Sleep Extension and Recovery in Rugby Union Players

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TABLE OF CONTENTS

ATTESTATION OF AUTHORSHIP

I hereby declare that this submission is my own work and that, to the best my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

Signature:

Date: 25/2/17

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LIST OF FIGURES

LIST OF TABLES

ETHICAL APPROVAL

Ethical approval was obtained from the Auckland University of Technology Ethics Committee (AUTEC):

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ABSTRACT

Sleep is an important factor that has recently become of interest in the sporting arena. The benefits of sleep include memory consolidation and metabolism regulation, as well as aiding immune function, mood and recovery. Rugby Union has been "professional" since 1996 and, with the increased focus on success throughout the world, coaches, athletes and practitioners are investing time and resource into "small gains" in preparation, recovery and performance. Therefore, the purpose of this thesis was to quantify the quality and quantity of sleep in rugby union players and examine the effect of sleep extension on players' perceptions of recovery, physical performance and skill acquisition.

In part one, sixty-one professional and semi-professional rugby union players (mean age ± SD; 23.2 ± 3.9 years) completed the Pittsburgh Sleep Quality Index (PSQI) questionnaire, which assesses sleep quality over a one month period. Twenty (33%) scored greater than five indicating poor sleep, while 41 (67%) scored less than five indicating good sleep. The ethnic group with the highest mean PSQI score (5.64 ± 1.96) and therefore the poorest sleep was Maori (n=11). When related to training phase, those in the off-season reported the highest score (5.45 ± 1.82) indicating poor sleep. Further investigation is needed to understand the contributing factors to sleep quality in rugby union players.

Part two was a repeated measures design with participants undertaking a three-week habitual sleeping period to establish a baseline for normal sleeping behaviour and then a five-week period of extended sleep. Fifteen rugby players at a professional and semi-professional provincial level with no previous sleep issues participated in the study. Peak velocity (m/s), mean power (W) for squat jump, body weight (kg), sum of 8 skin folds (mm) and time in bed (mins), self-reported sleep quality, fatigue, muscle soreness and passing accuracy were measured before and after the three week sleep extension phase. After sleep extension, the players had a small increase (ES = 0.46 ± 0.47) in time in bed from post-baseline. Sleep was only extended by an average of 22 minutes per night. There were no significant or meaningful changes in any performance related variables following the sleep extension. Sleep extension was only partially achieved during the season with these players and may explain minimal changes in variables measured, therefore promoting sleep extension to a meaningful level in-season was not achieved.

In conclusion, 33% of players were found to not sleep well (part 1). However, an intervention to try to extend sleep through basic education and monitoring did not appear to extend sleep sufficiently. Therefore, methods to help rugby players extend, as well as improve the quality of their sleep, in-season and therefore realise 'potential' benefits requires more careful consideration and research.

INTRODUCTION

A large amount of training and practice is required to be considered an expert in any specific skill or task (Ericsson and Lehmann, 1996). However, what remains to be clarified is the impact that other influences, such as quantity and quality of sleep, have on skill acquisition and physical recovery (Ericsson and Lehmann, 1996; Baker, Horton, Ronertson-Wilson and Wall, 2003; Sarode et al., 2013). The function of sleep in learning and recovery has recently become of interest in the sporting arena; with particular interest in how the body adapts physiologically and psychologically with deprived and extended sleep (Reilly & Piercy, 1994; Leger, Metlaine and Choudat, 2005; Mah, Mah, Kezirian and Dement, 2011). Indeed, while sleep has previously been identified as having a significant role in skill learning (Walker and Stickgold, 2005; Korman et al., 2007; Mednick, Nakayama and Stickgold, 2003; Sejnowski and Destexhe, 2000), there is a dearth of research related to athletic performance.

The most prevalent research into sleep and athletic performance has been in the topic of sleep deprivation. In a key study, a group of collegiate level weight lifters were deprived sleep for a 24-hour period (Blumert et al., 2007). The results showed that there was little or no effect of sleep deprivation on physical performance. However, their findings indicated that mood, as assessed by the Profile of Mood States (POMS; McNair, Lorr and Doppleman, 1971) questionnaire, deteriorated. The practical application of this study is limited as most athletes are unlikely to suffer from complete sleep deprivation for a 24-hour period (Lastella, Roach, Halson and Sargent, 2015). Other studies which discussed sleep disruption and insomnia with relevance to athletic performance (Leger et al, 2005; Shearer, Jones, Kilduff and Cook, 2015) state that optimum performance needs both physical and mental states to be combined effectively, hence many athletes find the night before competition stressful enough to disrupt their sleeping pattern.

Although much of the sleep and athletic performance research that has focused on sleep deprivation or sleep loss (Ledger et al., 2005; Davenne, 2009; Reilly et al., 1994), many also suggest that sleep is important for physical and psychological wellbeing and development (Fullagar et al., 2015; Cumminskey, Natis, Papathanasiou and Pigozzi, 2013; Savis, 1994; Lastella, Lovell and Sargent, 2014). The athletes' perceptions as to the importance of sleep concurs with the findings and recommendations made by much of the research conducted so far. Venter (2014) surveyed 890 athletes, asking them to prioritise the importance of various recovery modalities, with sleep being identified as one of the major means of recovery by athletes across all sports, genders and competition levels.

With the importance of sleep identified by researchers and athletes alike, and the lack of adequate quantity of sleep identified in some athletic populations (Venter, 2014; Sargent, Halson and Roach, 2014a; Kölling et al., 2015; Swinbourne, Gill, Vaile and Smart, 2015), there seems to be a lack of literature that has considered the role of extending sleep time in both recovery and as a mode of optimising learning and performance (Thun, Bjorvatn, Flo, Harris and Pallesen, 2015). Research that has occurred with a focus on sleep extension in non-athlete populations has typically found improvements to alertness, energy, mood and reaction time (Barbato, Barker, Bender, Giesen and Wehr, 1994; Kamdar, Kaplan, Kezirian and Dement, 2004). Furthermore, one study within an athletic population, considered the effects of extended sleep on the performance of collegiate basketball players (Mah et al., 2011). Participants were asked to extend their habitual sleep time with a target of ten hours, with results showing a significant improvement on sprint time, shooting accuracy, reaction time, mood and fatigue. Thereafter it was suggested that sleep extension could "…play an important role in peak performance in all levels of sports" (Mah et al., 2011: 950). However, there is a clear need to further explore the role of sleep extension on optimising learning and athletic performance.

Therefore, the aims of this research were to:

1. Quantify the quality and quantity of sleep in rugby union players.
2. Examine the effect of sleep extension on the quality and quantity of sleep, players' perceptions of recovery, physical performance and skill acquisition.

REVIEW OF LITERATURE

Introduction

Rugby union is a contact sport which requires players to recover rapidly from the physical exertion of the game in order to train and prepare themselves for the next round of competition, which usually takes place within five to seven days. Sleep has been identified as a component of recovery and skill acquisition, yet the overall benefits of sleep, for both the general population and athletes, are being continually investigated in the literature.

The main focus of this literature review is to consider sleep as a recovery means, as well as its influence upon skill acquisition. The overall benefits of sleep for the general population as well as those involved in the military have been reviewed to provide an understanding of the advancement of sleep in sports performance. Additionally, other sports have been included to provide an understanding of sleep in the sporting arena due to the limited availability of research specific to rugby union.

Physiology of sleep

Before sleep is considered as a recovery method in athletic performance it is important to discuss what is thought to be the function sleep and what happens when we sleep. The overriding function of sleep has been debated for some time with Siegel, (2005) suggesting that it is most likely a way of conserving energy, allow the nervous system to recuperate and consolidation of memories. Sleep itself can be separated into do distinct states, rapid eye movement (REM) and non- REM sleep. These states can be further divided. Non – REM sleep occurs in four stages. Firstly, there is a state of drowsiness, a transition from being awake to falling asleep. Muscle activity is reduced and in some individuals twitching can occur. In stage two, changes in breathing are apparent and an individual's heart rate decreases. Stages three and four are considered deep sleep. Breathing and heart rate are at the lowest levels during these stages and if an individual is woken at this point the often feel disorientated and groggy. Finally, there is REM sleep. This is the stage in which dreaming occurs and usually appears after around 90 minutes. Although not conscious the eyes can be seen to move and blood pressure and heart rate begin to rise again. As we sleep we cycle though non-REM sleep and REM sleep (Shapiro and Flanigan, 1993).

Influence of Sleep on General Life

Sleep has been a widely researched topic for many years and it is accepted that sleep is important in physical and mental recovery (Leeder, Glaister, Pizzoferro, Dawson and Pedlar, 2012; Samuels, 2008; Belenky et al., 2003; Adam and Oswald, 1984; Ferrara and De Gennaro, 2001). The function of sleep can be described as "a period of recuperation or restoration" (pg. 384, Shapiro and Flanigan, 1993). More specifically, the function of sleep is seen as a means of conserving energy and physical and/or neurological restoration. Subsequently, it is a period in which growth hormone is mainly released, especially during pregnancy, adolescence, or recovery from physical exertion. This makes it pertinent to athletic populations (Hodgson, 1991; Shapiro and Flanigan, 1993). It is obvious that sleep has numerous recuperative functions and sleep is an extremely important part of life for human beings. Holst and Landolt (2015), expressed that sleep is a necessity for humans, as important as eating, drinking and procreating, yet the absolute understanding of why we sleep is still unclear.

