ii) at a different time point or (iii) using a crossover trial design.

Search strategy for literature

A thorough literature search of multiple electronic databases will be performed to identify as many relevant articles as possible. Inclusion and exclusion criteria will be highlighted in each database to narrow the search. Limits used will include only articles published in English and conducted using human participants. Once the searches have been completed, the titles and abstracts will be

screened. Full-text journal articles will be selected for the review from the articles retrieved in the search. The reference lists of each of the selected articles will be scrutinised to identify any additional articles relevant to the scope of the review. Any further sources of information (i.e. unpublished reviews or publications in journals not searched) will be included. Contact will be made with authors to gain clarity regarding any confusion in a potential study and/or to ascertain whether they are aware of any similar studies. The reviewer will not be blinded to the names of the studies, authors or journals. Databases searches will include: Academic Search Complete, MEDLINE, CINAHL, SportDiscus, Biomedical Reference collection, AMED, PsycINFO and PsycARTICLES.

The search strategy will broadly use the term sleep, to include any potential interventions focusing on sleep (i.e. sleep hygiene, sleep optimization, sleep protocols, sleep extension, etc.). Terms with a focus on sport and athletes are necessary to exclude a non-athletic population. Due to limited articles exploring sleep interventions in team sports, all sports and/or general the athletic population will be considered. The search strategy will represent this by including a variety of sporting terms. Varied recovery and performance indices will be included to ensure all options are considered; therefore, the researchers will not include any recovery or performance specifics in the search strategy. The researchers specifically aim to review intervention based studies and will attempt to isolate these using experiment- and investigation-like terms. The final search strategy will be: ((sleep[Title/Abstract]) AND (athlet*[Title/Abstract] OR football*[Title/Abstract] OR sport*[Title/Abstract] OR soccer[Title/Abstract])) AND (baseline OR random* OR control* OR research OR experiment or investigat*).

Search criteria

Inclusion and exclusion criteria are imperative to isolate the correct articles from the search strategy. A clear search strategy with definitive inclusion and exclusion criteria will easily allow the researchers to clarify their decision-making process regarding article selection. Non-pharmacological interventions which aimed to enhance sleep in athletes will be reviewed.

The present review will include:

- Articles which reviewed non-pharmacological interventions to enhance sleep in athletes, which had outcome measures of recovery and/or performance indices;
- Studies employing an intervention of some sort with a comparison group;
- Studies originating from any country as long as they are published in English. This may possibly introduce a language bias;

- Studies carried out on human participants;
- Original or review articles with titles and abstracts relevant to the research questions; and
- All studies from any year.

Articles were excluded if any of the below criteria occurred:

- Articles not written in English;
- Articles not using human sporting participants (athletes);
- Studies involving complete or partial sleep deprivation;
- Studies involving any pharmacological interventions;
- Studies combining a variety of interventions;
- Studies with altitude changes;
- Studies which involve travelling participants;
- Studies using nutrition as an intervention (i.e. as the benefits of nutrition on sleep has already been established in previous reviews);
- Studies undertaking a significant change in exercise intensities, as acute increases in exercise has an effect on sleep indices (Uchida et al., 2012);
- Studies where participants have a sleep disorder, concussion or flag in a pre-test evaluation;
- Articles without an abstract;
- Studies not utilising an intervention (i.e. a purely observational study); or
- Studies not using a recovery or performance measurement as an outcome measure.

The researcher independently reviewed the titles and abstracts of each search results to assess eligibility. Any studies that the researcher felt unsure whether to include, the supervisor was consulted for consensus. Duplicates were removed to isolate the final number of studies for inclusion in the review.