If we are deprived of sleep, especially for prolonged periods of time, it has been shown to have an adverse effect on decision making, mood, learning and a number of physical markers, possibly leading to serious health issues (Benington and Heller, 1995; Belenky et al., 2003; Leger et al., 2005; Cook, Crewther, Kilduff, Drawer and Gaviglio, 2011). Although there seems to be wide acceptance that sleep has restorative effects and is important for well-being, adequate sleep duration and quality may not be happening in practice. Lack of sleep is often seen as a badge of honour by young doctors, although there is a clear link between lack of sleep and mental and physical illness (Pedersen et al., 2015). Indeed, Malow (1999), discussed the relevance of sleep in health and safety, making the point that even though lack of sleep in the work place leads to accidents, it is not given the prioritisation it deserves.

The question of how much sleep is needed for effective daytime functioning has been reflected upon by several authors. It has been shown that those who slept for long periods tended to be anxious and in some cases depressed, whereas short sleepers were recorded as being efficient and hardworking (Hartmann, Baekeland, Zwilling and Hoy, 1971). In contrast, reductions in sleep have been related to increased accidents in an industrial setting (Ferrara et al., 2001). Shift work is now prominent in many industries, with research showing this type of work causes significant sleepiness, which in turn affects performance (Åkerstedt, 1995). Putting a true cost to the impact of sleep reduction is obviously speculative, yet it is estimated that between 1999 and 2008, reduced sleep was a contributing factor in approximately 69,300 traffic fatalities in the United States (Teft, 2014). It also has a cost to the US economy of hundreds of billions of dollars per year due to industrial and home accidents (Colten and Altevogt, 2006). However, it may be unreasonable to put a finite number on how much sleep a person needs. Sleep duration and its relationship to daytime performance and wellbeing may be different for each individual, with personality, lifestyle and genetics thought to influence this relationship (Hartmann et al., 1971; Horne and Ostberg, 1976; Webb and Bonnet, 1978; Hor and Tafti, 2009).

Sleep in the Military

Members of the armed forces fundamentally have to deal with life and death situations and often make extremely difficult decisions in stressful environments. Therefore, sleep has been identified as an important component of military life. Research in this area, like that of elite sport, is focused on getting the best out of the military population. In 2013, the US Army developed the Performance Triad in an effort to improve the readiness and overall health of their soldiers (Pedersenet al., 2015). In the performance triad, the importance of sleep and description of good practice or sleep hygiene is clearly described. However, work by Lentino, Purvis, Murphy and Deuster (2013) identified that sleep among military populations is problematic; as military personnel often work in dangerous environments, their sleeping location is often associated with loud noise and unpredictable hours are common, especially when on active duty. Although the working environment of military personnel is different for those of the general population, the symptoms and end result of lack of sleep remains the same. Continued lack of sleep results in an increase in obesity and can negatively affect overall wellbeing (Taheri, Lin, Austin, Young and Mignot, 2004; Quick, et al., 2014; Woods and Scott, 2016).

It could be argued that even though the information pertaining to the importance of sleep is readily available, the culture of the military does not lend itself to accepting sleep as a way of improving performance. A study of sleep patterns of US Military cadets identified cadets suffered from significant chronic sleep debt, not due to active service in a war zone, but as a result of the training schedule at West Point Military Academy (Miller, Shattuck and

Matsangas, 2010). The author inferred that the bad habits developed in training may continue after graduation, and as the cadets are expected to become officers, the poor understanding of the importance of sleep may be transferred to soldiers in their charge. In essence, if a commanding officer cannot recognise that good sleep hygiene will increase the effectiveness of his soldiers, it is unlikely the recommendations made by the US Army Medicine's Performance Triad will be adhered to. Therefore, it could be reasoned in a sporting context, if the coach of a team does not consider sleep to be important, athletes in their charge will not understand the merits either.

Influence of Sleep on Learning

Learning a new skill does take significant practice; however, the learning process not only occurs during a practice or training session, but also between sessions. It has been found that the learning and development of a sequence of finger movement tasks, without additional practice, was dependant on sleep (Robertson, Pascual-Leone and Press, 2004). This is in agreement with a number of other studies who iterate that sleep serves as a way of consolidating memories (Hobson and Stickgold, 1995; Sejnowski and Destexhe, 2000; Fenn and Hambrick, 2012). More recent work identified that sleeping between bouts of learning can increase retention duration and decrease study time when learning both foreign and local vocabulary (Mazza et al., 2016; Huang et al., 2016). Although these studies do not directly look at the behaviours of athletes and the learning sport specific skills, it is suggested that this research can benefit athletes as in most sports there is a certain amount of "playbook" learning to complete as well as the learning of complex motor patterns. Current research, however, favours non-athletic skill learning and sleep, making the present study relevant as it considers sleep and the acquisition of a sport specific skill.

Sleep and Athletic Performance

It has become apparent that athletes sleep less than non-athletes of a similar age (Hudson, 2002; Leeder et al., 2012; Swinbourne et al., 2015; Shearer, Jones Kilduff and Cook, 2015). It has been reported that some athletes only achieved 6.8 ± 1.1 hours of sleep per night, with those involved in individual sports reporting the least amount of sleep (Lastella et al., 2015). This is very similar to the findings of Sargent et al., (2014b) who recorded that elite athletes averaged

6.5 hours of sleep per night. Further evidence of poor sleep in athletic populations was found by numerous studies, highlighting the need to better understand the causes of poor sleep in athletic populations (Fietze et al., 2009; Nedelec, Halson, Abaidia and Dement, 2015; Fullagar et al., 2015).

Sleep Deprivation

Blumert et al. (2007) investigated the effects of 24 hours of sleep loss on weightlifters and found that it had little effect on physical performance. It did, however, note that mood was decreased while sleepiness and confusion increased. While it may be unlikely that an athlete will lose sleep for such a prolonged period of time, this could be used as an example as a worst case scenario. It is clearly stated by the authors of this study that focus should be put on motivational aspects to aid performance, due to the effect on sleep deprivation on mood and confusion, rather than focusing on physical aspects. A less extreme sleep deprivation protocol initiated by Reilly et al. (1994) had participants limited to three hours sleep for three consecutive nights. They noted a significant effect on maximal lifts for three out of four exercises and a significant effect on all exercises for a sub maximal protocol. Once more, mood and confusion states were highlighted as being significantly affected by the period of sleep deprivation.

Sleep Extension

Early studies suggested that extended sleep had a similar effect to sleep deprivation when performing calculated, vigilant and complex motor tasks such as pinball (Taub and Berger, 1969; Taub et al., 1971). More recent work on sleep extension, however, has shown mood, vigilance, day time sleepiness and blood pressure, as well as other measures have all been positively affected (Kamdar et al., 2004; Boergers, Gable and Owens, 2014; Gangwisch, 2014; Walker and Stickgold, 2005). In athletic populations, extended sleep has also been found to be beneficial to performance. Mah et al. (2011) found that extended sleep improved performance in collegiate basketball players shooting accuracy, sprint time, reaction time and also reduced fatigue. As both athletes and coaches are continuously vying to find the competitive edge, the concept of simply extending sleep to enhance performance may be an effective and inexpensive method. The benefits of extended sleep were further verified by the use of a tennis serve accuracy test with college tennis players. Significant improvements in accuracy were found by extending sleep, with serving accuracy improving from 35.7% to 41.8%, highlighting the importance of sleep when considering skill-based training programmes (Schwartz and Simon, 2015). However, many elite sports people experience poor sleep quality and averaged 7.9 hours of sleep per night (Swinbourne et al., 2015). Research has suggested that around eight hours of sleep is required per night for non-athletic populations to function effectively and not suffer from day-time sleepiness (Van Dongen, Maislin, Mullington and Dinges, 2003). It can be reasoned that athletes need more sleep to recover effectively from the demands of training and competition. Duffield, Murphy, Kellett and Reid, (2014) worked with tennis players and found that self-perceived soreness and mood were improved by simple sleep hygiene methods such as low light, cool conditions and earlier bedtime. These recommendations are straightforward, cost effective and beneficial for both athletes and coaches in promoting sleep as a method of recovery and learning.

Sleep and Training Schedules

Along with stress related to performance, pain has been shown to affect the quality and quantity of sleep. As previously stated, rugby union is a contact sport, and an individuals' pain thresholds can be negatively affected by lack of sleep (Chiu et al., 2005; Fietze et al., 2009). Therefore, it is important that daily schedules be devised to optimise quality and quantity of sleep for athletes; with a view to increase retention of information, acquisition of skills, as well as allowing for physical recovery from training and competition. Indeed, research within numerous sports has identified that if sleep is not considered in the planning of training sessions, it has a detrimental effect on the subsequent mood and performance of the athletes involved (Kölling et al., 2015; Sargent et al., 2014b). For instance, consistent early morning training sessions were found to cause less sleep the night before and increased perceptions of fatigue. Furthermore, if continued for a prolonged period, it is suggested that athletes may suffer from overtraining or an increased likelihood of becoming ill or injured (Prather, Janicki-Deverts, Hall and Cohen, 2015; Milewski et al., 2014).

It has been recommended that after a period of intense training or early morning training, a period of extended sleep is a simple and effective way of restoring mood and allowing for physical recovery. Sleep was found to be negatively affected on nights prior to early morning training sessions and it is proposed if early morning training sessions are unavoidable, the training schedule should take this into account and allow times for napping and opportunities to recuperate effectively (Sargent et al., 2014a: Kolling et al., 2015). The effect of early evening training sessions on the quantity and quality of sleep of elite youth soccer players found that there was little difference between training nights and non-training nights (Robey et al., 2014). Therefore, early evening sessions may be better suited to young athletes rather than early morning as they allow consistent sleep patterns.

Training camps have also been shown to have an effect on the sleep patterns of athletes. It has been found that sleep quality can be negatively affected by training camps and the use of daytime naps was an effective recuperative measure without affecting night-time sleep. Changes in sleep environment reduce the quality of sleep of athletes and it is not just the day to day schedule that can effect players sleep, but the environment in which the training, recovery and sleep takes place. (Thornton et al., 2016; Pitchford et al., 2016).

Sleep and Incidence of Injury

The success of team performance in football (Hägglund et al., 2013), and rugby (Cross, Williams, Trewartha, Kemp and Stokes, 2016) has been shown to be adversely affected by injury rates. It has been suggested that if an athlete does not have adequate stress coping strategies there may be an increased incidence of injury (Andersen and Williams, 1988). Among those potential coping strategies mentioned to reduce stress, and therefore potential injury, was the ability to sleep. Adolescent athletes with chronic lack of sleep (<8 hours) were 1.7 times more likely to become injured compared to young athletes who slept ≥ 8 hours (Milewski et al., 2014). In contrast, no relationship between low sleep quality and quantity and injury incidence has been found in elite Australian Rules football players (Dennis, Dawson, Heasman, Rogalski and Robey, 2016). However, it may be the case that the elite Australian Rules football players were more resilient to injury due to a greater training age, or possibly had a greater understanding of recovery compared to younger, less experienced athletes.

Pre-Competition Sleep

As stated sleep, has been identified as having an important effect on recovery, learning physical performance and mood of athletes. Consequently, the sleep behaviours of athletes prior to competition can be deemed important. An investigation into sleep disturbances in elite Australian athletes (n = 283) prior to competitions found the main problem was in falling asleep (82.1%) with the prevailing reason being thoughts about competition (83.5%). More noteworthy was that over half of the team sport athletes surveyed had no strategies to assist them in sleeping, highlighting the need for education of both athletes and coaching staff. Similarly, it has been shown that 70% of endurance (marathon) athletes, experienced poorer sleep pre – competition than normal (Lastella et al., 2012; Juliff, Halson and Peiffer, 2015). However, little effect was found on athletic performance, with no discrepancies in performance after a night of sleep deprivation (Blumert et al., 2007; Erlacher, Ehrlenspiel, Adegbesan and El-Din, 2011). As with previous studies mentioned, the majority of athletes did not have an understanding of strategies to promote sleep, highlighting the importance of education for athletes and coaches once more. It may be that a single night of poor sleep has little effect on athletic performance, whereas prolonged periods of sleep deprivation may have detrimental effect on both to physical and mental health (Thun et al., 2015).

Post-Competition Sleep

Several studies have gone on to research the sleeping patters of athletes after competition. When considering the effect of sleep deprivation on recovery after rugby league matches, researchers found that sleep deprivation impaired cognitive function as well as lower body power (countermovement jump) compared with normal sleep of approximately 8 hours. However, the effects of lack of sleep highlighted and the differences in levels of recovery post-match may be down to the individual players' quality and quantity of sleep (Skein, Duffield, Minett, Snape and Murphy, 2013). Corresponding results were found when monitoring the sleeping patterns of competitive rugby players during training and competitive matches. These findings showed that players had significantly less sleep after games. Possible reasons sighted may be caffeine ingestion and late night finish time of the game compared to normal training nights (Eagles, Mclellan and Hing et al., 2014). Additional causes of wakefulness post-rugby matches may be changes in hormonal markers such as cortisol and testosterone as well participation in social events. This lack of sleep should be taken into account when scheduling recovery sessions the day after competitive matches.

Interventions to improve sleep

Lacks and Rotert (1986) considered what may help or hinder an individual getting to sleep referring to these processes as sleep hygiene. These authors considered sleep hygiene to include sleep schedules, pre-bed activities, daytime activities, sleeping environment as well as nutritional factors and attitude to sleep. More recently Bird (2013) made recommendations when considering sleep hygiene from an athletes' perspective and outlined strategies to improve the sleep of athletes. These recommendations included, yet were not limited to, maintaining a regular bedtime and wake up time, avoidance of caffeine and alcohol and not watching television in bed. This use of electronic equipment around bedtime has been discussed more recently with research maintaining that use of phones or tablet devices before bed can negatively impact sleep due to light exposure negatively affecting melatonin production (Figueiro et al. 2011; Marshall and Turner et al. 2016; Nedelec et al. 2015). As technology plays a greater role in our everyday lives this recommendation may be of greatest priority for athletes.

Summary

This review of existing sleep research has shown that sleep is extremely important for overall wellbeing as well as physical development, recovery and learning. For the general population, if sleep patterns become disrupted, especially for prolonged periods of time, it can have a significant effect on the health and well-being of individuals. If sufficient sleep is not achieved the health and safety of workers can be put at risk, as reaction time and decision making are compromised. When considered from a military point of view, sleep can influence morale and health of military personnel, and is therefore of upmost importance. Additionally, if those in command are sleep deprived and tasked with making decisions that may affect the welfare of soldiers under their command, poor judgement may have disastrous consequences.

In regard to athletic performance, sleep is required for the body to grow, regenerate and learn, as well as make decisions under pressure. With sleep being so beneficial for sportspeople it is recommended that more education is needed for coaches and athletes in the benefits of sleep and its promotion (Simpson, Gibbs and Matheson, 2017). Aiding an athletes' recovery may be as simple as changing the training schedule or night time routine, yet the importance of sleep does not seem to have been fully taken on board by those working or performing at the highest level of sport. Sleep extension during competitive season has not been thoroughly considered in the research. The benefits of sleep during this time and how it will affect skill acquisition and recovery should be further considered. However, the question still remains of how much sleep is needed for each individual, and this may be related to their sport, lifestyle and genetics.

METHODS

Part One

Participants

Sixty one rugby union players volunteered to take part in the present study. Participants (mean age ± SD; 23.2 ± 3.9 years) were asked to specify the highest level of rugby they currently competed in, the ethnic group they believed themselves to belong to, and identify their playing position and current training phase. All participants were aged 18 years or older and provided written informed consent to participate in the study. The study was approved by the Auckland University of Technology Ethics Committee (AUTEC).

Research Design

Measures of sleep quantity and quality were determined using a modified Pittsburgh Sleep Quality Index (PSQI) questionnaire which measures sleep quality and disturbances over a one month period (Buysse, Reynolds, Monk, Berman and Kupfer,1989). More specifically, the PSQI is designed to identify poor sleepers through the completion of questions relating to sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances and use of sleep medication. Subjects were instructed to complete all sections which contribute to the final score, which can range from 0-21. A global PSQI score of > 5 has a diagnostic sensitivity of 89.6% and a specificity of 86.5% in characterising 'poor' sleepers, with < 5 being characterised as a 'good' sleeper (Buysse et al., 1989). The questionnaire was emailed to each participant with a link to an online survey site (SurveyMonkey®), similar to the protocol of Juliff et al. (2015).

Part Two

Participants

Fifteen rugby union players at a professional and semi-professional provincial level (mean age ± SD; 25.9 ± 2.9 years) volunteered to take part in the study. No subjects reported previous sleep issues. The participants were made up of nine forwards and six backs and were in the competition phase of the 2014 ITM Cup. Players were informed of any experimental risk and signed an informed consent document before the research period began. Ethical approval was provided by the AUTEC.

Research Design

The study was a repeated measures design with participants undertaking a three-week habitual sleeping period, with no instruction, to establish a baseline for normal sleeping behaviour. Time in bed (TIB) was logged using a phone application (Sleep Log v1.2, Midtown, 2010) and a daily questionnaire. Players initiated the sleep app when they were ready to sleep at night and stopped it when they woke in the morning. The daily questionnaire required the participants to record body weight, sleep quantity (time spent sleeping), sleep quality (EX – excellent, G-good, A – average, P – poor and T - terrible), and a five-point scale indicating fatigue (1- not fatigued to 5 - extremely fatigued) and muscle soreness (1- no soreness to 5 - extremely sore). Naps could not be recorded on the sleep application but were recorded on the sleep questionnaire. The questionnaire was composed on Microsoft Excel 2010 and made available to players on a laptop either in the gym or in the team meeting room. All participants were sent a daily text message to remind them to complete the application and daily questionnaire. Following the baseline sleep period, participants were asked to aim for ten hours of sleep in a 24-hour period for five weeks. Sleep hygiene protocols similar to those proposed by Bird (2013) were given to each player prior to the sleep extension period. Sleep during this period was logged using the phone sleep application and a daily questionnaire as previously described. It was made clear to participants that napping could be used to top up nightly sleep in order to achieve the target of ten hours of sleep in 24 hours.