Assessment of methodological quality

All studies included in the present review will be assessed for methodological quality. A critical appraisal of each article will limit bias or error in quantitative data (Evans and Pearson, 2001a). For this review, a quantitative tool will be used to specifically isolating cohorts or RCT's. A CASP checklist (see Appendix IX) will be used to aid in methodically analysing the research, ensuring reliability and allowing accurate conclusions to be drawn (Singh, 2013). The Cochrane Collaboration outlines specific criteria for methodologically assessing the quality of RCTs (Higgins et al., 2011). These criteria will be considered by the researcher when considering the studies in this review, to determine

whether any of the outlined criteria outlined are applicable. The criteria outlined include: random sequence generation, allocation concealment, blinding of participants/personnel, incomplete outcome data, selective outcome reporting and any other sources of bias (Higgins et al., 2011). Any uncertainty on the quality of a study was reviewed with the supervisor. Questions were included from the CASP Cohort Study Checklist (13.03.17) and the CASP Randomised Controlled Trials Checklist (13.03.17). The CASP checklist allowed for the use of a scoring system, where the researcher would award points per criterion met in the study. All scores were reviewed by the supervisor and any discrepancies were mediated by an external expert. The CASP outlines a systematic process whereby the strengths and weaknesses of an article can be identified (Singh, 2013). The 11 questions considered in the tool include:

1. Did the study address a clearly focused issue?
    - The population studied
    - The risk factors studied
    - The outcomes considered
    - Intervention/Comparator given (RCT)
    - Is it clear whether the study tried to detect a beneficial or harmful effect?

2. Were the cases recruited in an acceptable way?
    - Precisely defined case
    - Specific inclusion criteria
    - Representative of defined population
    - Were RCT randomised and how was this carried out

3. Was the exposure/outcome accurately measured to minimize bias?
    - Did they use subjective or objective measurements?
    - Do the measurements truly reflect what you want them to (have they been validated)?
    - Were all the subjects classified into exposure groups using the same procedure.
    - Were patients, study personnel “blind’ to treatment in RCT
    - Were “groups” treated equally aside from intervention (if RCT)

4. Were the controls selected in an acceptable way?
    - If the study compared between athletes and non-athletes
    - Did the subject characteristics differ significantly from each other?
    - Was the selection process bias?

5. Have the authors taken account of the potential confounding factors in the design and/or in their analysis?
    - The same personnel for measurements, assessment protocol clearly defined, details on practice effects, controlling anything that may affect findings

6. Was the follow up of subjects complete enough?
    - Long enough time to reveal good or bad effects
    - Many lost to follow up might have different results

7. How precise are the results? (no point scored)
    - Results outcome and conclusion of the study8. Statistics clearly reported?
    - P-values
    - Actual values
    - 95% confidence intervals
    - Standard deviations

9. Are the results believable?
    - Methods and design appropriate
    - Confounding factors adequately addressed

10. Can the results be applied to the local population?
    - Population correlates with our population of interest
    - The measurement tool they used is available to us/widely available

11. Do the results of this study fit with other available evidence?
    - If there are no available studies with similar measurements, they get no point.
    - If there are other available studies with similar measurements, they get a point.

The primary aim would be to assess whether the article addressed the research question within the inclusion/exclusion criteria listed, rather than the specific quality of the article. The scoring indicated a vague idea of quality, according to the CASP rating.

Data extraction

Data extraction carried out correctly should limit any potential bias, assisting with validity (Evans and Pearson, 2001a). To allow for consistent data extraction, each of the included articles will first need to be read before extracting. If it is not possible to extract any data due to availability, the first

author will be contacted for assistance. Key data will be extracted into pre-made tables with defined sub-headings. Data will be extracted into separate tables for the CASP methodological assessment (topics listed above). Pre-made tables used sub-headings including: study name, author(s) and year published, participants, study design, sleep intervention/protocol and comparator, different outcomes measures of sleep, different recovery and performance outcome measures, and results of the study.

Data synthesis

The evidence for the effectiveness of each intervention will be determined by reporting the number of articles evaluating each intervention, the methodological quality of the study, and the strength of the evidence. Where possible, the intervention effects will be combined into a meta-analysis. In the event that there is sufficient data for subgroups, data for specific athletic populations, as well as specific data for recovery and performance indices, these will be analysed and summarised separately.