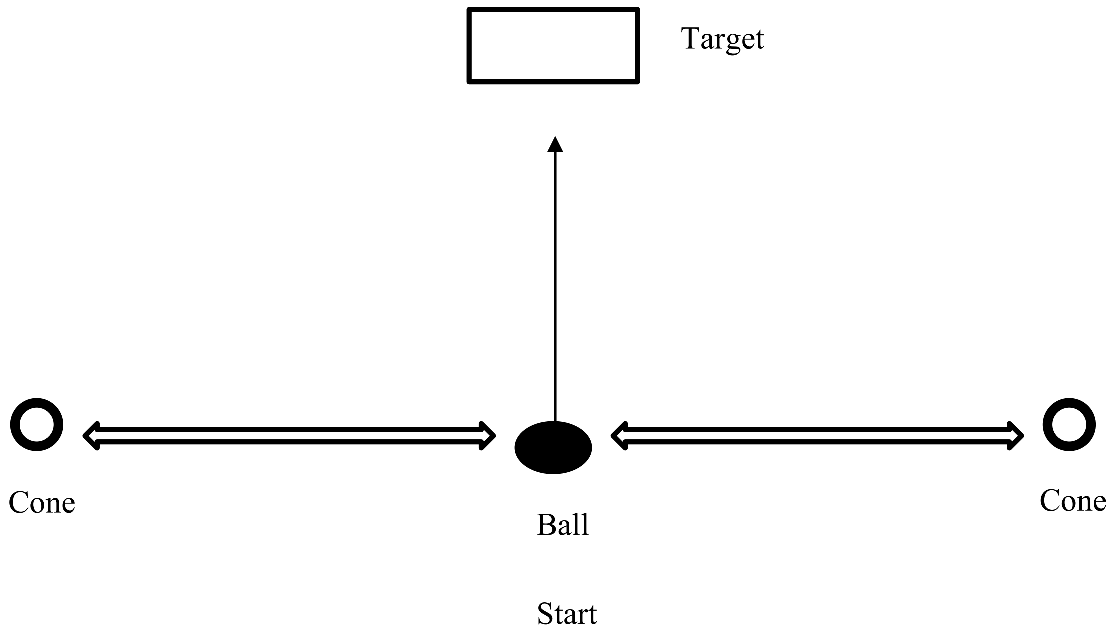
Adherence

During the study, some participants suffered injuries which they reported as affecting their sleep patterns. This was seen as unavoidable due to the contact nature of rugby union. If it was deemed an injury that would require prolonged treatment and withdrew them from selection for games they would be removed from the study. Other participants had young children who disrupted their regular sleep/wake schedule, this was also deemed unavoidable. Sleep was not recorded on the phone application the nights prior to a game or after a game as not all participants were selected to play in all games. Only time in bed was recorded at home. Not on away trips.

Passing Accuracy Task

During the three-week baseline sleep period, participants performed two familiarisation protocols on the outdoor repeated passing accuracy. On the third week participants were then tested. The testing was completed at the end of a team training session. The passing task was based on that of Cook et al. (2011), with participants required to make ten rugby passes of the ball, left and right hand facing target (alternately), to a target 10m away after completing a 10-metre sprint with a change of direction after 5 metres. (Figure 1). Players identified their perceived stronger passing side. Each pass had to be completed in a 10s timeframe and no motivation was given to complete the task quickly. The time was counted down by a coach with a stopwatch. Accuracy was defined by the position of the ball striking the target. A pass to the centre of the target (30cm in diameter) scored ten points, with a decreasing score of seven (54cm diameter), five (78cm diameter) and three (115cm diameter) the further away from the centre the ball struck the target. A complete miss of the target was scored as zero. All passing tasks were filmed to ensure accuracy in scoring.

Figure 1: Passing accuracy task. The player completed ten rugby passes of the ball, left and right hand facing target (alternately), to a target 10 m away after completing a 10-m sprint with a change in direction after 5m.



Sum of 8 Skin-folds

Bodyweight and players sum of 8 skin-folds (Triceps, Sub-scapular, Bicep, Iliac Crest, Supraspinale, Abdominal, Mid-Thigh and Medial Calf) were recorded prior and post the sleep familiarisation period and the sleep extension period. Skinfolds were performed by an International Society for the Advancement of Kinanthropometry (ISAK) level one qualified technician and collected using Harpenden skinfold callipers (Baty International, England).

Measurement of Concentric Peak Velocity (m/s) and Concentric Mean Power (W)

Concentric Peak Velocity (m/s) and Concentric Mean Power (W) were measured using a Gymaware device (Kinetic Performance Technologies, Australia). The participants performed a 50-kg Counter Movement Jump (CMJ) with an Olympic bar loaded to the desired weight held across the posterior deltoids whilst connected to the Gymaware device. The methodology used is similar to that of Argus, Gill, Keogh, McGuigan and Hopkins, (2012) with players lowering themselves to approximately 90° knee flexion before jumping as high as possible. Three sets of 5 repetitions were completed for each player two days before a game with the best repetition recorded. The test was completed after a general mobility warm up and before any other lifting in the weight room had been completed.

Statistical Analysis

Means and standard deviations were calculated for all variables in both parts of the study. Effect size was also calculated for all variables at all-time points during part two. Effect sizes were calculated between baseline and experimental periods to determine any meaningful change. Effect sizes were determined trivial < 0.2, small 0.2 – 0.59, moderate 0.6 – 1.19, large 1.2 – 1.99 and very large > 2.0 (Hopkins, Marshall, Batterham and Hanin, 2009). The effect was deemed unclear if its confidence interval overlapped the thresholds for small positive and negatives (Batterham and Hopkins, 2006).

RESULTS

Part One

The mean PSQI score for all participants was 5.08 ± 1.72. Sixty-one players fully completed the sleep quality questionnaire, in which 20 scored > 5, indicating poor sleep, while the remaining 41scored < 5 indicating good sleep. Table 1 shows PSQI scores by ethnic group, playing position, training phase and level of rugby. Players from a Maori ethnic background showed the poorest sleep quality score (5.64 ± 1.96). International level players had the highest mean PSQI score (6.00 ± 1.00) indicating poor sleep, however only three players had played that level. Inside backs had the highest score for sleep quality (5.53 ± 1.58), while players who completed the questionnaire in the off-season reported the higher scores (5.45 ± 1.82), compared to players in-season (4.40 ± 1.54 and 5.08 ± 1.72 for pre- and competition seasons respectively).

Table 1: Rugby union players' Self-reported time in bed, sleep duration and sleep quality (PSQI) global scores by ethnic group, playing position, training phase and level of rugby related to previous month (N = 61) (Mean ± SD). A PSQI score of >5 is associated with poor sleep quality.

	N	Time in Bed (hours)	Sleep Duration (hours)	PSQI Score
All	61	8.65 ± 0.94	7.80 ± 1.08	5.08 ± 1.72
NZ European	35	8.90 ± 0.88	8.05 ± 0.81	5.03 ± 1.50
Pacific Islander	12	8.16 ± 0.88	7.71 ± 0.69	5.33 ± 1.87
Maori	11	8.45 ± 1.00	7.11 ± 1.86	5.64 ± 1.96
Other	3	8.33 ± 0.47	7.75 ± 0.25	2.67 ± 0.58
Tight 5	18	8.86 ± 0.89	7.91 ± 0.84	4.59 ± 1.20
Back Row	18	8.50 ± 0.94	7.63 ± 0.92	5.06 ± 2.15
Inside Backs	18	8.99 ± 0.96	7.61 ± 1.55	5.53 ± 1.58
Outside Backs	7	8.36 ± 0.95	7.90 ± 0.96	5.29 ± 1.80
Off Season	31	8.6 ± 0.95	7.57 ± 1.20	5.45 ± 1.82
Pre-Season	20	8.51 ± 0.98	8.03 ± 0.89	4.40 ± 1.54
Competition	10	9.06 ± 0.70	8.06 ± 0.95	5.08 ± 1.72
International Rugby	3	8.67 ± 0.85	8.00 ± 1.32	6.00 ± 1.00
Professional Rugby (Non NZ)	9	9.18 ± 0.64	8.12 ± 0.99	5.56 ± 1.24
Super Rugby (NZ)	2	8.00 ± 0.50	7.75 ± 0.35	5.00 ± 0.00
National Provincial (NZ)	15	8.54 ± 0.76	7.15 ± 1.56	5.60 ± 2.20
Club (NZ)	29	8.57 ± 1.05	8.03 ± 0.66	4.69 ± 1.61
Other	3	8.75 ± 1.06	7.67 ± 1.26	4.00 ± 1.73

Part Two

Changes in player body weight (kg), sum of 8 skin folds (mm) and time in bed (mins), self - perceived sleep quality, muscle soreness and fatigue are shown in Table 2. A small increase in TIB (ES = 0.46 ± 0.47) occurred post sleep extension compared to baseline post sleep extension. Peak velocity (m/s) and mean power (W) measurements and passing task score are displayed in Table 3. All other changes were trivial or unclear for all other variables.

Table 2: mean ± SD of body weight, skin-fold (mm) and time in bed per night (mins), self-reported sleep quality (1 = excellent and 5 = terrible), fatigue (1 = no fatigue and 5 = very fatigued) and muscle soreness (1 = no soreness and 5 = very sore) of 15 semi-professional rugby union players during 3-weeks of sleep extension compared to baseline.

	Post-Baseline	**Pre-Sleep Extension**	**Post-Sleep Extension**
Body Weight (kg)	105.2 ± 10.6	105.3 ± 10.3	104.7 ± 11.1
Skin-fold (mm)	85.5 ± 20.0	95.6 ± 7.4	83.5 ± 24.7
Time in bed per night (mins)	517 ± 44.2	518 ± 50.7	539 ± 45.1*
Self-Reported Sleep Quality	2.4 ± 0.8	1.9 ± 0.7	1.9 ± 0.9
Fatigue	2.0 ± 0.8	1.8 ± 0.8	1.8 ± 0.7
Muscle Soreness	2.1 ± 0.8	1.9 ± 0.9	2.1 ± 0.7
Effect size - * small change from Post-Baseline			

Table 3: mean ± SD of concentric peak velocity (m/s) and power (W) of a 50 kg squat jump and passing task score in 15 semi-professional rugby union players during 3-weeks of sleep extension compared to baseline.