Discussion

Given the presence of athletes not maintaining optimal sleep quantity and quality, and the research which links sleep to optimal performance and recovery, it is necessary to consolidate a summary regarding beneficial sleep practices in an athlete environment. The proposed systematic review will consider the effects of various interventions aimed at benefitting sleep to improve athlete recovery and performance outcomes. The various interventions will have both pros and cons for athlete implementation, which will be reviewed. Outcomes of the present review will guide athletes and medical staff/coaches in their approach to implementing sleep interventions. These findings will highlight the importance and need for mandatory sleep interventions in all athlete's schedules and allows all athletes/staff/coaches easy access to these strategies.

Ethical considerations

No ethical procedure has been formalised for this review as systematic reviews do not require ethical clearance. All studies used in this review are publicly available and have already obtained ethical approval.

Dissemination Strategy

This study will be submitted as part of a dissertation submitted in fulfilment of the requirements for a Master of Science degree. Additionally, the results of the review will be submitted for publication in peer reviewed journals and presented at scientific conferences. The review intends to highlight beneficial strategies to assist and improve sleep quality/quantity which directly affect athlete performance and recovery.

Timelines

Task	Date	Lead Researcher	Supervision/Support
Draft protocol for internal review	29/09/2017	Dustin Maree	Dr. Theresa Burgess, Dr. Jason Tee, Prof Mike Lambert
Protocol for external review	05/10/2017	Dustin Maree	Dr. Theresa Burgess, Dr. Jason Tee, Prof Mike Lambert
Search Strategy and study selection	15/10/2017	Dustin Maree	Dr. Theresa Burgess, Dr. Jason Tee, Prof Mike Lambert
Data extraction	05/11/2017	Dustin Maree	Dr. Theresa Burgess, Dr. Jason Tee, Prof Mike Lambert
Quality assessment of extraction	10/11/017	Dustin Maree	Dr. Theresa Burgess, Dr. Jason Tee, Prof Mike Lambert
Analysis of Outcomes	28/11/2017	Dustin Maree	Dr. Theresa Burgess, Dr. Jason Tee, Prof Mike Lambert
First draft	31/09/2018	Dustin Maree	Dr. Theresa Burgess, Dr. Jason Tee, Prof Mike Lambert
Second draft	20/12/2018	Dustin Maree	Dr. Theresa Burgess, Dr. Jason Tee, Prof Mike Lambert
Final draft	10/02/2019	Dustin Maree	Dr. Theresa Burgess, Dr. Jason Tee, Prof Mike Lambert
Submit for publication	20/06/2019	Dustin Maree	Dr. Theresa Burgess, Dr. Jason Tee, Prof Mike Lambert

APPENDIX VIII: Excluded Studies for Systematic Review

Study	Reasons for Exclusion & Comments on Outcomes and Results
Jones et al., 2017	The primary aim of the study was to investigate the influence of different types of tasks performed with/without an electronic device rather than a primary aim of benefitting sleep indices to aid in recovery and performance measurements. There were no significant differences in sleep quality or quantity or next-day athletic performance between any of the tested conditions.
Thornton et al., 2016	There was no intervention, only an observational effect noted. The primary aim was not to benefit sleep indices and subsequent recovery and performance metrics. The increase in training load and change in environment negatively affected sleep. An allowance of increased nap time showed beneficial results in improved nighttime sleep (duration, SE) and subjective wellness.
Louis et al., 2016	The study focused on nutrition as an intervention for sleep, which was excluded in the present review. Minimal differences were noted between groups. The low-glycogen group observed a small increase in nighttime wakings and a decrease in SE, however reported improved performance scores compared to normal glycogen group.
Pitchford et al., 2016	There was no intervention except for environment change, only observational information. No performance or recovery outcome measures were taken, only sleep indices. The change in sleep environment from normal to a training camp resulted in a decrease in SE, increase in time in bed and no change in sleep duration.
Kolling et al., 2016	The main aim of the study was to monitor and assess sleep-wake patterns rather than an intervention to benefit sleep. As the primary aim was not to benefit sleep indices this study was excluded. However, the study observed rowers with extended sleep patterns reported enhanced sleep quality and improved stress related markers. The key was the ability to provide the athlete with the day off to allow for the sleep extension.