	Post-Baseline	Pre-Sleep Extension	Mid-Sleep Extension	Post-Sleep Extension
Peak velocity (m/s)	2.54 ± 0.20	2.48 ± 0.18	2.50 ± 0.20	2.49 ± 0.26
Mean power (W)	4232 ± 414	4083 ± 413	4101 ± 567	4221 ± 514#
Passing score	49.15 ± 8.71			49 ± 13.75#
Effect size = # unclear from Post-Baseline				

DISCUSSION

The purpose of the present study was twofold. Firstly, to establish the quantity and quality of sleep of elite rugby union players and, secondly, investigate the effect of sleep extension on physical performance, recovery and skill acquisition during a competitive season.

Sleep Quality

The results in part one show that poor sleep was prevalent in a third of the players who completed the questionnaire. When considering sleep, it is important to discuss the quality of sleep rather than just the quantity. Research by Andrade, Bevilacqua, Coimbra, Pereira and Brandt (2016) with elite Volleyball athletes found that when sleep quality was reduced, confusion levels were increased. As decision making is of major importance in elite sport, poor sleep quality can have a direct impact on performance and learning. One area of note in the present study is that players in the off-season scored worse than players in pre-season and competition with regards to sleep quality. This is contradictory to the results found by Swinbourne et al. (2015) who found that those involved in pre-season were most likely to have poor sleep quality and those in the off-season having the best sleep quality. It may be the case that those involved in the present study were under a significant training load in their off-season programme. This strenuous load could then justify the difficulty in sleeping at this time (Hausswirth et al., 2014). Many of the players involved in the present study were semi-professional and, most likely, may have been balancing work and or study, as well as a training load.

Sleep Duration

The average time in bed in the present study increased by 22 minutes compared to pre-sleep extension. This was a similar increase to that found by Van Ryswyk et al., (2016) who used sleep diaries rather than a phone application as used in the present study; however, noted a corresponding decrease in fatigue and increase in well-being. Little difference was found in any of the variables measured pre- and post- sleep extension. If sleep had been extended to a greater amount it may be possible that these variables would show a meaningful difference.

Quantifying the amount of sleep someone needs to perform optimally has proven to be a difficult task. The National Sleep Foundation recommends seven to nine hours sleep per night for adults (Hirshkowitz et al., 2015). As a result, sleep extension has been researched as a possible tool in aiding recovery and improving performance in athletes (Schwartz et al., 2015; Mah et al., 2011; Van Ryswyk et al., 2016; Kölling et al., 2016). Mah et al. (2011) extended the sleep of collegiate basketball players by 110.9 ± 79.7 minutes and recorded that participants reduced their sprint time; improved shooting accuracy, showed increased vigour and decreased fatigue. Participants also reported improved physical and mental well-being. Similar results have also been found in Australian Rules Footballers (Van Ryswyk et al., 2016), college tennis players (Schwartz et al., 2015) and rowers (Kölling et al., 2016). The lack of sleep extension in the present study may be down to the players already having a good understanding of the benefits of sleep and recovery and none of them having any sleep duration problems. In two of the studies compared, the baseline length of sleep was less than the base-line pre-extension TIB for players involved in the present study (~415 minutes and 517 minutes respectively) and thus the ability to extend their sleep more substantially may have been more easily achieved. In contrast, however, athletes with similar baseline sleep duration (~530minutes) have shown positive changes in performance, thus highlighting other factors such as training scheduling, volume and load may have a role in determining how much sleep extension is achieved (Van Ryswyk et al. 2016)

Anthropometric Changes

Trivial changes were found in body composition within the subjects from baseline sleep to sleep extension. Anthropometric data was deemed important during the present study due to the possible association of sleep disorders and athletic populations. More specifically, partial sleep deprivation has been linked to an increase in Body Mass Index (BMI) (Taheri et al., 2004; Vioque, Torres and Quiles, 2000) and also increased BMI and body mass correlating to sleep disorders such as sleep apnoea within athletic populations (Griffin, Maxwell and Griffin, 2016; George, Kab, Villa and Levy, 2003). Although actual sleep time was not recorded in the present study, perceived sleep duration by athletes of ~8.6 hours indicates they might not have been prone to sleep disorders. The results of part one, which were in a similar subject sample, show only slightly lower sleep times, further reinforcing the greater sleep duration in this population.

The players involved in the present study may therefore not have been susceptible to sleep apnoea due to the amount of sleep achieved and the restorative effect of sleep reported (Emsellum and Murtagh, 2005). Furthermore, the players involved were not sleep deprived to an extent that it had an effect on their anthropometry.

Passing Task

Sleep has been found to have a clear link with skill acquisition, and while a small increase was found between pre-extension TIB and post extension TIB, the change in passing task score from pre-to post sleep extension was unclear. The passing skill chosen to measure skill acquisition in the present study was selected as it was deemed a skill in which all players have to complete in a game situation, rather than a specialist skill such as line out throwing or goal kicking. However, certain positions are more likely to perform that skill on a regular basis than others, and certain players may have had more experience and coaching than other in that passing from the ground. Nonetheless there was no obvious trend in changes in passing score between different positions.

Several studies have found that sleep extension had a beneficial effect on sport specific skills. Sleep extension has been found to improve the serving accuracy of college level tennis players (Schwartz et al., 2015). The players involved were asked to extend their habitual sleeping time to at least nine hours, with serving accuracy improving by 6.1%. This improvement in performance concurs with the results found in collegiate level basketball players (Mah et al., 2011). Participants in both these studies, however, were younger than those of the present study. The rugby union players had a higher mean age of approximately 6 years and of a semi-professional and professional level. This increased expertise level, compared to younger collegiate athletes, may have affected their ability to meaningfully progress in a skill they were already very proficient in.

As mentioned above, the baseline sleep scores for the players in the present study were of an already high level. Comparatively, those that found significant change in skill acquisition has substantially lower baseline level. Basketballers that took part in the Mah et al. 2011) research reported a mean baseline of 470 minutes and a sleep per gain of 154 minutes per night during sleep extension. The collegiate tennis players involved in Schwartz et al. (2015) work reported a mean baseline of 428.4 minutes sleep per night yet increasing sleep by a mean of 102.6 minutes per night during sleep extension. Both these baseline scores are lower than the mean of 517 minutes TIB reported by the players involved in the present study, with only a mean of 22 minutes more sleep being achieved during the sleep extension period. It should be noted that both the studies mentioned used self-reporting sleep diaries, with only Mah et al. (2011) also using actigraphy (which reported a slightly lower time asleep). The present study recorded TIB rather than perceived time asleep which may have discrepancies when comparing. Yet, it could be that the greater difference in baseline sleep to sleep extension found in the studies mentioned may be the reason for increased performance post-sleep extension.

Limitations

The lack of control group was a major limitation of the study. Due to the in-season timing of the research and the limited number of participants available, it was not possible for a control group to be included.

Although the PSQI is deemed valid on both the sedentary and athletic populations for the quantification of sleep quality, it is still a questionnaire and not a sleep monitoring tool such as actigraphy or polysomnography. Issues with questionnaires have been highlighted previously as having poor relationship with objective measures of sleep, as self-reported sleep time is often over reported. Under or over estimation of sleep time may have been made when using questionnaires alone compared to sleep monitoring tools as those mentioned previously (Lauderdale, 2008; Leeder et al., 2012). Players involved with part 2 of the present study were unable to complete the PSQI due to the competition schedule, concerns over selection and injury, therefore, it was not contained. Further research should look to ensure PSQI, or a similar questionnaires inclusion.

Napping was not measured by sleep application and only in the daily questionnaire. Napping has been shown to have positive effects on learning (Mednick, et al., 2003; Korman et al., 2007) and could have been utilized to a greater degree to extend sleep.

The athletes involved in this study were advised that prolonged screen use prior to sleep was not advised although this was not monitored and may have affected the sleep of the players involved. Research has shown that excessive screen time can have a negative effect on sleep (Cajochen et al., 2011) highlighting that the use of such devices needs to be considered in future research.

Future Research

Further research is needed into sleep extension and athletic performance, specifically, how sleep effects the learning of sport specific skills. The present study has shown that achieving sleep extension during a competitive season with semi-profession and professional rugby union players by education and scheduling is challenging. Further research is needed into interventions that will allow players to achieve extended sleep during the season. The effectiveness of areas for sleep at training grounds and less expensive and invasive methods of monitoring sleep should be explored.

Social media use has been highlighted as causing anxiety, low self-esteem and poor sleep (Woods & Scott, 2016) and therefore warrants further investigation in athletic populations, as overuse may negatively affect performance. Similarly, video game and internet use was not monitored during the present study and, as overuse has been shown to affect sleep quality and quantity and well as wellbeing (Lam, 2014), may have affected performance of participants.

Practical Implications

The daily schedule should give athletes opportunities to optimise sleep with the inclusion of nap times and reduce early training therefore, facilities should be available to players at training grounds to allow for sleep. Continued and regular sleep screening of athletes throughout the training year is recommended as optimising sleep is likely to improve recovery, skill acquisition and mood. The use of sleep mobile phone applications is a simple and effective way of bringing sleep quantity to the attention of athletes.

The use of a phone sleep application as a method for athletes to record their time in bed with only 84 entries missed out of a possible 379, over a 7-week period. The application gave an accurate expression of athletes' TIB, and although this relied on players' honesty, it made them aware of consistent bed and wake times as the study went on. This, alongside a wellness questionnaire, could be a simple method for monitoring the bedtime and wake up time of athletes.