Kiler et al., 2015	The primary aim was not to use the intervention to benefit sleep quality or quantity specifically and the intervention was nutrition based which was excluded in the review. Increased training loads decreased sleep in both groups. However, sleep duration was increased in the moderate glycogen group compared with high glycogen group.
Kolling et al., 2015	This was an observational study and no specific intervention was administered. Sleep extension (i.e. off day for athletes) improved stress scores. Mixed report of which training improved sleep quality.
Poussel et al., 2015	No intervention noted, only observational study. The runners who adopted a sleep management strategy based on sleep extension before the race, completed the race faster.
Roach et al., 2013	This study did not have a primary aim to benefit sleep indices and used altitude which was excluded in the present review. Exposure of athletes from a sea-level base to high altitude showed significant acute and chronic sleep disruptions. Athletes based in high altitude reported no sleep disruption.
Waterhouse et al., 2007	The study used healthy males instead of athletes and used the intervention in sleep deprived participants, which is excluded in the present review. An afternoon nap lowered heart rate and intra-aural temperature, and improved alertness, sleepiness, short-term memory and sprint-time.
Kinsman et al., 2003	This was a case-study and the primary aim was not to benefit sleep quality or quantity. Sleep outcomes were considered rather than performance and recovery outcomes. REM sleep increased in an oxygen-rich atmosphere.
Atkinson et al., 2001	The participants of the study were not athletes and melatonin was considered a pharmacological aid which was excluded in the present review. Melatonin ingestion did not improve athletic performance or sleep quality.
Javierre et al., 1996	The study combined altering sleep cycles and nutrition as an intervention. Nutrition and combining different interventions were excluded in the present review. Manipulation of sleep and meal schedules allowed sprinters to synchronize peak power output with the time of competition, increasing chances of improved performance.

Pierce et al., 1993	Participants were not athletes. Improved performance initially after an acute period of sleep, however a decrease in performance compared to no nap (control) was noted towards the end of the race – providing a mixed report.
McCloughan et al., 2016	This study did not consider performance or recovery outcomes, only sleep outcomes. Progressive Muscle Relaxation was indicated as an effective strategy to improve SOL in elite dancers with anxiety personality traits.
Duffield et al., 2014	The sleep interventions were combined with other recovery interventions. In this review a combination of intervention studies was excluded. The authors concluded that sleep-hygiene recommendations helped reduce perceived muscle soreness and psychological parameters; however, as the sleep protocol was combined with CWI and CG, no specific recovery method was isolated to show which actually benefitted.
O'Donnell and Driller, 2017	No recovery or performance outcomes were measured, only sleep outcomes. A sleep-hygiene education session improved sleep duration and quality indices in elite female athletes.
Tuomilehto et al., 2017	No performance and recovery outcomes were measured. Sleep counselling was found to improve sleep quality in ice-hockey players.
Total	**18 studies excluded**

Abbreviations: SE- sleep efficiency; SOL – sleep onset latency; TIB – time in bed; CWI – cold-water immersion; CG – compression garments; REM – rapid eye movement

APPENDIX IX: CASP Summary of Criteria and Justifications

Study	Focused Issue	Appropriate Recruitment of cases	Outcome and Exposure accurately measured	Appropriate recruitment of controls	Control of confounding factors	Complete follow up	Precision of results	Statistics clearly reported	Results believable	Generalisability of results	Results correlate with other evidence
Abeln et al., 2014	✓ The population and measure of interest were clearly specified. Outcomes were defined.	✓ Precisely defined cases Specific inclusion criteria Representative of defined population	✓Exposure/intervention and outcomes clearly defined Methods were specified. Reliability and validity only mentioned for Mood/psychophysical state questionnaire.	× *Control Group were not athletes* *Control group was mixed gender*	× All questionnaires were done within the same timeslot *Holidays interfered with data collection. Questionnaires collected online once per week only. Sleep environment not controlled*	× *High dropout rate* Followed active participants for 8 weeks while testing and not after	Brainwave entrainment showed improvements in perceived sleep quality, however no change was noted in psychophysical states	✓ P-values, 95% confidence intervals, standard deviations and actual values reported along with statistical methods	× *Confounding factors were not adequately addressed.* Design and methods were appropriate. *Better objective performance or recovery outcomes were needed.*	✓ The subjects included in the study correlates with our population e.g. football players/athletes The measurement tool used is available to us.	× *This pilot study's findings are a first using this intervention in an athletic population and therefore do not correlate with available evidence*

Study	Focused Issue	Appropriate Recruitment of cases	Outcome and Exposure accurately measured	Appropriate recruitment of controls	Control of confounding factors	Complete follow up	Precision of results	Statistics clearly reported	Results believable	Generalisability of results	Results correlate with other evidence
Dunican et al. 2017	✓ The population and measure of interest were clearly specified.	✓ Precisely defined cases Specific inclusion criteria Representative of defined population (judo). Intervention group was all male vs control group predominately female (>90%)	✓Exposure/intervention and outcomes clearly defined Methods were specified. Actigraphy validated and reliable (93%) to gold standard polysomnography. Cogstate research tool shown to be reliable Sleep diary subjectively measured	✗ *Control group was 90% female and intervention group all male. Groups were self-allocated.* Therefore a selection bias was evident.	✓All testing and living conditions for study duration took place in same place, therefore stricter monitoring, (caught participants using devices). Cognitive /Performance testing was standardized to time of day, equipment uses and environment.	✗For the acute effect athletes were sufficiently monitored to notice effects of intervention Five athletes were excluded due to incompliance.	The removal of electronic devices for 48 hours did not affect sleep quality, quantity or influence athletic performance or cognition	✓ P-values, standard deviations, means and actual values were reported.	✗ *Selection bias skewed the outcome measure results. Poor choice to use self-allocated group selection.* Confounding factors adequately addressed.	✓ The subjects included in the study correlates with our population e.g. athletes, however not specific to football players The measurement tools used is available to us.	✗ *These results contrast to previous literature which suggested electronic device use led to sleep loss*

Study	Focused Issue	Appropriate Recruitment of cases	Outcome and Exposure accurately measured	Appropriate recruitment of controls	Control of confounding factors	Complete follow up	Precision of results	Statistics clearly reported	Results believable	Generalisability of results	Results correlate with other evidence
Fullagar et al., 2016	✓ The population and measure of interest were clearly specified.	✓ Precisely defined cases Specific inclusion criteria Representative of defined population, however no age of participants given.	✓Exposure/intervention and outcomes clearly defined. Methods were specified. Good reliability stated for most measurements.	× Enforced later bed times for controls will skew results in favour of intervention The controls were defined precisely. Being a cross-over design (1-week apart), the controls were not significantly different from the cases in terms of age, height, mass and skill level.	✓ Both matches were played at the same time of night. Testing times and procedures were standardized each morning. Sleeping environment (besides intervention additions) was standardized. Players photographed nutrition intake to match to previous session. Although it is difficult to control all variables, they attempted as much as possible.	× *30% of the participant's data could not be used for sleep analysis and recovery questionnaire because of faulty equipment or lack of baseline data.*	An acute sleep hygiene programme improved sleep quantity without significantly improving physical performance, perceptual recovery or blood markers of muscle inflammation	✓ P-values and actual values reported along with statistical methods. Due to multitude of analyses, only large effect sizes were reported.	× *The method to only allow the control group to go to sleep at 2am (2 hours later then intervention group) encouraged sleep deprivation and did not allow for an appropriate control group.* Confounding factors were adequately addressed; however, intervention was only one-night (too short)	✓The subjects included in the study correlates with our population. The measurement tools used is available to us, however the matches were friendly games and therefore missed out on match component (interviews, social/club demands, anxiety, etc.)	✓ This study correlates to Duffield et al 2014 which shows SHS increased sleep quantity but differs to their study in regard to improvements seen in next day perceived fatigue and soreness.