Although the benefits of sleep are well known, sleep may not be utilised by coaching staff or athletes effectively as a method of recovery and performance enhancement. As an instrument of recovery that has no monetary cost involved and can be promoted through sleep hygiene guidelines, it is recommended that athletes and coaches are educated further on the benefits of sleep and sleep extension for recovery and performance enhancement.

Conclusion

The findings of the present study indicate that a sleep is a problem for many athletes. Ethnic background may play a part in this as well as level of rugby involved in and time of season. Players that had been involved at international level had the poorest PSQI score and this may be related to the stressful nature of competition at that level. Promoting sleep extension to an adequate level that had an effect on mood and performance within rugby union players during a period of 3 weeks in season did not occur in the present study. The high skill level of the players involved and inconsistency of the competition schedule may have led to the unclear or trivial changes in the other variables. Nonetheless, if adequate sleep extension can be achieved through education, proper scheduling and the provision of sleeping areas, there is a likelihood of increased recovery, learning and skill acquisition in semi-professional and professional rugby union players.

REFERENCES

Adam, K., & Oswald, I. (1984). Sleep helps healing. *British Medical Journal, 289*(6456), 1400–1401.

Åkerstedt, T. (1995). Work hours and sleepiness. *Neurophysiologie Clinique / Clinical Neurophysiology*, *25*(6), 367–375.

Andersen, M. B., & Williams, J. M. (1988). A model of stress and athletic injury: prediction and prevention. *Journal of Sport & Exercise Psychology*, *10*, 294–306.

Andrade, A., Bevilacqua, G. G., Coimbra, D. R., Pereira, F. S., & Brandt, R. (2016). Sleep quality, mood and performance: A study of elite Brazilian volleyball athletes. *Journal of Sports Science and Medicine*, *15*(4), 601–605.

Argus, C. K., Gill, N. D., Keogh, J. W., McGuigan, M. R., & Hopkins, W. G. (2012). Effects of two contrast training programs on jump performance in rugby union players during a competition phase. *International Journal of Sports Physiology and Performance*, *7*(1), 68-75.

Baker, J., Horton, S., Robertson-Wilson, J., & Wall, M. (2003). Nurturing sport expertise: Factors influencing the development of elite athlete. *Journal of Sports Science and Medicine*, *2*(1), 1–9.

Barbato, G., Barker, C., Bender, C., Giesen, H. A., & Wehr, T. A. (1994). Extended sleep in humans in 14 hour nights (LD 10:14): relationship between REM density and spontaneous awakening. *Electroencephalography and Clinical Neurophysiology*, *90*(4), 291–297.

Batterham, A. M., & Hopkins, W. G. (2006). About Magnitudes. *International Journal of Sports Physiology and Performance*, *1*(1), 50–57.

Belenky, G., Wesensten, N. J., Thorne, D. R., Thomas, M. L., Sing, H. C., Redmond, D. P., Balkin, T. J. (2003). Patterns of performance degradation and restoration during sleep restriction and subsequent recovery: A sleep dose-response study. *Journal of Sleep Research*, *12*(1), 1–12.

Benington, J. H., & Heller, H. C. (1995). Restoration of brain energy metabolism as the function of sleep. *Progress in Neurobiology*, *45*, 347–360.

Bird, S.P. (2003). Sleep recovery and athletic performance: A brief review and recommendations. *Strength and conditioning Journal,* 35(5), 43-47.

Blumert, P. A., Crum, A. J., Ernsting, M., Volek, J. S., Hollander, D. B., Haff, E. E., & Haff, G. G. (2007). The acute effects of twenty-four hours of sleep loss on the performance of national-caliber male collegiate weightlifters. *Journal of Strength and Conditioning Research*, *21*(4), 1146–1154.

Boergers, J., Gable, C. J., & Owens, J. A. (2014). Later school start time is associated with improved sleep and daytime functioning in adolescents. *Journal of Developmental & Behavioral Pediatrics*, *35*(1), 11-17.

Buysse, D. J., Reynolds, C. F. 3Rd, Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989). The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Research,* 28(2), 193-213.

Cajochen, C., Frey, S., Anders, D., Späti, J., Bues, M., Pross, A., Roenneberg, T. et al. (2011). Evening exposure to a light-emitting diodes (LED)-backlit computer screen affects circadian physiology and cognitive performance. *Journal of Applied Physiology*, 110(5), 1432–1438.

Chiu, Y. H., Silman, A. J., Macfarlane, G. J., Ray, D., Gupta, A., Dickens, et al. (2005). Poor sleep and depression are independently associated with a reduced pain threshold. Results of a population based study. *Pain*, *115*(3), 316-321.

Colten, H. R & Altevogt, B. M. (Eds.). (2006). *Sleep disorders and sleep deprivation: an unmet public health problem*. Washington (DC), National Academies Press.

Cook, C. J., Crewther, B. T., Kilduff, L. P., Drawer, S., & Gaviglio, C. M. (2011). Skill execution and sleep deprivation: effects of acute caffeine or creatine supplementation - a randomized placebo-controlled trial. *Journal of the International Society of Sports Nutrition*, *8*(1), 2.

Cross, M. J., Williams, S., Trewartha, G., Kemp, S. P., & Stokes, K. A. (2016). The influence of in-season training loads on injury risk in professional rugby union. *International Journal of Sports Physiology and Performance*, *11*(3), 350-355.

Cummiskey, J., Natsis, K., Papathanasiou, E., & Pigozzi, F. (2013). Sleep and athletic performance, *European Journal of Sports Medicine*, 1(1), 13-22.

Davenne, D. (2009). Sleep of athletes – problems and possible solutions. *Biological Rhythm Research*, *40*(1), 45–52.

Dennis, J., Dawson, B., Heasman, J., Rogalski, B., & Robey, E. (2016). Sleep patterns and injury occurrence in elite Australian footballers. *Journal of Science and Medicine in Sport*, *19*(2), 113–116.

Duffield, R., Murphy, A., Kellett, A., & Reid, M. (2014). Recovery from repeated on-court tennis sessions: Combining cold-water immersion, compression, and sleep interventions. *International Journal of Sports Physiology and Performance*, *9*(2), 273–282.

Eagles, A., Mclellan, C., & Hing, W. (2014). Changes in sleep quantity and efficiency in professional rugby union players during home based training and match-play. *The Journal of Sports Medicine and Physical Fitness,* 56(5), 565-571.

Emsellem, H. A., & Murtagh, K. E. (2005). Sleep apnea and sports performance. *Clinics in Sports Medicine*, *24*(2), 329–341.

Ericsson, K. A, & Lehmann, A C. (1996). Expert and exceptional performance: evidence of maximal adaptation to task constraints. *Annual Review of Psychology*, *47*, 273–305.

Erlacher, D., Ehrlenspiel, F., Adegbesan, O. A, & El-Din, H. G. (2011). Sleep habits in German athletes before important competitions or games. *Journal of Sports Sciences*, *29*(8), 859–866.

Fenn, K. M., & Hambrick, D. Z. (2013). What drives sleep-dependent memory consolidation: greater gain or less loss? *Psychonomic Bulletin & Review*, *20*(3), 501–516.

Ferrara, M., & De Gennaro, L. (2001). How much sleep do we need? *Sleep Medicine Reviews*, *5*(2), 155–179.

Fietze, I., Strauch, J., Holzhausen, M., Glos, M., Theobald, C., Lehnkering, H., & Penzel, T. (2009). Sleep Quality in Professional Ballet Dancers. *Chronobiology International*, *26*(6), 1249–1262.

Figueiro, M.G., Wood, B., Plitnick, B., Rea, M.S. (2011). The impact of light from computer monitors on melatonin levels in college students. *Biogenic Amines 25(2),* 106-116.

Fullagar, H. H. K., Skorski, S., Duffield, R., Hammes, D., Coutts, A. J., & Meyer, T. (2015). Sleep and athletic performance: The effects of sleep loss on exercise performance, and physiological and cognitive responses to exercise. *Sports Medicine*, *45*(2), 161–186.

Gangwisch, J. E. (2014). A review of evidence for the link between sleep duration and hypertension. *American journal of hypertension*, 27(10), 1235-1242.

George, C. F. P., Kab, V., Kab, P., Villa, J. J., & Levy, A. M. (2003). Sleep and breathing in professional football players. *Sleep Medicine*, 4(4), 317–325.

Griffin, J.R., Maxwell, T.M., & Griffin, L. (2016). The prevalence and consequences of obesity in athletes. *Current Orthopaedic Practice*, *27*(2), 129–134.

Hägglund, M., Waldén, M., Magnusson, H., Kristenson, K., Bengtsson, H., & Ekstrand, J. (2013). Injuries affect team performance negatively in professional football: an 11-year follow-up of the UEFA champions league injury study. *British journal of sports medicine*, *47*(12), 738-742.

Hartmann, E., Baekeland, F., Zwilling, G., & Hoy, P. (1971). Sleep need: how much sleep and what kind?. *American Journal of Psychiatry*, *127*(8), 1001-1008.

Hausswirth, C., Louis, J., Aubry, A., Bonnet, G., Duffield, R., & Le Meur, Y. (2014). Evidence of disturbed sleep and increased illness in overreached endurance athletes. *Medicine and Science in Sports and Exercise*, 46(5), 1036–1045.

Hirshkowitz, M., Whiton, K., Albert, S. M., Alessi, C., Bruni, O., DonCarlos, L., et al. (2015). National Sleep Foundation's updated sleep duration recommendations: Final report. *Sleep Health*, 1(4), 233–243.