Study	Focused Issue	Appropriate Recruitment of cases	Outcome and Exposure accurately measured	Appropriate recruitment of controls	Control of confounding factors	Complete follow up	Precision of results	Statistics clearly reported	Results believable	Generalisability of results	Results correlate with other evidence
Mah et al. 2011	✓ The population and measure of interest were clearly specified.	✓ Precisely defined cases Inclusion and exclusion criteria mentioned. Representative of defined population.	✓ Exposure and measurement tools clearly defined. Methods were specified. Good reliability stated for some measurements.	✗ The control was the baseline measurement of the same subjects for 2-4 weeks, which was shorter than the intervention of 5-7. A control group should have been sourced.	✗ Holidays interfered with some participation. When athletes travelled for sport, sleep schedules were difficult to maintain. Caffeine, alcohol and sleeping alone for extended periods difficult for students and lack of monitoring. However, testing measured by same person at same time of day.	✓ Appropriate follow up on all participants was conducted throughout the study and enough time elapsed for the desired effects to be noted	A sleep extension programme increased sleep quantity, decreased daytime sleepiness and PVT reaction time scores. Basketball specific measures were improved following sleep extension.	✓ P-values, means, standard deviations and actual values reported along with statistical methods. No 95% CI were mentioned.	✗ The study design needed to use a control group or cross-over to minimize the practice effects potential perceived. Multiple confounding variable difficult to monitor or address due to logistics. Sleep time also included naps which does not allow effective distinction between the two.	✓ The subjects included in the study correlates with our population e.g. athletes, however not specific to football The measurement tools used is available to us.	✓ This correlates with literature by Schwartz and Simon which found sleep extension increases sport-specific performance.

Study	Focused Issue	Appropriate Recruitment of cases	Outcome and Exposure accurately measured	Appropriate recruitment of controls	Control of confounding factors	Complete follow up	Precision of results	Statistics clearly reported	Results believable	Generalisability of results	Results correlate with other evidence
Petit et al., 2014	✓ The population and measure of interest were clearly specified.	✗ Precisely defined cases, however no sport was mentioned and therefore baseline fitness across population was likely to be very varied. Inclusion criteria mentioned.	✓ Exposure and measurement tools clearly defined. Methods were specified. Good reliability and validity for all outcome measurements.	✓ Design was counter-balanced.	✓ Caffeine was not allowed on the testing days and napping, or intense exercise was not allowed the day before testing (measured using Actiwatch). Camera monitored sleep and napping of participants in laboratory. Laboratory environment was standardized. Intervention and testing was at the same time of day and a habituation night was used.	✓Appropriate follow up on all participants was conducted throughout the study for all four conditions.	Napping post-lunch in non-sleep deprived athletes did not show any benefit on acute athletic performance. Napping increased sleep onset latency, during sleep later that night.	✓ P-values, standard deviation, means and actual values reported along with statistical methods.	✓ Design and methods were appropriate. Confounding factors addressed.	✗The subjects included in the study correlates with our population e.g. athletes, however not specific to football The measurement tool used is not easily available to us, PSG (laboratory) and rectal probe (patient comfort issues).	✗ Other research shows benefits with napping (although in non-athletes and sleep deprived subjects), which is in contrast to the results found in this study.