Hobson, J. A., & Stickgold, R. (1995). Sleep: Sleep the beloved teacher? *Current Biology*. 5(1) 35-36

Hodgson, L. A. (1991). Why do we need sleep? Relating theory to nursing practice. *Journal of Advanced Nursing*, *16*(12), 1503–10.

Holst, S. C., & Landolt, H. P. (2015). Sleep homeostasis, metabolism, and adenosine. *Current Sleep Medicine Reports*, 1(1), 27–37.

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sports and Exercise*, *41*(1), 3–12.

Hor, H., & Tafti, M. (2009). Physiology. How much sleep do we need? *Science*, *325*(5942), 825–826.

Horne, J. A., & Ostberg, O. (1976). A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. *International Journal of Chronobiology*, 4, 97-110.

Huang, S., Deshpande, A., Yeo, S.-C., Lo, J. C., Chee, M. W. L., & Gooley, J. J. (2016). Sleep restriction impairs vocabulary learning when adolescents cram for exams: The need for sleep study. *Sleep*, *39*(9), 1681–1690.

Hudson Walters, P. (2002). Sleep, the athlete, and performance. *Strength and Conditioning Journal*, *24*(2), 17-24.

Juliff, L. E., Halson, S. L., & Peiffer, J. J. (2015). Understanding sleep disturbance in athletes prior to important competitions. *Journal of Science and Medicine in Sport*, *18*(1), 13–18.

Kamdar, B. B., Kaplan, K. A., Kezirian, E. J., & Dement, W. C. (2004). The impact of extended sleep on daytime alertness, vigilance, and mood. *Sleep Medicine*, *5*(5), 441–448.

Kölling, S., Steinacker, J. M., Endler, S., Ferrauti, A., Meyer, T., & Kellmann, M. (2016). The longer the better: Sleep-wake patterns during preparation of the world rowing junior championships. *Chronobiology International*, 528 (February), 1–12.

Korman, M., Doyon, J., Doljansky, J., Carrier, J., Dagan, Y., & Karni, A. (2007). Daytime sleep condenses the time course of motor memory consolidation. *Nature Neuroscience*, 10(9), 1206–1213.

Lacks, P. & Rotert, M. (1986). Knowledge and practice of sleep hygiene techniques in insomniacs and good sleepers. *Behavioural research and therapy, 24(3), 365-368.*

Lam, L. T. (2014). Internet gaming addiction, problematic use of the internet, and sleep problems: a systematic review. *Current Psychiatry Reports*, *16*(4), 1-9.

Lastella, M., Lovell, G. P., & Sargent, C. (2014). Athletes' precompetitive sleep behaviour and its relationship with subsequent precompetitive mood and performance. *European Journal of Sport Science*, 14(1) 123-130.

Lastella, M., Roach, G. D., Halson, S. L., & Sargent, C. (2015). Sleep/wake behaviours of elite athletes from individual and team sports. *European Journal of Sport Science*, *15*(2), 94–100.

Lauderdale, D. (2008). Sleep duration: how well do self-reports reflect objective measures? The CARDIA Sleep Study. *Epidemiology*, *19*(6), 838–845.

Leeder, J., Glaister, M., Pizzoferro, K., Dawson, J., & Pedlar, C. (2012). Sleep duration and quality in elite athletes measured using wristwatch actigraphy. *Journal of Sports Sciences*, *30*(6), 541–545.

Leger, D., Metlaine, A., & Choudat, D. (2005). Insomnia and sleep disruption: Relevance for athletic performance. *Clinics in Sports Medicine*, *24*(2), 269–285.

Lentino, C. V., Purvis, D. L., Murphy, K. J., & Deuster, P. A. (2013). Sleep as a component of the performance triad: the importance of sleep in a military population. *US Army Medical Department Journal*, 98-108.

Mah, C. D., Mah, K. E., Kezirian, E. J., & Dement, W. C. (2011). The effects of sleep extension on the athletic performance of collegiate basketball players. *Sleep*, *34*(7), 943–950.

Malow, B. (1999). Waking up to the importance of sleep in neurologic disorders. *Neurology*, *52*(9), 1732–1733.

Mazza, S., Gerbier, E., Gustin, M.-P., Kasikci, Z., Koenig, O., Toppino, T. C., & Magnin, M. (2016). Relearn faster and retain longer: Along with practice, sleep makes perfect. *Psychological Science*, 27(10) 1321-1330.

McNair, D. M., Lorr, M., & Doppleman, L.F. (1971). *Manual profile of mood states*. San Diego (CA), Educational & Industrial testing service.

Mednick, S., Nakayama, K., & Stickgold, R. (2003). Sleep-dependent learning: a nap is as good as a night. *Nature Neuroscience*, *6*(7), 697–698.

Milewski, M. D., Skaggs, D. L., Bishop, G. a., Pace, J. L., Ibrahim, D. a., Wren, T. a. L., & Barzdukas, A. (2014). Chronic lack of sleep is associated with increased sports injuries in adolescent athletes. *Journal of Pediatric Orthopaedics*, *34*(2), 129–133.

Miller, N. L., Shattuck, L. G., & Matsangas, P. (2010). Longitudinal study of sleep patterns of United States military academy cadets. *Sleep*, *33*, 1623–1631.

Nedelec, M., Halson, S., Abaidia, A. E., Ahmaidi, S., & Dupont, G. (2015). Stress, sleep and recovery in elite soccer: A critical review of the literature. *Sports Medicine*, *45*(10), 1387–1400.

Pedersen, E. R., Troxel, W. M., Shih, R. A., Pinder, E., Lee, D., & Geyer, L. (2015). Increasing resilience through promotion of healthy sleep among service members. *Military Medicine*, *180*(1), 4–6.

Pitchford, N. W., Robertson, S. J., Sargent, C., Cordy, F., Bishop, D. J., & Bartlett, J. D. (2016). A change in training environment alters sleep quality but not quantity in elite Australian Rules football players. *International journal of sports physiology and performance*, 12(1) 75-80

Prather, A. A., Janicki-Deverts, D., Hall, M. H., & Cohen, S. (2015). Behaviourally assessed sleep and susceptibility to the common cold. *Sleep*, *38*(9), 1353-1359.

Quick, V., Byrd-Bredbenner, C., White, A. A., Brown, O., Colby, S., Shoff, S., et al. (2014). Eat, sleep, work, play: associations of weight status and health-related behaviors among young adult college students. *American Journal of Health Promotion. 29*(2), 64-72.

Reilly, T., & Piercy, M. (1994). The effect of partial sleep deprivation on weight-lifting performance. *Ergonomics*, *37*(1), 107–115.

Robertson, E. M., Pascual-Leone, A., & Press, D. Z. (2004). Awareness modifies the skill-learning benefits of sleep. *Current Biology*, *14*(3), 208–212.

Robey, E., Dawson, B., Halson, S., Gregson, W., Goodman, C., & Eastwood, P. (2014). Sleep quantity and quality in elite youth soccer players: a pilot study. *European Journal of Sport Science*, *14*(5), 410–417.

Samuels, C. (2008). Sleep, recovery, and performance: The new frontier in high-performance athletics. *Neurologic Clinics*, *26*(1), 169–180.

Sargent, C., Halson, S., & Roach, G. D. (2014a). Sleep or swim? Early-morning training severely restricts the amount of sleep obtained by elite swimmers. *European Journal of Sport Science*, *14*(sup1), 310–315.

Sargent, C., Lastella, M., Halson, S. L., & Roach, G. D. (2014b). The impact of training schedules on the sleep and fatigue of elite athletes. *Chronobiology International*, *31*(10), 1160–1168.

Sarode, D. P., Mathie, D., Gao, N., Gray, L., Monaghan, I., Preston, A et al. (2013). A sleep to remember: The effects of sleep on memory. *Res Medica*, *21*(1), 23-34

Savis, J. C. (1994). Sleep and athletic performance: Overview and implications for sport psychology. *Sport Psychologist*, *8*(2), 111–125.

Schwartz, J., & Simon, R. D. (2015). Sleep extension improves serving accuracy: A study with college varsity tennis players. *Physiology and Behavior*, *151*, 541–544.

Sejnowski, T. J., & Destexhe, A. (2000). Why do we sleep? *Brain Research*, *886*, 208–223.

Shapiro, C. M., & Flanigan, M. (1993). ABC of sleep disorders. Function of sleep. *British Medical journal*, *306*(6874), 383–385.

Shearer, D. A., Jones, R. M., Kilduff, L. P., & Cook, C. J. (2015). Effects of competition on the sleep patterns of elite rugby union players. *European Journal of Sport Science*, *1391*(January), 1–6.

Siegel, J. M., (2005). Clues to the functions of mammalian sleep. *Nature, 437, 1264-1271*.

Simpson, N.S., Gibbs, E.L., & Matheson, G.A. (2017). Optimizing sleep to maximise performance: Implications and recommendations for elite athletes. *Scandinavian Journal of Medicine and Science in Sports,* 27 (3), 266-274.

Skein, M., Duffield, R., Minett, G. M., Snape, A., & Murphy, A. (2013). The effect of overnight sleep deprivation after competitive rugby league matches on post-match physiological and perceptual recovery. *International journal of sports physiology and performance*, *8*(5), 556-564.

Swinbourne, R., Gill, N., Vaile, J., & Smart, D. (2015). Prevalence of poor sleep quality, sleepiness and obstructive sleep apnoea risk factors in athletes. *European Journal of Sport Science*, 16(7), 850-858.