Study	Focused Issue	Appropriate Recruitment of cases	Outcome and Exposure accurately measured	Appropriate recruitment of controls	Control of confounding factors	Complete follow up	Precision of results	Statistics clearly reported	Results believable	Generalisability of results	Results correlate with other evidence
Schwartz and Simon, 2015	✓ The population and measure of interest were clearly specified	× *Adequate details on inclusion and exclusion was not provided.* *Participants were paid* Precisely defined cases.	× *Lack of information provided on sleep monitoring and overall unreliable outcome measures tested besides ESS and SSS for daytime sleepiness*	× The control was the baseline measurement of the same subjects for only 1 week. Appropriate controls should have been sourced.	× *Self-reported sleep not adequate measurement to control sleep data*	✓ All participants were tested at baseline and throughout the study to allow for intervention effects to be measured.	Results demonstrated that an increase in sleep (by approximately 2 h per night) significantly increased athletic performance (tennis specific) and decreased daytime sleepiness.	✓ P-values, standard deviation, means and actual values reported along with statistical methods.	× *Design and methods were not sufficient.* *No control group* *Cannot rule out practice effects*	✓ The subjects included in the study correlates with our population e.g. athletes, however not specific to football The measurement tools used is widely available to us.	✓ This study correlates other literature (Mah et al., 2011), which also showed sleep extension increased sport specific performance and decreased daytime sleepiness.
Van Ryswyk et al., 2017	✓ The population and measure of interest were clearly specified	✓ Precisely defined cases Inclusion criteria mentioned. Representative of defined population.	✓ Exposure and measurement tools clearly defined. Methods were specified. Good reliability for most outcome measurements.	× *No control group or sufficient baseline measurement to measure effectively against.*	✓ Study conducted pre-season to allow uninterrupted participation (in-season is difficult). Actigraphy results taken over an average to decrease outliers. Testing was performed in the same location by the same researchers in the mid-morning on all occasions.	✓Almost all participants were tested initially and followed up after the six-week programme.	Improvements in self-reported sleep duration, sleep efficiency, fatigue and vigour. Reaction time and training stress did not significantly improve post sleep optimization intervention.	✓ P-values, standard deviation, means and actual values reported along with statistical methods.	× *A control group would gave more accurately measured significant differences.* Methods were appropriate. *Better objective performance or recovery outcomes were needed*	✓ The subjects included in the study correlates with our population. The measurement tools used is widely available to us.	✓ The results correlate with other studies which found improvements in POMS (fatigue and vigour scale) with increased sleep duration (Mah et al., 2011).

Study	Focused Issue	Appropriate Recruitment of cases	Outcome and Exposure accurately measured	Appropriate recruitment of controls	Control of confounding factors	Complete follow up	Precision of results	Statistics clearly reported	Results believable	Generalisability of results	Results correlate with other evidence
Zhao et al., 2012	✓ The population and measure of interest were clearly specified.	✓ Precisely defined cases. Specific inclusion and exclusion criteria noted. Representative of defined population.	✓ Exposure and measurement tools clearly defined. Methods were specified. Participants were blinded to their group. Groups were treated equally. *Lack of objective sleep measures*	✓ The controls were appropriate and not significantly different from the cases in terms of age, height and skill level. Controls were randomly selected for the groups.	✓ Testing was done by the same researchers at the same time of day on both occasions to limit diurnal variation. The participants were blinded to treatment group. Exercise training remained the same throughout the intervention for all groups. Good detail on practice effects.	✓ All participants were tested at baseline and again post-test after 14 days. Fourteen days was shown as sufficient time to incite an effect response or not in previous studies.	The 14-day whole-body irradiation with red-light treatment improved the sleep, serum melatonin levels, sleep quality and marginally improved endurance performance.	✓ Effect sizes stated for each outcome measure. P-values and actual values reported along with statistical methods and comparison between groups.	✖ *Objective measures of sleep should have been included to accurately measure sleep indices.* Design and methods were appropriate. Confounding factors addressed.	✖ The subjects included in the study correlates with our population of concern e.g. athletes, *however not football specific* *The intervention used is not widely available to us. The performance outcome measures are easily usable, however melatonin collection and analyses is not pragmatically available for us.*	✓ This study concurs with previous literature which shows a correlation between melatonin secretion and red-light therapy (Yeager et al., 2007) which aid in promoting sleep qualities.