Taheri, S., Lin, L., Austin, D., Young, T., & Mignot, E. (2004). Short sleep duration is associated with reduced leptin, elevated ghrelin, and increased body mass index. *PLoS Medicine*, *1*(3), 210–217.

Taub, J. M. (1971). Extended sleep and performance. *Nature*, *233*, 142–143.

Taub, J. M., & Berger, R. J. (1969). Extended sleep and performance: the Rip Van Winkle effect. *Psychonomic Science*, *16*(4), 204-205.

Tefft, B. C. (2014). Prevalence of motor vehicle crashes involving drowsy drivers, United States, 2009–2013. *Rep. Prepared for the American Automobile Association (AAA) Foundation for Traffic Safety, Washington, (DC*).

Thornton, H. R., Duthie, G. M., Pitchford, N. W., Delaney, J. A., Benton, D. T., & Dascombe, B. J. (2016). Effects of a two-week high intensity training camp on sleep activity of professional rugby league athletes. *International Journal of Sports Physiology and Performance*, 1-19.

Thun, E., Bjorvatn, B., Flo, E., Harris, A., & Pallesen, S. (2015). Sleep, circadian rhythms, and athletic performance. *Sleep Medicine Reviews*, *23*, 1–9.

Van Dongen, H. P. a, Maislin, G., Mullington, J. M., & Dinges, D. F. (2003). The cumulative cost of additional wakefulness: dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. *Sleep*, *26*(2), 117–126.

Van Ryswyk, E., Weeks, R., Bandick, L., O'Keefe, M., Vakulin, A., Catcheside, P. et al. (2016). A novel sleep optimisation programme to improve athletes' well-being and performance. *European Journal of Sport Science*, 1–8.

Venter, R. E. (2014). Perceptions of team athletes on the importance of recovery modalities. *European Journal of Sport Science*, *14*(Supplement 1), S69-76.

Vioque, J., Torres, A, and Quiles, J. (2000). Time spent watching television, sleep duration and obesity in adults living in Valencia, Spain. *International Journal of Obesity* 24, 1683–1688.

Walker, M. P., & Stickgold, R. (2005). It's practice, with sleep, that makes perfect: Implications of sleep-dependent learning and plasticity for skill performance. *Clinics in Sports Medicine*, *24*(2), 301–317.

Webb, W. B., & Bonnet, M. H. (1978). The sleep of "morning" and "evening" types. *Biological Psychology*, *7*, 29–35.

Woods, H. C., & Scott, H. (2016). #Sleepyteens: Social media use in adolescence is associated with poor sleep quality, anxiety, depression and low self-esteem. *Journal of Adolescence*, *51*, 41–49.

APPENDICES

APPENDIX ONE: ETHICS APPROVAL

AUTEC
SECRETARIAT

24 September 2014
Nic Gill
Faculty of Health and Environmental Sciences

Dear Nic

Re Ethics Application: **14/276 Skill learning and sleep extension in rugby union.**

Thank you for providing evidence as requested, which satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC).

Your ethics application has been approved for three years until 24 September 2017.

As part of the ethics approval process, you are required to submit the following to AUTEC:

- A brief annual progress report using form EA2, which is available online through http://www.aut.ac.nz/researchethics. When necessary this form may also be used to request an extension of the approval at least one month prior to its expiry on 24 September 2017;
- A brief report on the status of the project using form EA3, which is available online through http://www.aut.ac.nz/researchethics. This report is to be submitted either when the approval expires on 24 September 2017 or on completion of the project.

It is a condition of approval that AUTEC is notified of any adverse events or if the research does not commence. AUTEC approval needs to be sought for any alteration to the research, including any alteration of or addition to any documents that are provided to participants. You are responsible for ensuring that research undertaken under this approval occurs within the parameters outlined in the approved application.

AUTEC grants ethical approval only. If you require management approval from an institution or organisation for your research, then you will need to obtain this.

To enable us to provide you with efficient service, please use the application number and study title in all correspondence with us. If you have any enquiries about this application, or anything else, please do contact us at ethics@aut.ac.nz.

All the very best with your research,

Kate O'Connor
Executive Secretary
Auckland University of Technology Ethics Committee

Cc: Iain Cleland iain@trfu.co.nz

APPENDIX TWO:

Participant Information Sheet

Date Information Sheet Produced: 18/8/14

Project Title

What are the effects of a sleep extension on variables of exercise adaptation and skill acquisition in Rugby Union?

An Invitation

My name is Iain Cleland. I am the Head Strength and Conditioning Coach for Taranaki Rugby and the NZ U20s. I am doing my MPhil in the area of sleep for athletic performance. I would like to invite you to take part in this study, which will contribute towards my MPhil. Your participation is completely voluntary, and you are free to withdraw at any time prior to the completion of data collection. If you chose not to participate in this study there will not be any consequences. There is no pressure to participate, I am not in a position of selection within this team.

What is the purpose of this research?

It appears that there are a large number of athletes who do not sleep well or for long enough. Furthermore, it seems that if athletes sleep more, they adapt to exercise and learn sports skills faster. Compared to other areas of sports science relatively little is known about sleep and its relationship with sport skill acquisition, and even less is known about this in relation to rugby. It is essential we better understand sleep, its relationship with exercise adaptation and skill learning, and determine the extent to which these change during a competitive season. Results from this research will contribute towards my MPhil, may be presented at scientific conferences and published in a scientific journal.

How was I identified and why am I being invited to participate in this research?

You have been identified because you are a player within the Taranaki ITM Cup Squad, which was targeted for this research. You are being invited to participate in this research because you are a member of an athletic group of interest with respect to sleep.

What will happen in this research?

If you agree to take part in the study, initially you will go through a familiarisation period for a passing task. Once this has been completed you will be asked to monitor your habitual sleep and then sleep more often aiming for 10 hours per day. They will also be given advice and guidance around sleep. During both periods, you will complete the passing task with the scores being recorded pre and post the intervention period. Incidence of injury, fatigue monitoring and quantity and quality of sleep will be recorded during the five week period as well as GPS data for training and games.

What are the discomforts and risks?

There are no discomforts or risks to completing these tests other than those of normal training load.

What are the benefits?

Your participation will benefit me in gaining my MPhil qualification. Participating may also puts you in a benefit as an athlete in learning about your sleep and skill learning.

How will my privacy be protected?

All data and consent forms will be kept confidential and stored securely for an indefinite time on AUT premises. Data may be used in future research. All data will be stored securely by for at least 10 years, and consent forms will be stored at AUT for at least 10 years. By giving your consent it is deemed that you understand and consent that information will not be shared with an identified team doctor/medical team/team management in the case of a sleep disorder or sub-optimal sleep being diagnosed, unless you give explicit and prior consent to do so, so that help or medical referral can be actioned. The team doctor may discuss this medical issue with the coaches and management team, but only if you consent to this first. No medical information will be shared with me by the medical team, only summary statistics on injury/illness rates.

What are the costs of participating in this research?

The only cost to you is your time, you may have to sleep more, use the sleep monitor application to record your sleep and wake up time each day in a diary (1 minute each day) as well as fill in 2 short questionnaires each week (5 minutes), and complete a passing task twice weekly (5 minutes). All associated costs for running this project have been paid for by me.

What opportunity do I have to consider this invitation?

You have approximately one week to consider this invitation before I seek your voluntary participation and consent, and you may withdraw at any time before completion if you do not wish to continue.

How do I agree to participate in this research?

You need to sign a consent form, which I will give to you prior to participating in the study.

Will I receive feedback on the results of this research?

Yes you will, an anonymous team average sleep score will be provided to team management, and your individual data summary and score will be emailed to you, once data is analysed.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Dr Nicholas Gill, Research fellow, AUT, Nicholas Gill Nicholas.Gill@nzrugby.co.nz, ph 0274 888 699, and Executive Secretary of AUTEC, Kate O'Connor, *ethics@aut.ac.nz* , 921 9999 ext 6038.

Whom do I contact for further information about this research?

Researcher Contact Details: Iain Cleland : Iain@trfu.co.nz, ph 021 500 036

Project Supervisor Contact Details: Dr Nicholas Gill, Strength and Conditioning Coach, All Blacks, Nicholas Gill Nicholas.Gill@nzrugby.co.nz, ph 0274 888 699

Approved by the Auckland University of Technology Ethics Committee on…

AUTEC Reference number…

APPENDIX THREE: CONSENT FORM

Consent Form

Project title: ***Skill Learning and Sleep Extension in Rugby Union***

Project Supervisor: ***Dr Nicholas Gill, Dr Dan Smart***

Researcher: ***Iain Cleland***

- ○ I have read and understood the information provided about this research project in the Information Sheet dated 18th August 2014.
- ○ I have had an opportunity to ask questions and to have them answered.
- ○ I understand that I may withdraw myself or any information that I have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.
- ○ If I withdraw, I understand that all relevant information, or parts thereof, will be destroyed.
- ○ I understand and consent that information will not be shared with an identified team doctor/medical team/team management in the case of a sleep disorder or sub-optimal sleep being diagnosed, unless I give my explicit and prior consent to do so, so that help or medical referral can be actioned. The team doctor may not share information about me with coaches and management without my consent.
- ○ I understand all information will be securely stored at AUT for an indefinite period of time.
- ○ I agree to take part in this research.
- ○ I wish to receive a copy of the report from the research (please tick one): Yes○ No○

Participant's signature: ....

Participant's name: ....

Participant's Contact Email Details:……………………………………………………………………

Date:

Approved by the Auckland University of Technology Ethics Committee on AUTEC Reference number

Note: The Participant should retain a copy of this form.